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LA DEDUCCIÓN CON CONDICIONALES EN NIÑOS Y ADULTOS: SUPRESIÓN DE INFERENCIAS, CONTRAFACTUALIDAD Y USO DE LA INFORMACIÓN EPISTÉMICA

DEDUCTION WITH CONDITIONALS IN CHILDREN AND ADULTS: INFERENCE SUPPRESSION, COUNTERFACTUALITY AND USE OF EPISTEMIC INFORMATION

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'*': indicates that the chapter is written in English

Resumen

La capacidad deductiva ocupa un lugar fundamental en el rendimiento académico, formando parte del amplio conjunto de las habilidades esenciales para el aprendizaje escolar. Sin embargo, el escaso volumen de investigación sobre él contrasta con el que se ha dedicado a otros procesos cognitivos. Esta tesis doctoral se centra en el estudio de la capacidad deductiva con condicionales y, más concretamente, con condicionales contrafácticos.

Los objetivos generales de esta tesis tratan de abarcar diferentes aspectos. Por un lado, se examina el papel de algunos factores en la supresión de inferencias, así como si existe un efecto "aditivo" en el empleo de varios de ellos. Por otro lado, nos centramos en el razonamiento con condicionales de tipo contrafáctico tratando de analizar posibles factores causantes de las limitaciones encontradas en este tipo de razonamiento por parte de los niños y niñas. Por último, investigamos cómo personas adultas y niños/as construyen la posibilidad contrafáctica y si esta depende del carácter evolutivo que la construcción de la negación presenta.

Esta tesis consta de cinco capítulos. En el primero de ellos se lleva a cabo una introducción de los aspectos más relevantes sobre la temática, incluyendo conceptos y terminología clave, así como algunos de los estudios más relevantes.

El capítulo dos contiene un estudio con dos experimentos en los que se analiza el efecto de diferentes factores en la supresión de inferencias, así como el posible efecto aditivo de la puesta en práctica de varios de ellos. Para llevar a cabo el estudio se diseñaron ambos experimentos con E-Prime. En ellos los participantes tenían que realizar las cuatro inferencias básicas (MP, MT, AC y NA) tras serle presentada diferente información (solo el condicional -"si corre, tiene sed"-, información adicional al condicional -"sabemos que no corrió, pero tenía sed"- o tras generar contraejemplos -"comió sal, hacía mucha calor, etc."-) Los resultados permiten confirmar el efecto de

supresión de los tres factores estudiados. Asimismo, apoyan un efecto de supresión "sumatorio" o aditivo cuando se emplean varios de ellos.

En el capítulo tres se evalúa la capacidad de razonamiento con contrafácticos en personas adultas y niños/as, examinando posibles factores causantes de la dificultad que, especialmente los más pequeños, muestran a la hora de razonar con condicionales de este tipo. Más concretamente, analizamos el papel del estatus epistémico (distinguir situación real e hipotética) y del componente gramatical. Para ello, diseñamos una tarea con un total de 8 historias manipulando el componente gramatical ("si hubiera…" vs. "aunque hubiera…") que eran leídas por la examinadora. Tras cada una de ellas, se realizaban dos preguntas a los participantes: una relativa a la inferencia con contrafácticos y otra al estatus epistémico. Los resultados más relevantes sostienen el carácter evolutivo, no solo del razonamiento contrafáctico, sino también de la capacidad para mantener las etiquetas mentales y poder distinguir, de esta forma, situación real de hipotética. Además, confirman la especial dificultad que los niños y niñas presentan ante de esta última habilidad. Asimismo, los resultados sugieren que el uso de la concesiva "aunque" facilita la respuesta inferencial tanto en personas adultas como en niños/as.

El capítulo cuatro, al igual que el anterior, consta de un estudio con dos experimentos. Estos se centran en estudiar cómo, tanto personas adultas (experimento 1) como niños/as (experimento 2), construyen la posibilidad contrafáctica y cuál es el efecto de la negación en este proceso. Para ello, se elaboró una tarea similar a la del capítulo tres. Esta constaba de 8 historias en las que se manipulaba el tipo de contraejemplo (alternativa vs. disabler) y la concreción de la negación (concreta vs. abstracta). Cada una de ellas, contaba con tres preguntas: una inferencia con contrafácticos, otra sobre el estatus epistémico y una tercera sobre la causa subyacente en la relación causal establecida. Los resultados sugieren que generalmente construimos la posibilidad contrafáctica recuperando una

alternativa al antecedente, en lugar de utilizando la negación explícita a través de elementos sintácticos (“no”). Asimismo, los resultados parecen subrayar la importancia del carácter evolutivo de la construcción de la negación en este aspecto, con los niños y niñas recuperando más fácilmente alternativas concretas a la negación que abstractas. Sin embargo, no se encuentran diferencias en personas adultas debido, probablemente, a su habilidad para pensar con contenidos de tipo abstracto.

Por último, en el capítulo 5 se presenta una discusión general de los resultados más relevantes obtenidos en los diferentes estudios. Asimismo, se comentan algunas posibles implicaciones prácticas, limitaciones y futuras líneas de investigación.

Overview

Overview

Deductive ability holds an important place in academic performance, being part of the broad set of essential skills for school learning. However, the scarce volume of research on it contrasts with that devoted to other cognitive processes. This doctoral thesis focuses on deductive ability with conditionals and, in particular, with counterfactual conditionals.

The general objectives of this thesis try to cover different aspects. On the one hand, we examine the role of some factors in the suppression of inferences, as well as whether there is an "additive" effect when several of them are used. On the other hand, we focus on reasoning with counterfactual conditionals, trying to analyse possible factors responsible for the limitations found in this kind of reasoning by children. Finally, we investigated how adults and children construct the counterfactual possibility and whether this depends on the developmental nature of the construction of negation.

This thesis consists of five chapters. The first chapter introduces the most relevant aspects of the subject, including key concepts and terminology, as well as some of the most relevant studies.

Chapter two contains a study with two experiments in which the effect of different factors on the suppression of inferences is analysed, as well as the possible additive effect of the use of several of them. To carry out the study, both experiments were designed with E-Prime. In them, participants had to perform the four basic inferences (MP, MT, AC and DA) after being presented with different information (only the conditional -‘if she runs, she is thirsty’-, additional information to the conditional -‘we know that she did not run, but was thirsty’- or after generating counterexamples -‘she could have eaten salt, it was very hot, etc.’-) The results confirm the suppression effect of the three factors studied. They also support an "additive " suppression effect when several factors are used.

In chapter three we evaluate the ability to reason with counterfactuals in adults and children, examining possible factors causing the difficulty that, especially the youngest children, show when reasoning with this kind of conditionals. More specifically, we analyse the role of epistemic status (distinguishing the real and the hypothetical situation) and the grammatical component. For this purpose, we designed a task with a total of 8 stories, manipulating the grammatical component ("if there were..." vs. "even if there were...") that were read by the examiner. After each of them, two questions were asked: one related to making an inference from the counterfactual and the other related to the epistemic status of the counterfactual. The most relevant results support the developmental character, not only of counterfactual reasoning, but also of the ability to keep in mind mental labels and to distinguish real from hypothetical situations. In addition, they confirm the particular difficulty that children show in the latter ability. Likewise, the results suggest that the use of the concessive "even if" facilitates inferential response in both adults and children.

Chapter four, as the previous one, consists of a study with two experiments. These focus on studying how both adults (experiment 1) and children (experiment 2) construct the counterfactual possibility and how negation affects this process. For this purpose, we designed a task similar to the one in chapter three. This consisted of 8 stories in which the type of counterexample (alternative vs. disabler) and the concreteness of the negation (concrete vs. abstract) were manipulated. Each of them had three questions: an inference from counterfactuals, another one about the epistemic status and a third one about the underlying cause in the established causal relationship. The results suggest that we tend to construct the counterfactual possibility by retrieving an alternative to the antecedent, rather than by using explicit negation through syntactic elements ("not"). The results also seem to highlight the importance of the developmental nature of the construction of

negation in this aspect, with children more easily retrieving concrete alternatives to the negation rather than abstract alternatives. However, no differences are found in adults, probably due to their ability to think with abstract content.

Finally, Chapter 5 offers a general discussion of the most relevant results obtained in the different studies. It also discusses some possible practical implications, limitations and future lines of research.

Capítulo 1

Marco teórico de la investigación y objetivos

Las personas, tanto niños/as como adultos, constantemente nos interesamos por cómo podrían haber sido las cosas en situaciones diferentes a las reales, especialmente cuando nos enfrentamos a situaciones desagradables o a acciones con resultados negativos o desfavorables (Epstude & Roese, 2008; FitzGibbon et al., 2019; Guajardo et al., 2016). Este pensamiento es crucial para el aprendizaje humano pues, entre otros aspectos, nos permite aprender de nuestros errores permitiéndonos tratar de evitarlos en el futuro (Byrne, 2016) o corregirlos, si cabe la posibilidad, a partir de la información con la que contamos (FitzGibbon et al., 2019). Por ejemplo, un niño que toca el horno y se quema, podría anticiparse en un futuro pensando qué habría ocurrido si no hubiera tocado el horno. Esto facilitaría que en el futuro no se acercara a él o lo hiciera con más cuidado. Uno de los retos actuales en la sociedad es comprender cómo esta capacidad se desarrolla y, sobre todo, qué factores influyen en su correcta ejecución.

En este tipo de pensamiento se requiere la realización de inferencias a partir de condicionales del tipo "si-entonces", por ejemplo "si hubiera vigilado al niño, no se habría quemado". No obstante, tal y como veremos a lo largo de la introducción, el desarrollo de este tipo de razonamiento condicional sigue un proceso evolutivo largo y la consideración de diferentes contenidos y contextos pueden condicionar la realización de las inferencias, llevándonos a cometer falacias o, incluso, favoreciendo que rechacemos inferencias válidas.

A lo largo de los siguientes capítulos abordaremos el desarrollo evolutivo en la realización de inferencias teniendo en cuenta las teorías más relevantes, así como su supresión. Además, veremos en qué consiste el razonamiento contrafáctico y su carácter evolutivo, abordando la consideración de posibles alternativas a las situaciones expuestas en la expresión condicional, los condicionales semifácticos y el efecto de la negación.

1. Las inferencias con condicionales

Las expresiones condicionales del tipo "si-entonces" son utilizadas para establecer relaciones entre dos elementos, donde la parte "si" contiene la causa (oración subordinada) y la parte "entonces" hace referencia a la consecuencia o efecto (oración principal). Con ellas podemos indicar la pertenencia de un elemento a una categoría, establecer reglas sociales, éticas y relaciones causales, entre otras.

Para estudiar la deducción se han utilizado argumentos que constan de dos premisas, denominadas mayor o principal y menor o categórica, y una conclusión. Así, un argumento condicional, se construye con una expresión condicional como premisa mayor, como

(1) "Si Daniela llora por la noche, entonces Jesica está despierta" (Si A, B)

una premisa categórica, como "Daniela llora"(A) y una conclusión "Jesica está despierta"(B).

Existen cuatro premisas categóricas que surgen de afirmar y negar la proposición primera (antecedente) y la segunda (consecuente). A partir de las premisas propuestas y de la información proporcionada, las personas extraen conclusiones utilizando su conocimiento del mundo y la lógica. Tomando como referencia el condicional (1) las cuatro inferencias lógicas posibles serían (ver Tabla 1):

- Modus ponens (MP; A B): el efecto o consecuencia se produce siempre y cuando la causa esté presente. Es decir, ante la premisa "Daniela llora" (A) se concluye "Jesica está despierta" (B).
- Negación del antecedente (NA; noA noB): el efecto no se produce en ausencia de la causa. Es decir, ante la premisa "Daniela no llora" (noA), se concluye "Jesica no está despierta" (noB).

- Afirmación del consecuente (AC; B A): el efecto se produce y se concluye que la causa también se da. Es decir, ante la premisa "Jesica está despierta" (B), se concluye "Daniela está llorando" (A).
- Modus tollens (MT; noB noA): la consecuencia o efecto no se produce y, por tanto, se concluye que la causa no está presente. Es decir, ante la premisa "Jesica no está despierta" (noB), se concluye "Daniela no está llorando" (noA).

Aunque, como hemos mencionado anteriormente, las cuatro inferencias son posibles, solo dos de ellas son consideradas inferencias válidas[1]: MP y MT. Sin embargo, las dos restantes (AC y NA) se denominan "falacias", puesto que no pueden ser aceptadas como correctas desde la lógica proposicional, al no garantizarse que exista una única conclusión posible.

La lógica establece que la interpretación de implicación material de un condicional "Si A, B", solo es falsa si "A" es verdadero y "B" es falso (A noB), siendo el resto de posibilidades verdaderas: A B, noA noB y noA B. Es por ello que el hecho de que "B" sea verdadero, no implica que "A" también lo sea. Por ejemplo, en el caso de la AC, si Jesica está despierta (B), puede ser por otras causas diferentes, como que haya sonado el despertador (noA) y no necesariamente porque Daniela esté llorando (A). Por la misma razón, el hecho de que Daniela no llore (noA) no significa que Jesica no esté despierta (noB) (ver apartado 2.1. y Tabla 3 para más información).

[1] Nótese que hablamos de casos lógicos, lo que no implica que sean verdaderos empíricamente. Es decir, en una inferencia MP "si es un pez, entonces pía" ante el caso "es un pez", la respuesta válida desde la implicación lógica es "pía". Sin embargo, empíricamente se trata de un caso falso (los peces no pían).

Tabla 1

Ejemplo de las cuatro inferencias lógicas con el condicional, la premisa categórica y la conclusión

Condicional Si Daniela llora por la noche, entonces Jesica está despierta		
	Premisa categórica	Conclusión
Inferencias válidas		
Modus ponens (MP) *Si A, B; A ∴ B*	Daniela llora	Jesica está despierta
Modus tollens (MT) *Si A, B; ¬B ∴ ¬A*	Jesica no está despierta	Daniela no llora
Falacias		
Afirmación del consecuente (AC) *Si A, B; B ∴ A*	Jesica está despierta	Daniela llora
Negación del antecedente (NA) *Si A, B; ¬A ∴ ¬B*	Daniela no llora	Jesica no está despierta

Nota: Los símbolos "¬" y "∴" significan "no" y "entonces", respectivamente.

El razonamiento deductivo ha sido estudiado generalmente mediante el uso de relaciones "A>B; B>C; luego ¿A>C?", condicionales "si tiene tres lados, entonces es un triángulo. Tiene cuatro lados, luego ¿es un triángulo?" y silogismos "todos los médicos son jardineros. Javier es médico, luego ¿es jardinero? (Evans et al., 2019; Santamaría et al., 2013). Este tipo de razonamiento requiere la puesta en práctica de las inferencias abordadas en este apartado. Estas pueden ser estudiadas de numerosas formas, aunque, generalmente, los tipos de tarea más utilizados son:

1. Tareas de generación en las que, dado un condicional y una premisa categórica como las vistas en la Tabla 1, se pide al participante que genere una conclusión. Por ejemplo "si Javier es médico, entonces es jardinero"; Javier no es médico, ¿qué se puede concluir?

2. Tareas de evaluación en las que se solicita que se evalúe una conclusión dada. Son muy similares a las anteriores, con la diferencia de que se ofrecen tres conclusiones a la premisa categórica. Por ejemplo, ante el condicional anterior se ofrecerían las siguientes respuestas: Javier es jardinero, Javier no es jardinero, no se puede concluir.
3. Tareas de evaluación de la verdad en las que se pregunta acerca de la veracidad de una inferencia, considerando el condicional dado como cierto. Por ejemplo, ante el condicional previamente descrito se preguntaría: ¿es verdad que Javier es médico y jardinero?

2. El desarrollo del razonamiento condicional

Las inferencias a partir de condicionales están sujetas a un proceso evolutivo largo y complejo que pasa por tres grandes niveles (Barrouillet et al., 2000; Barrouillet & Gauffroy, 2013; Johnson-Laird, 2006) y que, en el razonamiento sobre posibilidades, parece culminar alrededor de la etapa de educación secundaria.

Teniendo como referencia el condicional

(2) "Si tiene chupete, entonces es un bebé"

podemos pasar a explicar los tres niveles de desarrollo:

- *Interpretación conjuntiva* (<8 años): en este primer nivel los niños interpretan el condicional como si se tratara de una conjunción ("tiene chupete y es un bebé"), concibiendo, por tanto, únicamente el caso *A&B*.
- *Interpretación bicondicional* (8-10 años): en este siguiente nivel se consideran dos situaciones resultantes de afirmar o negar antecedente y consecuente de manera conjunta: "tiene chupete y es un bebé" (*A B*) y "no tiene chupete y no es un bebé" (no*A noB*). Es decir, se añade una segunda posibilidad: no*A noB*. Se

trata de una representación limitada que no permite una comprensión completa del condicional, por lo que lleva a conclusiones falaces como las que veremos en el capítulo 2.

- *Interpretación condicional* (>10-12 años): en este último nivel las personas se apoyan, como veremos en el siguiente apartado, en la representación de las tres posibilidades consistentes con un condicional: *A B, noA noB* y *noA B.* Por ello, son capaces de entender que también es posible que no tenga chupete y sea un bebé (no*A B*). Se trata de la interpretación que realizan las personas adultas y la mayoría de adolescentes.

Como se mencionaba previamente, la edad a la que se alcanza cada una de las interpretaciones está basada en la consideración de posibilidades a partir de una afirmación. No obstante, cuando nos referimos a la evaluación de la veracidad o falsedad de un caso, la edad a la que se alcanza cada una de las interpretaciones varía.

Esta distinción entre razonamiento sobre posibilidades y razonamiento sobre los valores de verdad ha sido fuente de varias investigaciones, poniendo de manifiesto que, aunque ambos tipos de razonamiento siguen el mismo patrón de desarrollo, el segundo se desarrolla de una manera más tardía (Barrouillet et al., 2008) al tratarse de un tipo de razonamiento más complejo, puesto que implica componentes metalógicos (Johnson-Laird & Byrne, 2002; Moshman, 1990): la interpretación conjuntiva a los 8-11 años, la interpretación bicondicional en torno a los 15 años y la interpretación condicional ya entrada la edad adulta. No obstante, su desarrollo depende de numerosos factores que afectan directamente a la construcción de las posibilidades y, con ello, a la interpretación llevada a cabo, como puede ser el uso de condicionales binarios o no binarios o el uso de condicionales causales con pocas o muchas alternativas, entre otros (Barrouillet & Gauffroy, 2015). Esto mismo también ocurre en el caso del razonamiento sobre

posibilidades. El significado de antecedente y consecuente, las relaciones que pueden establecerse entre ellos y el conocimiento general, entre otros factores, pueden contener información que favorezca o perjudique la generación de las diferentes posibilidades, tal y como veremos más adelante (Johnson-Laird & Byrne, 2002).

Desde la psicología del razonamiento se ha estudiado cómo pensamos con este tipo de oraciones y qué factores influyen en él. Más concretamente, podemos partir de cómo se aborda en tres de las aproximaciones que más impacto tienen en la actualidad: la teoría de los modelos mentales (Johnson-Laird, 1983, 2006; Johnson-Laird & Byrne, 1991, 2002), la teoría suposicional (Evans et al., 2005; Evans, 2007) y las aproximaciones de tipo probabilístico (Geiger & Oberauer, 2007).

2.1. La teoría de los modelos mentales

Una de las teorías de razonamiento por excelencia, es la teoría de los modelos mentales (en adelante TMM; Johnson-Laird, 1983, 2006; Johnson-Laird & Byrne, 2002). Esta concibe que las personas representamos los condicionales como posibilidades o modelos mentales. Estos consisten en una representación icónica de la realidad, que puede contener elementos simbólicos para codificar características abstractas, como puede ser la negación. Estos modelos inicialmente incluyen el caso A & B (aquel que el condicional describe: chupete & bebé en (2)) y una nota mental que, de manera implícita, nos indica que existen otras posibilidades alternativas no representadas inicialmente y, por tanto, no accesibles de manera inmediata (Johnson-Laird & Byrne, 1991, 2002).

A B (Representación inicial; *chupete bebé*)

... (Representación implícita)

El acceso a esas otras alternativas contenidas en la representación implícita requiere de un gran esfuerzo, pues la construcción y manipulación de más de un modelo al mismo

tiempo supone una gran carga en la memoria operativa. No obstante, si es necesario, la información implícita puede hacerse explícita llevando a cabo un proceso de "despliegue" que permitiría alcanzar los dos modelos adicionales: ¬A ¬B ("no tiene chupete y no es un bebé") y ¬A B ("no tiene chupete y es un bebé"). Con ello, se alcanzaría una representación mental completa de las tres posibilidades consistentes con un condicional:

Tabla 2

Representación inicial y desplegada de los modelos mentales según la TMM

Representación inicial	A	B	(chupete	bebé)
Representación desplegada	¬A	¬B	(no chupete	no bebé)
	¬A	B	(no chupete	bebé)

La TMM mantiene que, es a partir de la construcción y manipulación de dichos modelos, como las personas realizamos las inferencias lógicas. Algunas de las abordadas en el apartado 1 de esta introducción, las realizamos sin apenas esfuerzo. Es por ejemplo el caso de la inferencia MP, pues se basa en la representación inicial. Es decir, ante el condicional "si tiene chupete, entonces es un bebé" (A B) y la premisa "tiene chupete"(A) las personas concluimos de manera relativamente fácil y rápida "es un bebé"(B), pues coincide con el modelo enunciado por el propio condicional. Sin embargo, para llegar a conclusiones válidas con las demás inferencias (AC, NA y MT) se requiere el despliegue de la representación implícita y, por tanto, la puesta en marcha de numerosos recursos y procesos complejos como la memoria de trabajo o la atención. Es por ello que el razonamiento inferencial está sometido a un largo proceso evolutivo.

Consistente con esta visión, encontramos la propuesta de la existencia de dos sistemas o tipos de razonamiento (Evans, 2011): uno intuitivo (Tipo 1 o sistema I) y otro reflexivo (Tipo 2 o sistema II) que, en este caso, jugaría un papel clave en el despliegue de los modelos implícitos y que está influenciado por factores de tipo motivacional así

como por los recursos cognitivos disponibles. El Tipo 1 se basaría fundamentalmente en el aprendizaje por experiencia, permitiendo repetir los comportamientos que han tenido éxito en el pasado. El Tipo 2, sin embargo, se haría cargo de aquel tipo de razonamiento que requiere imaginar el futuro, realizar simulaciones y tomar decisiones ante problemas nuevos para los que el aprendizaje experiencial no puede ofrecer soluciones (Evans, 2014).

Como hemos visto, en el condicional

(1) "Si Daniela llora por la noche, entonces Jesica está despierta"

la posibilidad "Daniela llora y Jesica está despierta" está representada inicialmente y, por tanto, la inferencia MP se realiza de manera casi automática al coincidir con el modelo presentado en el condicional. Sin embargo, tal y como veremos en el capítulo 2, dependiendo de numerosos aspectos como pueden ser el contexto, el contenido del propio condicional y el conocimiento general, también se podrían representar los modelos de la representación implícita (¬A & ¬B y ¬A & B) (Johnson-Laird & Byrne, 2002; Quelhas et al., 2010, 2017).

Por ejemplo, si una madre dice a su hija "si haces los deberes, saldrás a jugar", es posible que la niña interprete el contenido como una amenaza, haciendo una interpretación bicondicional y representando, no solo que si hace los deberes jugará (A & B), sino también que, si no hace los deberes, no jugará (¬A & ¬B). De esta forma, aunque se representan dos posibilidades sin necesidad de realizar el despliegue, una de ellas queda implícita (¬A B), lo que nos llevaría a cometer las falacias (AC y NA), al no contar con una representación completa. Por ejemplo, ante la premisa "B" ("no sale a jugar"), concluiríamos con "A" ("no ha hecho los deberes"), cometiendo la falacia de AC. Sin embargo, esto podría evitarse si se desplegaran todos los modelos (ver Tabla 2).

Por ejemplo, retomando el condicional (1), saber que Jesica tiene que trabajar por la noche, facilitaría que se representara la posibilidad "¬A B" (Daniela no llora, pero Jesica está despierta de todas formas). En este caso, el consecuente "B" estaría presente en dos modelos: el previamente descrito (¬A B) y el representado inicialmente por el condicional (AB). Es por ello que, ante la premisa "Jesica está despierta" (B), sería menos probable que los participantes cometieran la falacia de AC concluyendo "Daniela llora" (A). Esto se debe a que pueden pensar que Jesica puede estar despierta (B) bien porque tiene que trabajar (¬A) o bien porque Daniela llora (A). Es decir, la presencia de una posibilidad alternativa (¬A) llevaría igualmente a la conclusión "B" y, con ello, al rechazo de la falacia AC ("no se puede concluir"), puesto que existen dos opciones de respuesta opuestas dentro de los modelos representados (ver Tabla 2 y Tabla 3).

Lo mismo ocurriría en el caso de la falacia NA. Si se accede a los dos modelos implícitos (¬A¬B y ¬AB), a partir de la premisa ¬A ("Daniela no llora") no se podría concluir ¬B ("Jesica no está dormida"), puesto que existirían dos posibilidades opuestas: B y ¬B (Jesica despierta y Jesica no despierta, respectivamente), no existiendo una conclusión válida y rechazando, de esta forma, la falacia (consultar de nuevo Tabla 2 y Tabla 3).

Tabla 3

Ejemplo de representación inicial e implícita y de rechazo de falacias

	Condicional Si Daniela llora por la noche, entonces Jesica está despierta					
Repr. inicial	Daniela llora	A		Jesica despierta	B	
Repr. implícita	Daniela no llora	noA		Jesica no despierta	noB	
	Daniela no llora	noA		Jesica despierta	B	
AC	Jesica despierta	B		→¿?	(B ∴ ¿A o noA?)	
NA	Daniela no llora	noA		→¿?	(noA ∴ ¿B o noB?)	

2.2. La teoría suposicional y las aproximaciones probabilísticas

La teoría suposicional (Evans et al., 2005) y, en general, las teorías probabilísticas, establecen que, al evaluar un condicional del tipo "si A entonces B", las personas asumimos el antecedente "A" como verdadero y estimamos la probabilidad con la que puede darse una conclusión ("B") dado el antecedente (Evans & Over, 2004). Es decir, ante el condicional

(2) "Si tiene chupete, entonces es un bebé"

la suposición "tiene un chupete" se representaría como verdadera y pensaríamos cómo de probable es que, teniendo chupete, fuera un bebé.

De esta forma, el razonamiento con condicionales consistiría en el cálculo de la probabilidad condicionada de que se dé el consecuente ("B"; bebé) dado el antecedente ("A"; chupete), es decir, "P(bebé|chupete)". Sin embargo, aquellos casos en los que el

antecedente es falso (noA; no tiene chupete) se considerarían irrelevantes para el condicional (Barrouillet et al., 2008; Barrouillet & Gauffroy, 2015; Evans et al., 2005; Evans & Over, 2004). Esto es así puesto que, tal y como hemos visto, para determinar la credibilidad del condicional se considera que el antecedente es verdadero. Es por ello que se dirige la atención a los casos "A" y no a los "noA" o "B" (Evans et al., 2005).

Más concretamente, podemos decir que los condicionales son evaluados mediante el test de Ramsey. Este consiste en la evaluación de la probabilidad de que una premisa sea verdadera o falsa. Lo que defiende es que, en la evaluación de un condicional del tipo "si A, entonces B", lo que hacemos es añadir el antecedente ("A") a nuestro bagaje de conocimiento, asumiéndolo como cierto, y realizar un cómputo de probabilidades, calculando la probabilidad condicionada de que se dé el consecuente ("B") dado que el antecedente está presente (P(A|B)) (Evans et al., 2005; Evans & Over, 2004; Johnson-Laird et al., 2015). Por ejemplo, para saber si el condicional

(1) "Si Daniela llora por la noche, entonces Jesica está despierta"

es verdadero, se realiza una simulación mental asumiendo que el antecedente se cumple ("Daniela está llorando") y calculamos, en base a ello, cómo de probable es que se dé el consecuente, es decir, que "Jesica esté despierta". Si la probabilidad es alta, se aceptará el condicional como verdadero; si no lo es, se indicará que el condicional es falso.

Por su parte, para computar las cuatro inferencias lógicas (MP, MT, NA y AC), se calcula la probabilidad de que se dé el condicional (probabilidad condicionada), así como la premisa categórica y se calcula cómo de probable es que se dé la conclusión. Como ya hemos mencionado, dado que la verdad de un condicional se asocia a la simulación de la presencia del antecedente, los casos "noA" (noA B y noA noB) se consideran irrelevantes para la evaluación del condicional.

En definitiva, podemos decir que la diferencia más notable entre este tipo de teorías y la TMM es que esta última considera que construimos casos concretos que se corresponden con posibilidades, mientras que las teorías o aproximaciones probabilísticas defienden el cálculo de un cómputo de probabilidades, sin tener en cuenta posibilidades concretas ni considerar los casos noA. No obstante, es importante mencionar que, al igual que ocurría en la TMM, la estimación de la probabilidad que realizamos puede verse afectada por numerosos factores, como pueden ser la consideración de situaciones o casos alternativos, el conocimiento general o el contenido del condicional, entre otros (ver capítulo 2).

3. La supresión de inferencias con condicionales

Como hemos visto en el capítulo anterior, existen cuatro tipos de inferencias a realizar ante un condicional, que surgen de la afirmación o negación de antecedente (A) y consecuente (B): MP (A.∴B), MT (¬B.∴¬A), AC (B.∴A) y NA (¬A.∴¬B) (ver Tabla 1), siendo solo las dos primeras inferencias válidas desde la lógica proposicional.

Algunas de ellas se realizan de manera mucho más rápida e intuitiva que otras. Es el caso de la inferencia MP, donde la premisa menor ("tiene chupete") encaja perfectamente con la información proporcionada en la premisa mayor ("si tiene chupete, es un bebé") y nos lleva, prácticamente de forma automática, a la conclusión válida ("es un bebé"). Es por ello que el número de inferencias MP que las personas realizamos es muy elevado en comparación con otras inferencias (Evans et al., 1993; Nickerson, 2015).

En el caso de las tres inferencias restantes (MT, AC y NA), para concluir de manera correcta se requiere de la consideración de otras posibilidades y, con ello, del despliegue de los modelos adicionales propuestos por la TMM (ver Tabla 2). Por ejemplo, tal y como hemos visto previamente, ante las falacias, el despliegue de la representación implícita nos lleva a ver que hay dos opciones posibles e inconsistentes (A y noA en AC; B y noB

en NA) como respuesta y, por tanto, no se puede alcanzar una conclusión (consultar Tabla 2 y Tabla 3). En MT, por el contrario, el despliegue de los modelos implícitos, junto con el modelo inicial, nos hacen ver que, ante la premisa noB, la única opción disponible es noA, siendo la respuesta correcta.

Sin embargo, existen diferentes mecanismos que pueden interferir en la aceptación de cada una de estas inferencias, contribuyendo a su rechazo, y que han sido utilizados en diferentes investigaciones con el objetivo de demostrar su efecto. Incluso la inferencia MP que acabamos de mencionar como "prácticamente automática" es susceptible de dicha supresión (Byrne, 1989; Espino & Byrne, 2020).

Uno de los mecanismos que demuestran el efecto de supresión es el contenido del propio del condicional (Johnson-Laird & Byrne, 2002; Quelhas et al., 2010, 2017). Este, puede generar un efecto conocido como de modulación en la construcción de modelos, viéndose afectada la aceptación de inferencias por el contenido del condicional, el contexto al que se hace referencia o el conocimiento general. Por ejemplo, si ante el condicional "si llueve entonces hay tormenta", presentamos la premisa "no llueve", es muy difícil que las personas desplieguen el modelo noA B (no llueve, pero hay tormenta), puesto que nuestro conocimiento del mundo nos dice que la tormenta es lluvia.

Otro de los factores que afectan a la supresión de inferencias es la consideración de contraejemplos, tratándose de condiciones que están relacionadas con la necesidad y suficiencia para la ocurrencia, o no, de las acciones definidas en el condicional. Entre ellos encontramos dos tipos: las alternativas y los disablers.

Las alternativas (¬A B) establecen que en un condicional "si A entonces B" puede existir un antecedente diferente de "A" que cause el mismo efecto ("B"). Por ejemplo, una condición alternativa en (1) podría ser "Jesica tiene trabajo" (¬A), por lo que, aun no estando presente la causa o antecedente original (Daniela llora; A), la consecuencia

seguiría siendo la misma (Jesica está despierta; B). Teniendo en cuenta esa información, si proporcionamos la premisa menor "Daniela no llora" (¬A) es probable que las personas rechacen la falacia NA (¬A.∴¬B): "Jesica no está despierta" (¬B), y consideren que no existe una conclusión válida pues puede ser que, aun no estando Daniela llorando, Jesica esté despierta porque tiene trabajo.

Lo mismo ocurre con el otro tipo de falacias: AC (B.∴A). Ante la premisa menor "Jesica está despierta"(B), las personas tienden a concluir en menor medida "Daniela está llorando"(A), puesto que consideran que existe una posibilidad alternativa ("Jesica tiene trabajo"; ¬A) que puede causar ese mismo resultado (B). Es por ello que considerarían que no existe una conclusión válida. Con ello, vemos que este tipo de contraejemplos permite que las personas consideren la existencia de situaciones alternativas que llevan al mismo consecuente y, por tanto, a que no se pueda alcanzar una conclusión válida (Cariani & Rips, 2017; Cummins, 1995). Esto afecta, como hemos visto, a la realización de falacias, pero no a las inferencias válidas (MP y MT).

Los disablers (A ¬B), por su parte, son aquellos que, aun estando presente la causa original (Daniela llora; A), evitan que se dé el consecuente (Jesica está despierta), puesto que hay una situación que imposibilita esa relación inicial. En el condicional (1) un ejemplo de disabler podría ser "Jesica lleva tapones en los oídos", por lo que "si Daniela llora, Jesica no está despierta (A ¬B)". Es por ello que, si proponemos una inferencia MP(A.∴B), es decir, proporcionamos la premisa menor "Daniela llora"(A), se aceptará en menor medida la conclusión "Jesica está despierta"(B), rechazando así este tipo de inferencia válida.

Lo mismo ocurre con el otro tipo de inferencias válidas: MT (noB.∴noA). Si proporcionamos la premisa menor "Jesica no está despierta" y los participantes cuentan con el disabler previamente mencionado ("Jesica lleva tapones en los oídos"), es menos

probable que acepten “Daniela no está llorando”, pues pueden considerar que quizás llore, pero Jesica, al llevar tapones, no la escucha. Es decir, a diferencia de lo que ocurría con las alternativas, ante contraejemplos de tipo disablers las inferencias válidas se ven afectadas por la supresión, pero no las falacias (Cariani & Rips, 2017).

Son varios los investigadores que han tratado de determinar si la disponibilidad de un mayor número de este tipo de contraejemplos, tanto alternativas como disablers, afecta a la supresión o si, por el contrario, la mera disponibilidad de uno de ellos bloquea los modelos en cuestión, produciendo la misma magnitud de bloqueo. Los resultados hallados han sido contradictorios (De Neys et al., 2002, 2003a; Markovits & Quinn, 2002).

No obstante, lo que sí podemos decir es que, independientemente de esta controversia, la información adicional que proporcionan los condicionales, bien sean situaciones alternativas o disablers, generan posibilidades o modelos adicionales (noA B y A noB, respectivamente) que pueden explicar la supresión “explícita” que hemos mencionado previamente, tanto de las inferencias válidas como de las falacias. Sin embargo, como hemos mencionado previamente, también puede darse una supresión que podríamos denominar “implícita” cuando el propio contenido del condicional, sin información adicional, puede hacer pensar en posibilidades alternativas o disablers (Cummins, 1995; De Neys et al., 2003a; Geiger & Oberauer, 2007). No obstante, este tipo de supresión ha sido objeto de controversia (Cariani & Rips, 2017), poniéndose en duda su existencia.

Por último, es importante mencionar que existen otros muchos factores que pueden influir en gran medida en el efecto de supresión, como pueden ser la fuerza de asociación de las condiciones alternativas con la memoria (Quinn & Markovits, 1998), si se ofrecen las respuestas de manera dicotómica o como un continuo (Markovits et al., 2010), la

estrategia adoptada a la hora de inferir (Brisson & Markovits, 2020) o que los participantes crean, o no, en los condicionales que se les presentan (Stevenson & Over, 1995, 2001).

Nosotros, en este trabajo, pondremos a prueba el efecto de supresión haciendo uso de diferentes mecanismos (ver capítulo 2). Por un lado, y puesto que, como hemos mencionado, existe controversia al respecto, nos preguntamos si se puede conseguir la supresión únicamente con la información del condicional, sin incluir información adicional. Asimismo, y puesto que existen resultados contradictorios, nos preguntamos, ¿puede tener efecto el número de condiciones alternativas o disablers del que se dispone? Y, por último, en el caso de que utilizáramos varias de estas estrategias, ¿podría darse un efecto de supresión "acumulativo" o "aditivo" de todas las condiciones? ¿únicamente con una de ellas sería suficiente para que se produjera la máxima supresión?

4. El razonamiento contrafáctico

Los condicionales contrafácticos como

(3) "Si Paula hubiera dibujado en el folio, el folio habría estado pintado"

son expresiones condicionales que establecen una relación hipotética entre causa y efecto. Hacen referencia a qué podía haber ocurrido de manera alternativa a lo que realmente ocurrió, considerando posibilidades contrarias a la realidad, pues requieren notar que, por ejemplo en (3), Paula realmente no dibujó en el folio y este estaba en blanco.

Como hemos mencionado en el apartado 2.1, la TMM establece que las personas representamos los condicionales a través de posibilidades o modelos mentales (Johnson-Laird & Byrne, 1991, 2002). Estos cuentan con notas mentales, consistentes en una representación simbólica adjunta a los modelos mentales que indican, entre otros aspectos, negación (¬) o si el modelo representado es real o hipotético (*R*/*H*). Como

hemos visto, al razonar con condicionales las personas generamos una representación inicial compatible con el enunciado (AB) y una representación implícita que indica la existencia de otros modelos disponibles (ver Tabla 2). Sin embargo, los condicionales de tipo contrafáctico como (3) nos llevan a considerar dos situaciones o modelos mentales en su representación inicial: uno hipotético que hace referencia a la situación enunciada en el contrafáctico y otro acerca de lo que realmente ocurrió (Byrne, 2016):

[Hipotético]	Paula dibujó en el folio (A)	Folio pintado (B)
[Real]	Paula no dibujó en el folio (¬A)	Folio en blanco (¬B)

Es por ello que una correcta comprensión de los condicionales contrafácticos requiere pensar en ambas posibilidades. Además, para razonar con condicionales contrafácticos también es esencial mantener en mente cuál de las posibilidades es la real y cuál la hipotética. Esta habilidad para distinguir situación real e hipotética se denomina "estatus epistémico".

Un caso de particular interés es el razonamiento con condicionales semifácticos, como

(4) "Aunque Paula hubiera dibujado en el folio, el folio habría estado en blanco".

Al igual que ocurre con los condicionales contrafácticos, los condicionales semifácticos están conjugados en modo subjuntivo y establecen una relación hipotética entre dos situaciones. Sin embargo, denotan que, en realidad, ocurrió algo parcialmente diferente a lo enunciado (Byrne, 2016). Este tipo de condicionales parecen cancelar la relación causal que establecen entre antecedente y consecuente a través del uso de la concesiva "aunque" (Rodríguez Rosique, 2001; Schwenter, 2001): normalmente dibujar en un folio llevaría a que este estuviera pintado, pero esta relación parece inhibirse. Es por ello que, aunque la situación hipotética enunciada por ambos tipos de condicionales

coincide (A,B), la situación real difiere: en contrafácticos tanto antecedente como consecuente son falsos (¬A¬B), mientras que en semifácticos el consecuente sigue siendo verdadero (¬A B) (Goodman, 1983) (ver Tabla 4).

Tabla 4

Representación de modelos mentales en contrafácticos y semifácticos según la TMM. En [ ] el carácter epistémico de cada modelo

	Contrafáctico	Semifáctico
	"Si hubiera…"	"Aunque hubiera…"
Situación hipotética	*A, B* [H]	*A, B* [H]
Situación real	¬*A,* ¬*B* [R]	¬*A, B* [R]

Tal y como hemos visto en el apartado 1, existen 4 tipos de inferencias. De acuerdo con la TMM, estas se realizan a partir de la manipulación de los modelos que representamos. Es por ello que la realización de inferencias con contrafácticos difiere de aquellas que realizamos ante un condicional semifáctico.

Es importante mencionar que tomamos esta teoría, la TMM, como marco de trabajo y referencia puesto que, tal y como hemos visto en el apartado 2.2., las teorías o aproximaciones probabilísticas, como la teoría suposicional, defienden que no representamos casos concretos sino la probabilidad de que se den dichos casos. Es por ello que este tipo de teorías no nos permiten hacer predicciones diferenciales, al no distinguir la representación de los condicionales contrafácticos de aquella relativa a los condicionales básicos.

De esta forma y continuando desde la perspectiva de la TMM, como hemos visto, los contrafácticos generan dos modelos: AB y ¬A¬B, que coinciden con aquellos generados en una interpretación bicondicional, por lo que las predicciones en cuanto a frecuencia de inferencias no varían entre ambos. Los modelos representados llevarían a una mayor

aceptación de las inferencias válidas (MP y MP), pero también de las falacias (AC y NA) al no contar con el tercer modelo (¬A B); es este tercer modelo el que nos llevaría a alcanzar conclusiones válidas (aceptar las inferencias válidas, pero rechazar las falacias) (Moreno-Ríos et al., 2008).

Sin embargo, como hemos mencionado, los modelos representados a partir de un condicional semifáctico varían (AB y ¬AB) y es por ello que las predicciones serían diferentes. El MP(A∴B) mantendría una frecuencia de aceptación alta. Por el contrario, se esperaría una frecuencia muy baja de MT(¬B∴¬A), un aumento de frecuencia en respuestas correctas en AC(B∴A) señalando que no existe conclusión válida y, lo más interesante, una respuesta no esperada en NA(¬A∴¬B): B.

Si comparamos la inferencia MP entre ambos, se podría esperar una mayor proporción de inferencias MP con semifácticos al coincidir el consecuente en ambos modelos (hipotético y real). Esto sería esperable sobre todo en niños y niñas, donde podrían utilizar el "aunque" como facilitador a la hora de inferir. No obstante, aunque cabría esperar un menor número de respuestas correctas en contrafácticos debido a la dificultad que su comprensión genera, a continuación vamos a ver las discrepancias que existen en cuanto a su desarrollo evolutivo.

4.1. El desarrollo evolutivo del razonamiento contrafáctico

Aunque existen numerosos estudios que hablan acerca de cuándo los niños y niñas son capaces de razonar de manera fluida con condicionales contrafácticos, existe un gran debate al respecto. Algunos de ellos encuentran que ya en edad preescolar son capaces de hacerlo (Guajardo et al., 2009; Nyhout & Ganea, 2019). Sin embargo, hay otros que no encuentran esta habilidad hasta ya entrada la educación primaria, mostrando incluso un desarrollo evolutivo que no culmina hasta la adolescencia (McCormack et al., 2018; Rafetseder et al., 2013, 2021). Desafortunadamente, no hay una explicación clara acerca

de qué factores podrían ser los causantes de las discrepancias halladas. No obstante, es importante mencionar que algunos estudios han encontrado que incluso las personas adultas, en situaciones particulares, muestran dificultad para razonar con este tipo de condicionales (Ruiz-Ballesteros & Moreno-Ríos, 2017).

Esta discrepancia en los resultados podría deberse a múltiples factores. Desde problemas o diferencias en las tareas, hasta capacidades diferentes en cuanto a funciones ejecutivas varias como pueden ser la memoria de trabajo, la inhibición o la atención. En cuanto a los aspectos relativos a la tarea, para la evaluación del razonamiento contrafáctico se han utilizado tareas que difieren bastante en numerosos aspectos. Algunos autores han utilizado tareas de papel y lápiz, historias leídas o presentaciones en PowerPoint (Nyhout et al., 2019; Nyhout & Ganea, 2020; Rafetseder et al., 2013), mientras que otros han puesto en práctica tareas que implican causas de carácter físico y que son "actuadas" frente al participante con el consecuente apoyo visual en la realización de la misma (McCormack et al., 2018; Nyhout & Ganea, 2019), requiriendo por ello de diferentes recursos a la hora de resolverlas.

Otro aspecto que plantean y que es especialmente interesante, es el que hace referencia a los problemas de interpretación de la medida. Algunos autores han puesto de manifiesto que los resultados hallados en cuanto a la habilidad de razonar fácilmente con contrafácticos en edades tempranas podría deberse a que los participantes daban respuestas correctas al contrafáctico, pero sin comprenderlo (Rafetseder et al., 2010). Explicaron que podría deberse a que interpretaban el contrafáctico como un condicional básico. Por ello, defienden que el éxito de los más pequeños en tareas sobre razonamiento contrafáctico (RCF), podría deberse al uso de una estrategia más simple: el razonamiento condicional básico (RCB), interpretando el condicional contrafáctico de manera bicondicional (A&B y noA&noB; consultar apartado 2).

(5) Si Paula dibuja en el folio, entonces el folio está pintado

Para demostrarlo, desarrollaron un estudio con dos tipos de tarea: una de respuestas indiscriminadas y otra de respuestas discriminadas (Rafetseder et al., 2013). En aquellas de respuesta indiscriminada, los niños y niñas podían contestar correctamente al contrafáctico ("Si Paula no hubiera dibujado en el folio, el folio habría estado…¿pintado o en blanco?) llevando a cabo un RCB. Por ejemplo, ante el condicional contrafáctico anterior podrían responder reinterpretándolo como un condicional básico (5) y, por tanto, pensar que "si Paula no dibuja, entonces el folio está en blanco", siendo esta la respuesta correcta.

Sin embargo, en aquellas condiciones de respuesta discriminada, el uso del RCB ante la pregunta contrafáctica llevaría a una respuesta errónea y, por tanto, diferente a la que se obtendría si se hiciera uso del RCF. Por ejemplo, si a la historia añadimos que llegó una amiga y pintó en el folio, entonces "Si Paula no hubiera dibujado en el folio, el folio habría estado…¿pintado o en blanco?". La respuesta básica "si Paula no dibuja, entonces está en blanco" llevaría a una respuesta incorrecta, pues han de considerar que existe una situación alternativa que hace que el folio esté pintado. De esta forma, se aseguraban de que cuando los niños y niñas respondían correctamente al contrafáctico lo hacían porque ponían en práctica el RCF y no el RCB. Así, encontraron que era a partir de los 12 años cuando daban respuestas muy similares a las personas adultas.

Por su parte, ante un condicional semifáctico como (4) ("aunque Paula no hubiera dibujado") cabría esperar resultados diferentes, siendo uno de los aspectos a estudiar en la presente tesis doctoral. Los condicionales semifácticos, como hemos visto previamente, parecen cancelar la relación entre antecedente y consecuente por lo que, a diferencia de los contrafácticos, llevarían más fácilmente a concluir que el folio habría estado en blanco de todas formas. Se trataría de una condición de las denominadas

previamente discriminativas, pues lleva a una respuesta diferente a la adoptada con RCB sin necesidad de añadir información adicional a la historia. Además, tal y como hemos visto previamente, la persistencia del consecuente "B" en ambos modelos (hipotético y real) podría facilitar la inferencia (ver Tabla 4). Es por ello que, incluso niños/as más pequeños/as podrían obtener una mayor frecuencia de aciertos con este tipo de condicionales.

No obstante, tanto en contrafácticos como en semifácticos los resultados esperados en cuanto al conocimiento de qué ocurrió realmente (estatus epistémico), deberían ser similares. Esto es así puesto que, en ambos, los antecedentes de las situaciones representadas en sus modelos coinciden: A y ¬A en situación hipotética y real, respectivamente (ver Tabla 4). A pesar de ello, es importante mencionar que, en general, cabría esperar un alto número de respuestas erróneas, pues incluso las personas adultas muestran problemas para mantener en mente esas etiquetas mentales (Ruiz-Ballesteros & Moreno-Ríos, 2017). Esta habilidad para codificar el estatus epistémico de los modelos (conocer cuál de las situaciones es la real y cuál la hipotética), podría ser clave en las diferencias evolutivas que se encuentran a la hora de razonar con este tipo de condicionales. Es por ello que este aspecto ocupa un lugar importante en los capítulos 3 y 4 de la presente tesis.

Tal y como hemos visto, la negación es esencial en el razonamiento contrafáctico, pues para saber qué ocurrió realmente es necesario negar antecedente y consecuente. Es por ello que la construcción de la negación podría jugar un papel fundamental en la explicación de las dificultades que los niños y niñas muestran a la hora de razonar con este tipo de condicionales.

4.2.Diferencias evolutivas al inferir con negaciones

Las personas normalmente representamos la negación a través del uso de anotaciones simbólicas como "no" (Byrne & Johnson-Laird, 2009; Khemlani et al., 2014; Moreno-Ríos & Byrne, 2018). Por ejemplo, si nos dicen "no hay un círculo" nosotros pensamos "no-círculo". Sin embargo, este proceso puede verse facilitado si contamos con una alternativa que pueda representar esa negación de manera más concreta. Por ejemplo, si tenemos un círculo y un triángulo y nos dicen "no hay un círculo", esta negación nos llevaría a pensar en la alternativa ("triángulo"). Esta representación a partir de un modelo alternativo y explícito en contextos binarios facilitaría la negación en comparación con la representación abstracta utilizando "no" (Espino & Byrne, 2018; Mayo et al., 2004).

Estas diferencias en la representación de la negación se ven reflejadas en el desarrollo evolutivo que manifiesta. La negación a través del uso de modelos alternativos y más "imaginables" o concretos, sería propia de los niños y niñas. Sin embargo, el uso de la negación con un carácter más abstracto a través del uso del "no" se vería reflejada ya en adolescentes y personas adultas. Es decir, ante el ejemplo de negación anterior "no hay un círculo", los niños y niñas acudirían a "triángulo". Sin embargo, adultos y adolescentes serían capaces de representar la negación de manera abstracta representando "no círculo" (Markovits & Lortie-Forgues, 2011). De esta forma, se podría decir que la habilidad para realizar la negación de manera más abstracta muestra un carácter evolutivo, alcanzando esta habilidad ya en la adolescencia y edad adulta (Markovits, 2013).

Generalmente, en el caso de los contrafácticos la negación no se presenta de manera explícita sino implícita en la conjugación del condicional. Por ejemplo, en

(3) "Si Paula hubiera dibujado en el folio, el folio habría estado pintado"

podemos ver que realmente Paula no dibujó en el folio. Sin embargo, no se ha estudiado cómo se realiza esa negación a partir de condicionales contrafácticos, aspecto que

conforma parte de la presente tesis doctoral (ver capítulo 4). Generalmente, las historias utilizadas en la evaluación del razonamiento contrafáctico a través de tareas de "papel y lápiz" han sido, en su gran mayoría, de tipo alternativo (Rafetseder et al., 2013). No obstante, en aquellas tareas actuadas sí se han utilizado condiciones disabler (McCormack et al., 2018). Nosotros en el capítulo 4 tratamos de investigar cómo, tanto personas adultas como niños y niñas, construyen la posibilidad contrafáctica haciendo uso de los dos tipos de contraejemplos vistos en el apartado 3: alternativas y disablers. Esta comparación entre alternativas y disablers en la construcción de la negación es esencial, pues podríamos decir que las posibilidades a la hora de realizarla difieren.

En el caso de las historias tipo disabler, como

(6) "Una niña estaba en la playa jugando con un cubo. Su cubo se rompió y estaba vacío porque tenía un agujero en el fondo. Si la niña hubiera echado agua en su cubo, el cubo habría estado…¿lleno o vacío?"

la generación del antecedente en la situación real del contrafáctico (la niña no echó agua) tiene que hacerse de manera abstracta a través del uso del "no".

Por su parte, en las historias tipo alternativa, como

(7) "Un niño estaba despierto en su cama porque su despertador acababa de sonar. Su hermana entró a la habitación para coger un juguete. Si su hermana hubiera entrado en silencio, el niño habría estado…¿despierto o dormido?"

hay dos casos que llevan al mismo consecuente: el despertador hace que el niño esté despierto ($A\ B$), pero también lo ocasiona el hecho de su hermana hiciera ruido al entrar ($\neg A\ B$). Por ello, podríamos decir que existen dos posibilidades o "caminos" diferentes para representar la negación. Por un lado, podríamos generarla de manera sintáctica haciendo uso del "no": "la hermana no entró en silencio". Y, por otro lado, podríamos acudir a la consideración de la alternativa propuesta: "sonó el despertador".

Como vemos, en las historias de tipo alternativa la negación se corresponde con un elemento que aparece en la historia (despertador), por lo que se podría recuperar y realizar a partir de él de manera más fácil. Sin embargo, en disablers no existe ningún elemento alternativo al que acudir para realizar la negación, por lo que tendría que hacerse de manera sintáctica y algo más abstracta haciendo uso del "no".

Tal y como hemos mencionado previamente, la construcción de la negación difiere en personas adultas y niños/as, con estos últimos realizando más fácilmente la negación a partir de situaciones alternativas y encontrando dificultades para hacerlo de manera abstracta a través del uso del "no" (Markovits, 2013; Markovits & Lortie-Forgues, 2011). Este aspecto constituye uno de los objetivos de la presente tesis doctoral, comparando historias alternativas con disabler en cuanto a la construcción de la negación y, a su vez, dentro de las primeras comparando si la recuperación de alternativas concretas (despertador) es más fácil que la recuperación de alternativas abstractas (tener problemas para dormir).

Es importante destacar que una de las dificultades existentes en el estudio del razonamiento contrafáctico, es el uso de diferentes tareas a la hora de evaluarlo en personas adultas y niños/as. Sin embargo, en los dos estudios de carácter evolutivo de esta tesis se utilizó la misma tarea, con el objetivo de que los resultados fueran comparables.

Objetivos generales y específicos de la tesis doctoral

A lo largo de la introducción se ha puesto de manifiesto la importancia del razonamiento contrafáctico y de la capacidad deductiva en el aprendizaje escolar, así como el escaso volumen de investigación que hay sobre esta temática y las incógnitas todavía abiertas en cuanto a algunos de los resultados hallados.

El objetivo principal de esta tesis se centra en estudiar el papel de la consideración de alternativas en la deducción que personas adultas y, especialmente niños y niñas, realizan con condicionales. No obstante, este objetivo podríamos decir que engloba tres grandes objetivos generales. El primero de ellos se centra en evaluar qué factores podrían influir en la elaboración de las cuatro inferencias básicas: MP, MT, AC y NA, las cuales requieren la construcción de alternativas para alcanzar conclusiones válidas (aceptar inferencias válidas -MP y MT- y rechazar falacias -AC y NA-). Asimismo, se pretende estudiar la posible relación entre dichos factores. Otro de los objetivos principales radica en analizar las limitaciones de la capacidad deductiva en niños y niñas ante un tipo concreto de construcción que requiere de la elaboración de alternativas: el razonamiento contrafáctico. Más concretamente, se pretende localizar qué factores podrían ser causantes de las limitaciones encontradas en este tipo de razonamiento en numerosos estudios, centrándonos en el seguimiento epistémico (diferenciar situación real e hipotética) de las alternativas. Por último, dado que la generación de la alternativa contrafáctica requiere de la negación, y puesto que la literatura acerca de esta refleja cambios evolutivos a la hora de utilizarla, también se pretende analizar su papel en este tipo de razonamiento.

Es importante mencionar que, a lo largo de esta tesis, tomamos la TMM como marco de trabajo. Esta teoría permite establecer hipótesis concretas en cuanto a todos los objetivos propuestos, conllevando implicaciones evolutivas que vamos a poner a prueba.

A lo largo de la introducción, hemos visto que la consideración de alternativas parece ser clave en la deducción, a menudo mostrando un efecto directo en la supresión de las cuatro inferencias básicas (MP, MT, AC y NA). Asimismo, también hemos visto que son numerosos los factores que pueden influir en su realización. Sin embargo, el efecto de alguno de ellos ha sido cuestionado (Cariani & Rips, 2017) y no se ha estudiado si el uso de varios factores podría suponer un efecto aditivo de forma que aumentara la supresión o la facilitación de las inferencias. Es por ello que sería de interés clarificar y corroborar la capacidad de supresión de algunos de los factores propuestos, tales como el contenido del propio condicional, información contextual adicional acerca de este o el hecho de generar contraejemplos; asimismo, sería interesante investigar el efecto que podrían tener los tres factores de manera conjunta en la supresión. Más concretamente, podríamos decir que uno de nuestros objetivos consiste en determinar si el contenido del condicional, la información explícita y/o la búsqueda de contraejemplos (y la cantidad de ellos) influye en la elaboración de inferencias y si todos estos factores podrían conllevar un efecto aditivo en la supresión o facilitación de las mismas.

Si la consideración de alternativas realmente influye en las inferencias que se realizan, sería de interés utilizar construcciones que requieran de tal generación. Nosotros nos centraremos en el uso de condicionales contrafácticos. Tal y como hemos visto a lo largo de la introducción, aunque el razonamiento contrafáctico sigue un proceso evolutivo, es cierto que no existe un acuerdo respecto a qué edad se podría alcanzar cierta fluidez en esta capacidad, con numerosos debates abiertos acerca de a qué pueden deberse las discrepancias que se encuentran entre los diversos estudios. Es importante mencionar que el uso de diferentes tipos de tarea para analizar esta capacidad con niños/as y adolescentes podría dar lugar a cometer errores en la interpretación. Es por ello que en nuestros estudios 2 y 3 (capítulos 3 y 4, respectivamente), uno de nuestros objetivos

consiste en analizar el desarrollo evolutivo del razonamiento contrafáctico utilizando la misma tarea en niños/as, adolescentes y personas adultas. Además, se pretende identificar algunos factores que podrían dificultar la deducción con este tipo de condicionales en niños/as, como pueden ser la estructura gramatical y la identificación del estatus epistémico, tal y como veremos a continuación.

En cuanto al aspecto formal sintáctico del lenguaje, a lo largo de la introducción hemos visto cómo los semifácticos, gracias al uso del "aunque", parecen cancelar la relación inicial entre antecedente y consecuente. Más concretamente, vemos que, desde la TMM, se predice que su modelo real (¬A B), difiere de aquel alcanzado con los condicionales contrafácticos con "si" (¬A ¬B). Sin embargo, el modelo hipotético en ambos tipos de condicionales coincide (A B). Por esta diferencia en la generación del modelo real, cabría esperar un efecto facilitador del "aunque" frente al "si" en la inferencia MP. Es por ello que uno de nuestros objetivos consiste en analizar si el componente lingüístico en sí mismo, más concretamente la estructura gramatical con "aunque", contribuye a la mejora en el razonamiento contrafáctico.

El segundo factor que podría ser clave en la dificultad que experimentan los más pequeños para razonar con contrafácticos, es la capacidad para distinguir situación real e hipotética (estatus epistémico). Tal y como se ha abordado en la introducción, para el razonamiento con este tipo de condicionales se requiere la representación de los dos modelos que el contrafáctico o el semifáctico suscita (ver Tabla 4). En investigaciones previas se ha demostrado que, incluso las personas adultas en ciertas situaciones, pierden las notas epistémicas ([H] [R] en Tabla 4) que permiten distinguir ambas situaciones (Ruiz-Ballesteros & Moreno-Ríos, 2017). Esto no había sido estudiado hasta ahora en niños/as y consideramos que, dados los resultados encontrados con personas adultas, podría ser clave en la dificultad que los más pequeños encuentran para razonar con estos

condicionales. Es por ello que otro de nuestros objetivos consiste en determinar si la discriminación del estatus epistémico podría ser, o no, uno de los factores que dificultan la deducción en el razonamiento contrafáctico en niños.

Por último, analizamos el papel de la negación en la generación de alternativas contrafácticas. Esta es esencial en este tipo de razonamiento, pues la construcción del modelo real requiere de su uso. A lo largo de la introducción hemos visto el desarrollo evolutivo que la construcción de la negación frente a condicionales presenta y cómo, los más pequeños, la realizan de manera más "concreta" recuperando una alternativa, mientras que las personas adultas sí cuentan con la capacidad de hacerla de una manera más abstracta, haciendo uso de elementos sintácticos como el "no". Sin embargo, poco se sabe acerca de cómo niños/as y personas adultas construyen la negación ante condicionales contrafácticos. ¿Acuden a la mera negación sintáctica de la situación planteada haciendo uso del "no"? ¿o, en el caso de que exista, recuperan una situación alternativa? Es por ello que el último de los objetivos de esta tesis consiste en investigar cómo personas adultas y niños/as piensan acerca del antecedente frente a un enunciado contrafáctico.

A modo de resumen, podemos decir que los objetivos generales y específicos de esta tesis son los siguientes:

1. Evaluar el papel de la consideración de alternativas en la supresión de inferencias, así como los factores implicados.
    1.1. Analizar la capacidad de supresión de inferencias a partir del contenido de un condicional básico.
    1.2. Analizar la capacidad de supresión de inferencias a partir de información contextual adicional al condicional.
    1.3. Analizar la capacidad de supresión de inferencias a partir de la búsqueda de contraejemplos al condicional.

1.4. Determinar si el uso conjunto de los factores previamente mencionados supone un efecto aditivo en la supresión de inferencias.

2. Estudiar el carácter evolutivo del razonamiento contrafáctico, tratando a su vez de localizar qué factores podrían ser causantes de su dificultad.
   2.1. Analizar el desarrollo evolutivo del razonamiento contrafáctico.
   2.2. Determinar si la identificación del estatus epistémico podría ser uno de los factores que dificultan la deducción con este tipo de condicionales.
   2.3. Investigar si el componente lingüístico contribuye a la mejora del razonamiento contrafáctico.
3. Analizar el papel de la negación en la construcción de las alternativas contrafácticas y cómo su carácter evolutivo podría afectar a este tipo de razonamiento.
   3.1. Investigar si la negación en condicionales contrafácticos se construye a través del uso de elementos sintácticos como "no" o a través de la recuperación de alternativas.
   3.2. Examinar si la concreción de las alternativas a la negación influye en su recuperación.
   3.3. Analizar si existen diferencias en la construcción de la negación en función del tipo de contraejemplo (alternativa vs. disabler).

El objetivo 1 se pone a prueba en el estudio 1 gracias al diseño a través de E-Prime de una tarea inferencial en la que se presentan diferentes factores con el objetivo de determinar si afectan a la supresión de inferencias. Todos los objetivos específicos se evalúan en ambos experimentos. No obstante, en el primer experimento se evalúa el efecto del condicional frente al uso de todos los demás factores y en el segundo se limitan dichos factores, de modo que podamos poner a prueba de manera individual los dos factores restantes: información adicional y generación de contraejemplos.

El objetivo 2 se aborda en el estudio 2. Para su desarrollo, se elabora una tarea que permite poner a prueba el razonamiento con condicionales de tipo contrafáctico, así como

evaluar el mantenimiento del estatus epistémico a lo largo del proceso deductivo. Además, para poner a prueba el aspecto formal sintáctico del lenguaje, en la tarea se utilizan condicionales semifácticos haciendo uso del "aunque", así como contrafácticos con "si". El objetivo 2.1. se evalúa en el experimento 2, pues este es llevado a cabo con niños y niñas de entre 8 y 12 años. Los objetivos 2.2. y 2.3. se ponen a prueba tanto con personas adultas (experimento 1) como con niños/as (experimento 2). No obstante, es importante mencionar que los objetivos 2.1 y 2.2. también son puestos a prueba en el estudio 3 (experimento 1: objetivo 2.2. y experimento 2: 2.1. y 2.2.) pues, para estudiar el fenómeno en mayor profundidad, se elabora una tarea similar.

Finalmente, el objetivo 3 se investiga en el estudio 3 donde, con una tarea semejante a la diseñada para el estudio 2, se pregunta a los participantes acerca del porqué de una situación contrafáctica, con el objetivo de que hagan referencia a la causa y, con ello, poder arrojar luz a la construcción de la negación en situaciones contrafácticas. Todos los objetivos específicos derivados del objetivo 3 son puestos a prueba en los dos experimentos del estudio 3 (experimento 1 con personas adultas y experimento 2 con niños y niñas). No obstante, el objetivo 3.2. se investiga más directamente en el experimento 2, puesto que, como hemos visto, las personas adultas, a diferencia de los niños/as, no parecen mostrar dificultad para crear la negación de manera abstracta.

Es importante mencionar que los diseños de los estudios 2 y 3 incorporan a personas adultas a modo de control con el objetivo de comprobar que las tareas diseñadas y utilizadas capturan los efectos básicos tradicionales ya encontrados. De esta forma, los resultados que se encuentren con niños y niñas podrían ser comparables con aquellos encontrados en personas adultas, pudiendo así identificar diferencias evolutivas.

ESTUDIOS EMPÍRICOS

A lo largo de los siguientes capítulos vamos a ver la sección empírica de la presente tesis doctoral. Esta consta de tres estudios, divididos en tres capítulos:

- Capítulo 2: *Conditional content, explicit information and generating cases: Sources for suppressing inferences.*
- Capítulo 3: *How children and adults keep track of real information when thinking counterfactually.*
- Capítulo 4: *Alternatives or syntactic negation? Adults' and children's preferences for constructing counterfactual possibilities.*

Como hemos comentado a lo largo de los objetivos, en el capítulo 2 se pondrá a prueba el efecto de supresión a partir de diferentes factores con dos experimentos diseñados en E-Prime: el propio condicional, información adicional a este y la búsqueda activa de contraejemplos. Asimismo, se estudiará si estos factores se relacionan entre sí mostrando un efecto aditivo o sumatorio en la supresión.

En los capítulos 3 y 4 se analizará la habilidad para razonar con condicionales de tipo contrafáctico tanto en personas adultas, como en niños y niñas. En el capítulo 3 nos centraremos en estudiar el papel del contenido gramatical en este tipo de razonamiento, comparando las construcciones de tipo "si hubiera…" (contrafácticos) con "aunque hubiera…" (semifácticos). Asimismo, se analizará el papel del estatus epistémico (capacidad para distinguir situación real e hipotética) en la dificultad que, especialmente los más pequeños, parecen encontrar ante este tipo de razonamiento. Además, se estudiará el carácter evolutivo de ambas habilidades (habilidad inferencial y estatus epistémico). Todo ello lo haremos en dos experimentos, uno con personas adultas y otro con niños y niñas, en los que se emplea la misma tarea y metodología.

Por último, en el capítulo 4, además, se investigará cómo, tanto personas adultas (experimento 1) como niños y niñas (experimento 2), construyen la posibilidad

contrafáctica. Más concretamente, analizaremos si lo hacen recuperando alternativas o recurriendo a la negación sintáctica haciendo uso del "no". Asimismo, y puesto que la construcción de la negación muestra diferencias evolutivas, se analizará el papel de la concreción de la negación en la creación de la posibilidad contrafáctica. Al igual que en el estudio anterior, se mantiene la misma metodología y tarea en ambos experimentos, con el objetivo de que los resultados sean comparables.

Capítulo 2

Conditional content, explicit information and generating cases: Sources for suppressing inferences

Conditional content, explicit information and generating cases: Sources for suppressing inferences

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Abstract

In the present study, we evaluate the suppression effect by asking participants to make inferences with everyday conditionals ("if A, then B"; "if Ana finds a friend, then she will go to the theatre"), choosing between three possible conclusions ("she went to the theatre"; "she did not go to the theatre"; "it cannot be concluded"). We test how these inferences can be influenced by three factors: a) when the content of the conditional induces us to think about disabling conditions that prevent us from accepting the consequent (A and ¬B) or alternative conditions that induce us to think about other antecedents that could also lead to the consequent (¬A and B), b) when explicit information is given about what really happened (e.g. Ana found a friend but they did not go to the theatre; or Ana did not find a friend but she went to the theatre) and c) when participants have to look for concrete disabling (e.g. Ana´s friend had to work) and alternative cases (e.g. Ana's sister wanted to go to the theatre) before making the inferences. Previous studies have shown what were called "suppression effects": disabling conditions reduced valid inferences while considering alternatives led to a reduction in fallacies. These two "suppression effects" were shown in Experiment 1: a) in an Implicit condition that included just the content factor of the conditional and b) with a greater magnitude in a second Explicit condition that included the three factors (content, explicit information and search for counterexamples). Experiment 2 compared the same Explicit condition with another in which participants, instead of looking for counterexamples, completed a control task of looking for synonyms. In addition, half the participants looked for a few items (2 cases) and the other half for many items (5 cases). Results again showed the suppressing effect in all the conditions, but the magnitude was greater in the counterexample condition. No relevant differences were obtained according to the number of cases generated; the most relevant result was that the factors provided an additive effect on the suppression.

Keywords: suppression of inferences, counterexamples, conditional reasoning, disabling conditions, alternative conditions.

People draw conclusions from conditionals such as

"if Cristina ran, then she took the train" (if A, then B)

using their knowledge about the world and their logical knowledge. For example, knowing that "Cristina ran", most people choose the valid conclusion "she took the train" when they are given three possible ones (She took the train / She did not take the train / Nothing follows) (e.g. see Evans et al., 1993). However, knowing that "Cristina took the train", most people conclude that "she ran" instead of the valid inference "Nothing follows", from a material implication in propositional logic (e.g. see, Evans et al., 1993). The first inference is a Modus Ponens (MP; If A, then B; A, therefore B) while the second is a fallacy, called Affirmation of the Consequent (AC; If A, then B; B, therefore A). Table 1 shows the two valid inferences (MP and MT) and the two fallacies (AC and DA) resulting from affirming or denying the antecedent and the consequent of a conditional.

Table 1

Structure and example of the four logical inferences with the conditional, categorical premise and conclusion. The symbols "¬" and "∴" mean "not" and "therefore", respectively.

Conditional premise *If she ran, she took the train*		
	Categorical Premise	Conclusion
Valid inferences		
Modus ponens (MP) *If A, B; A ∴ B*	She ran	She took the train
Modus tollens (MT) *If A, B; ¬B ∴ ¬A*	She did not take the train	She did not run
Fallacies		
Affirm consequent (AC) *If A, B; B ∴ A*	She took the train	She ran
Deny antecedent (DA) *If A, B; ¬A ∴ ¬B*	She did not run	She did not take the train

Mental logic theories (Braine & O'Brian, 1998; Rips, 1994) have proposed the existence of a mental rule for modus ponens. When reasoners find a propositional argument that matches the MP structure (If A, then B; A), they automatically apply the mental rule to conclude "B," which explains the high proportion of MP endorsements (see Evans et al. 1993 and Nickerson, 2015, for reviews). There has not been a similar rule proposed for fallacies. One explanation for this is that the frequency of fallacies depends on the conditionals' content, while valid inferences do not (e.g., Rumain et al., 1983).

Based on the mental model theory, Byrne (1989) demonstrated that the modus ponens inference could be suppressed by adding information to the logical argument. This study demonstrated that the conditional's content also influences the MP inference, and therefore, the existence of a mental rule for valid inferences (MP) but not for fallacies was questioned (Byrne 1989; Espino & Byrne, 2020).

Since the publication of the original studies of suppression (Byrne, 1989; Cummins et al., 1991), many other studies have been carried out and the main deductive theories have had to be adjusted to explain the suppression effect. Despite many studies on suppression, some doubts remain about the conditions in which suppression occurs and whether the theories can easily explain everything, as shown in recent papers (Cariani & Rips, 2017; Espino & Byrne, 2020; Oaksford & Chater, 2020). In these studies, two conditions are critical and involve the action of *counterexamples* (following the example of conditional (1)):

Alternative conditions allow another antecedent but the same consequent (e.g. Cristina found a taxi and took the train; she did not need to run).

Disabling conditions *prevent* the consequent from happening even if the antecedent happens (e.g., a twisted ankle meant that even if Cristina ran, she would be too late to take the train).

This study aims to clarify some factors implicated in the suppression effect.

Experimental procedures to produce suppression of inferences

Earlier studies (see Cariani & Rips, 2017) used three procedures to create a suppression effect (the reduction of valid inferences and fallacies):

The first consists of using **Enabling conditions,** also called Additional conditions (see Espino & Byrne, 2020). For example, if after the conditional (1) "if Cristina ran, then she took the train", participants read

(2) "if Cristina's ankle recovered, then she took the train",

they tended to suppress the MP inference "she took the train" when provided with the information that "she ran". When participants consider additional content that may affect the relationship between the antecedent and the consequent of a conditional, they are more likely to suppress valid inferences (Byrne, 1989).

The second procedure uses **Disabling conditionals**, also called Contravening conditions (see Cariani and Rips, 2017). For example, if after the conditional (1) "if Cristina ran, then she took the train", participants read

(3) "if Cristina's ankle is twisted, then she did not take the train";

they were again less keen to make the modus ponens inference that Cristina took the train, knowing that "Cristina ran".

In both cases (1 & 2; 1 & 3), the second conditional suppressed the valid inferences (modus ponens and the modus tollens) but not the fallacies (see Cariani & Rips, 2017; Markovits et al., 2010). In the first case, to accept a conclusion, one must consider an

additional condition (a healthy ankle). In the second case, a condition (a twisted ankle) can prevent the conclusion.

The third procedure implies the use of **Alternative conditions**. For example, if after presenting the conditional (1) "if Cristina ran, then she took the train", participants read

(4) "if Cristina found a taxi, then she took the train",

they were less likely, given this information, to accept the Affirmation of the Consequent fallacy, "Cristina took the train; therefore, she ran". The same happened for the Denial of the antecedent, the other fallacy, but not for the valid inferences. This effect can be explained by the fact that people understand the existence of other possibilities (e.g., not only running but also taking a taxi) that allow the same consequent, and therefore, they conclude "nothing follows"[2] (Cariani & Rips, 2017; Cummins, 1995).

In these three procedures, the conditional (1) is followed by another conditional (2, 3, or 4). Cariani & Rips (2017) called the effect obtained with these three procedures "explicit suppression". Later studies showed that the suppression effect did not require the inclusion of a second conditional, just additional information that would lead people to think of disabling conditions or alternative possibilities. For example, after reading conditional (1), when participants were informed that "there were taxis available", they suppressed the conclusion that "Cristina ran", and chose "I cannot conclude whether or not she ran" (because she could have taken a taxi). Some authors (e.g., De Neys 2002, 2003a; Markovits & Quinn, 2002) have long demonstrated these effects of disablers (also called contravening conditions) and alternatives in inferential reasoning, shown even

[2] Although the prediction is an increase in "nothing follows" responses, many studies used an indirect estimation, using the reduction of the frequency of endorsed fallacies. The indirect measure is not clear because it includes changes in the frequency of the unexpected third conclusion (e.g. in AC; "if a, b; b, therefore …" the "not a" conclusion is computed as a suppression effect). In both experiments, we compute the "nothing follows" conclusions to test suppression.

without explicit information of counterexamples (e.g., Cummins, 1995; Markovits, 1986; Thompson, 1995).

It has also been demonstrated that some factors influence these effects, such as the strength of the alternative conditions in memory (Quinn & Markovits, 1998), participants' working memory spans, the strategies used, the options given in the conclusion, whether the conclusions are formulated with a degree of certainty (Geiger & Oberauer, 2007) or in a dichotomic way (Markovits 2012). In general, valid MP inferences are more likely to be reduced when disablers can be easily retrieved from long-term memory (Bonnefond 2014; De Neys et al., 2002, 2003a; Markovits & Quinn, 2002; Simoneau & Markovits, 2003). Recently, Markovits (2017) and Verschueren (2005a, 2005b) have studied how people can be classified depending on their tendency to look for counterexamples, while others seem to have a more probabilistic strategy (Brisson & Markovits, 2020). In any case, using a particular strategy does not increase the overall number of logical responses (see Markovits et al., 2017).

Theoretical approaches explaining inference suppression

Different theories have tried to explain the results of suppression studies: some of them based on logic (see e.g., Braine & O'Brien, 1998; Rips, 1994), including pragmatic implicatures and context-sensitivity (Cariani & Rips, 2017), others on suppositions (see Evans, 2007), on probability (see e.g., Cruz et al., 2015; Evans, 2012; Pfeifer & Kleiter, 2009) or on mental models (Byrne, 1989; Johnson-Laird & Byrne, 2002).

Probabilistic approaches to deduction with conditionals (if A, then B; e.g. If Cristina runs, she will take the train; see Geiger & Oberauer, 2007) propose that people's confidence in a conclusion (e.g., Cristina took the train) depends on the subjective conditional probability of the consequent, given the antecedent p(B/A) i.e., the probability of Cristina taking the train given that she ran (p(Take-Train/Run)). Instances that alter the

conditional probability will also influence inference acceptance, for example, disabling cases such as having a twisted ankle, or an alternative such as taking a taxi instead of running would reduce the acceptance for valid inferences and fallacies, respectively.

The mental model theory (Johnson-Laird & Byrne, 2002; Khemlani et al., 2018) states that people represent conditionals as mental possibilities (a model of reality known as a mental model) that include the case A & B and an implicit mental footnote indicating that other possibilities exist, but are not initially represented. In the conditional (1), the possibility that "Cristina ran, and she took the train" is represented:

She ran Took the train (A B)

…

However, depending on the context, content and knowledge, different instances may also be represented, such as "¬A & ¬B" and "¬A & B" (Johnson-Laird & Byrne, 2002; Quelhas et al., 2010, 2017), and inferences will depend on the possibilities represented:

She ran	Took the train	(A B)
She did not run	Took the train	(¬A B)
She did not run	She did not take the train	(¬A ¬B)

For example, knowing that Cristina can find a taxi (she does not need to run), people represent the alternative model "¬A B". In this case, there are two models in which B is present (the initial model AB and ¬A B), and when we tell participants that Cristina took the train (B), they are less likely to accept the fallacy "she ran" (A) because they have another possibility represented (¬A). This extra model could explain the suppression of fallacies. Similarly, the suppression of valid inferences occurs when participants think of disabling conditions, "A ¬B" cases, such as "Cristina had a twisted ankle". Given A (Cristina ran), they are less prone to conclude B, as they have in mind a model with "¬B", which is inconsistent with the model "A B".

Cariani and Rips (2017) proposed a model of suppression related to the mental model theory without assuming mental models where the meaning of a conditional (semantic) is captured by one indicative conditional rather than many, as proposed by the mental model theory (Johnson-Laird & Byrne, 2002). The suppression effect results from conversational pragmatic principles that alter the scope of the context in which people evaluate the argument. For example, participants assume that when they are told conditional (1), it is because there is a common ground knowledge based on typical properties (If you are in a hurry and run, you can catch the train) and this excludes atypical ones (such as your ankle is twisted and you cannot run fast). Participants consider the set of possibilities consistent with an argument. However, when additional information is given (as a contravening condition, e.g., "if Cristina's ankle is twisted, then she did not take the train"), people reevaluate the possibilities. In this case, most participants would not accept that "Cristina ran and took the train".

The role of explicit premises and thinking about concrete cases.

As we have seen, authors have used different experimental procedures to suppress inferences: using two conditionals, using an additional premise after the conditional or just using alternative or disabling content.

Alternative content induces us to think of alternative conditions that also lead to the same consequent:

(5) "If María studies hard, then she will get good grades".

Some students may think of other ways to get good grades without studying hard, such as cheating in the exam.

Disabling content induces us to think of disabling conditions that could prevent the consequent,

(6) "If Ana finds a friend, then she will go to the theatre".

People can find many circumstances that would prevent Ana from going to the theatre, such as going to a party instead.

Whether the content of the conditional alone can lead to suppression has been brought into question. Cariani and Rips (2017) compared the results from different suppression studies and sustain that suppression effects are more evident with the three traditional procedures (enabling-contravening conditions and alternative conditions). They questioned the robustness of the suppression effect in "Implicit suppression" studies, when participants receive one conditional with content that leads them to think of disabling or alternative conditions. Moreover, they pointed out that most of these studies reporting suppression used a different task: asking participants to give a response on a scale that varies on a continuum between "very sure that I can draw this conclusion" to "very sure that I cannot draw this conclusion" (e.g. Cummins, 1995; De Neys et al., 2003b; Geiger & Oberauer, 2007). As previously mentioned, this could lead participants to make an inference not assuming the truth of the premises, but answering to the degree of confidence that should be placed in the consequent. They cite three other experiments with more traditional conclusions, but find that their effects are unclear and differ from each other (see Cariani & Rips, 2017; p. 582).

In our study, we use an "implicit suppression" procedure referred to by Cariani and Rips (2017), but using a traditional inference task with the three possible discrete conclusions (such as in Table 1). In Experiment 1, we test whether it is the conditional's content leading to thinking about alternatives and disabler conditions that produces the suppression effect. We also test whether the magnitude of suppression is similar to that in a condition with unambiguous and explicit indications of alternatives or disabling conditions. According to theoretical models, such as probabilistic and suppositional approaches and models based on pragmatics, we would expect a maximum suppression

effect to be obtained when participants are explicitly informed of the existence of alternative or disabling conditions for a particular conditional (for example, by changing the conditional probability, as mentioned in the previous section). However, if participants represent particular cases (as the model theory proposes), an increase of the suppression effect would be obtained when participants think of different concrete cases in addition to the explicit information. We will test this possibility in Experiment 2. If a participant only needs evidence of the existence of a disabling condition to reduce a modus ponens inference, whatever source provides the effect will be sufficient, and no additional effect should emerge. However, if the sources influence different processes during the inference, we would expect additive effects.

Few studies have tried to test whether the concrete number of alternatives and disabling conditions directly affects the reduction of valid inferences and fallacies. Markovits and Quinn (2002) in their original model proposed that after successful retrieval of a single counterexample, the search process stops as there would be no advantage in accessing more counterexamples. However, De Neys et al. (2002) had mixed results, testing frequency and processing times. The authors suggested that the number of disabling conditions could influence not only valid inferences but also fallacies. The same authors in another study (De Neys et al., 2003b) manipulated the number of explicit counterexamples (0 or 4 alternatives or disablers) and found the expected effect for affirmative inferences (MP and AC). In contrast, the effect was less evident in the negative inferences (MT and DA). A possible explanation is that the additional processing requirements for these negative inferences burden the counterexample search process.

It is difficult to make specific differential predictions from the deductive theories. They can all integrate different results, and in some cases, opposite results. Probabilistic approaches maintain that people accept a conclusion when it is believable. We could

attribute to probabilistic approaches the primary role of factors such as the general probability of the conditional rather than the role of the number of particular cases such as disabling conditions, which is the argument used in some studies (Geiger & Oberauer, 2007). Nevertheless, it seems plausible that if one thinks of many alternatives or disabling cases, the perceived probability will change. Considering Cariani & Rips's (2017) proposal, when participants are told explicitly of alternatives or disabling conditions, we can expect suppression. However, we would not expect an increase in suppression when asking participants to think of concrete instances because there are no semantic or pragmatic changes. On the other hand, because the model theory assumes people consider models of reality, the concrete cases should affect the inferences. But once a critical case (such as "¬A B") has been represented, why would one expect many cases to be more effective than just a few?

Experiment 1. Conditional content for the suppression effect

As previously mentioned, Cariani and Rips (2017) maintained that the empirical results of suppression are not precise when only one conditional is presented instead of two. They also questioned whether some suppression effects, found previously in the literature, could be due to not using the traditional inference task with three options for conclusions. In this experiment, we test suppression with one conditional and use the standard inference set of conclusions. We are interested in testing whether the suppression effect is obtained in a simple implicit condition depending on the conditional content. We tested participants with two types of conditional: alternative contents that lead people to think of alternatives to the antecedent (¬A cases that lead to the same consequent). These conditionals should suppress fallacies by increasing the frequency of "nothing follows" conclusions. The second type relates to disabling contents that lead participants to think of disabling conditions (¬B even when A occurs), and should suppress valid

inferences. The contents were selected from previous studies (Couto, et al. 2010; Cummins, 1995) and from a pilot study conducted to increase the number of conditionals (see the Materials section in Experiment 1 and Appendix A for more details).

Based on the previously reviewed studies, we created an explicit suppression condition to contrast with an implicit suppression condition to test whether the implicit condition can produce suppression and if a difference in the magnitude of the suppression effect exists between the conditions.

The suppression procedure structure in this study is shown in Table 2 (first and second rows). In the implicit condition, in each trial, participants carry out a control task, in which they generate synonyms for a given word. We then present the conditional with disabling or alternative contents (see Appendix B for the conditionals list) followed by the minor premise, and ask participants to make the four inferences (MP, DA, AC, MT). In contrast, in the Explicit condition, we provide participants with disabling or alternative information, stating what happened after the conditional. For example, "we know that A occurred, but B did not." Following this, we ask participants to generate Disablers or Alternatives and then make the four inferences (see Table 2, second row).

Table 2

Structure of the suppression trials for a disabling conditional used in Experiment 1 (rows 1 and 2) and Experiment 2 (rows 2 and 3). See text for more details.

Implicit Procedure	**Experiment 1- Example**
Control Search cases:	*Write two possible synonyms for (big)*

Conditional:	If Ana finds a friend, then she will go to the theatre
Minor premise (MP):	Ana finds a friend, therefore,
Conclusions:	1) Ana goes to the theatre
	2) Ana does not go to the theatre
	3) It cannot be concluded
	…. (the 3 other inferences follow: AC, DA & MT)

Explicit Procedure (with concrete cases)	**Experiments 1 and 2 - Example**
Conditional:	If Ana finds a friend, then she will go to the theatre
Explicit information:	However, we know that Ana found a friend but she did not go to the theatre
Search for Alternative or Disabling cases:	*Write two possible cases in which that could have happened:* ----------
Conditional:	If Ana finds a friend, then she will go to the theatre
Minor premise (MP):	Ana finds a friend, therefore,
Conclusions:	1) Ana goes to the theatre 2) Ana does not go to the theatre 3) It cannot be concluded …. (the 3 other inferences follow: AC, DA & MT)

Explicit Procedure (without concrete cases)	**Experiment 2 - Example**
Conditional:	If Ana finds a friend, then she will go to the theatre
Explicit information:	However, we know that Ana found a friend but she did not go to the theatre
Control Search cases:	*Write two possible synonyms for big* ----------
Conditional:	If Ana finds a friend, then she will go to the theatre
Minor premise (MP):	Ana finds a friend, therefore,
Conclusions:	1) Ana goes to the theatre 2) Ana does not go to the theatre 3) It cannot be concluded …. (the 3 other inferences follow: AC, DA & MT)

Therefore, in the Explicit condition, there are two sources of information for alternatives and disablers that are not present in the Implicit condition: the explicit mention of there being disablers/alternatives and the search for specific disablers/alternative cases.

We test an additional factor to determine whether the number of concrete alternatives and disablers represented affects the magnitude of the suppression. Half the participants search for a few particular cases (two), and the other half search for many cases (five). Since executive function activity can influence the inference task, we created the control task for the implicit condition, where participants search for few (two) or many (five) synonyms. The synonyms are neutral words, not related to alternatives or disablers, and therefore not expected to produce any suppression effect.

If the content is enough to produce the predicted suppressing effect, this would appear in both conditions. However, if the suppression requires participants to consider explicit information, the suppressing effect will only appear in the Explicit condition. Finally, if the number of alternatives or disablers generated is responsible for the suppression effect, we could expect a more significant suppression effect in the many cases group than in the few cases group.

Participants

Sixty-three adults between 19 and 27 years (M = 19.64; SD = 1.50) participated in the study. Fifty were women with a mean age of 19.48 years (SD = 1.45) and thirteen were men whose mean age was 20.23 years (SD = 1.60). The size of each group was determined before data collection and based on effect sizes in the literature. All participants were native Spanish speakers and were recruited in colleges or universities in Granada. They were compensated with course credits. Before starting the experiment, they read a consent form complying with the University Research Ethics Committee guidelines.

Materials

We used twelve conditionals, half having many alternatives available, the other half many disablers (see Appendix B). We selected these conditionals based on previous studies (Couto et al., 2010; Cummins, 1995) and a pilot study (see Appendix A) to reach the 12 conditional sentences.

Materials test: we asked 33 adults (from 20 to 54 years old) to test 12 conditionals of the same kind, similar to those previously mentioned. We presented six conditionals to each participant (in a disabler or an alternative condition), and they had to write down on a sheet of paper as many counterexamples as possible for each conditional. An example of the alternative condition is:

"If María jumps into a swimming pool, then she will get wet.

However, we know that María did not jump into the pool, but she got wet.

Write down as many explanations as you can think of for this fact."

For the disabling condition, we negated the consequent:

"If Ana finds a friend, then she will go to the theatre.

However, we know that she did not go to the theatre, but she found a friend.

Write down as many explanations as you can think of for this fact."

Of the 12 conditionals tested, we selected three as having many alternatives available but few disablers and three others as having many disablers available but few alternatives. The time spent generating the maximum number of alternatives and disablers was no longer than two minutes.

With the complete set of 12 final conditionals (six from previous studies and six selected in the pilot study), we carried out our experiment using E-prime software v.2.

Participants received the 12 conditionals (6 with many alternatives available and 6 with many disablers available). Participants were randomly assigned to two groups to generate either two or five counterexamples (explicit condition) or synonyms (implicit

condition) for each conditional. For each conditional, they also had to make the 4 inferences (MP, MT, AC, DA) in a total of 48 inferences.

The six synonyms trials for the Implicit procedure condition and six counterexample trials for the Explicit procedure condition were presented in block order (Implicit vs Explicit), both blocks being counterbalanced by participants.

Procedure and design

Participants were tested in a quiet room using a computer to display stimuli and record responses on a keyboard controlled by E-prime software v.2. (Schneider et al., 2002). The sessions lasted between 15 and 30 minutes. Participants were distributed randomly in two groups depending on the number of elements they had to generate: Few items (two) or Many items (five).

They read the instructions on the screen to ensure comprehension of the "Synonyms" and "Counterexample" tasks. Each participant then performed twelve trials: 6 for the Explicit Procedure condition (with 3 alternatives and 3 disablers in the generation task) and 6 for the Implicit Procedure condition (with 6 synonyms in the generation task).

Implicit condition: The participants started with the generation task, where they had to generate 2 or 5 synonyms depending on their assigned group. For example:

Type 2 synonyms for the word "good" [generation task - synonyms]

After that, a conditional was displayed on the screen, followed by the minor premise and the three response options. Participants had to press one of three keys to select the appropriate conclusion. An example of the Affirmation of the consequent (AC) is:

If Vera turns on the air conditioning, then she will be cold" [Conditional]

Knowing that Vera was cold, what can you conclude? [minor premise]

1. Vera turned on the air conditioning

2. Vera did not turn on the air conditioning

3. It cannot be concluded

Press 1, 2 or 3 according to your response

For each conditional, they were asked to make all four inferences. Once the participant had completed the inferences, a new generation task would appear, followed by the conditional and inferences.

Explicit condition: In the explicit condition, the participants started with the conditional, followed by explicit alternative or disabler information and the generation task. For example:

> If Vera turns on the air conditioning, then she will be cold" [conditional]
> However, we know that Vera turned on the AC but did not feel cold [explicit information]
> Write two/five possible cases in which that could have happened [generation task - counterexamples].

After completing the generation task, they made the four inferences as described above for the implicit condition.

The six synonyms trials for the Implicit procedure condition and six counterexample trials for the Explicit procedure condition were presented in blocks (Implicit vs Explicit); the presentation of the blocks was counterbalanced.

In the "Few items" group, participants had 1.50 minutes for each generation task (synonyms and counterexamples), meaning that for each word they had 1.50 minutes to generate two synonyms and for each conditional in the explicit condition they had 1.50 minutes to generate two counterexamples. In the "Many items" group, participants had 2 minutes for each generation task. The time was fixed based on the results in a pilot study without a time limit.

In this way, we created a 2 (Group: few items vs. many items) x 2 (Condition: Implicit vs. Explicit) x 2 (Counterexample: Alternatives vs. Disablers) x 2 (Inference:

Valid vs. Fallacy) mixed design with the group variable manipulated between participants.

The suppression effect was computed for the traditional, logical valid conclusions (interpretation of the conditional material implication): endorsed valid inferences and "nothing follows" conclusions for fallacies.

Results Experiment 1

The data are available at https://sl.ugr.es/0aVB for the two experiments.

As expected, fewer cases were generated in the Few items group than in the Many items group, for both the Explicit Condition (Few items: $M = 1.94$ $SD = .11$; Many items: $M = 4.16$ $SD = .62$; U-Mann Whitney test $Z = 6.97$, $\eta 2 = .74$, $p < .001$) and the Implicit Condition (Few items: $M = 1.71$ $SD = .21$; Many items: $M = 3.06$ $SD = .88$; $Z = 5.91$, $\eta 2 = .55$, $p < .001$).

Table 3

Experiment 1. Mean percentage of logically valid conclusions in bold (and standard deviations) for Inferences (valid, fallacies), Condition (explicit, implicit), Counterexample *(alternative, disabler) and Group (few items, many items)*

	Explicit Procedure				Implicit Procedure			
	Alternatives		Disablers		Alternatives		Disablers	
	Valid	Fallacies	Valid	Fallacies	Valid	Fallacies	Valid	Fallacies
Few items								
Accept	**83 (.20)**	19 (.28)	**34 (.30)**	80 (.20)	**91 (.18)**	44 (.37)	**79 (.29)**	73 (.31)
Nothing follows	16 (.19)	**80 (.29)**	65 (.31)	**19 (.21)**	9 (.18)	**55 (.37)**	20 (.29)	**25 (.31)**
Many items								
Accept	**82 (.21)**	26 (.38)	**42 (.35)**	78 (.24)	**86 (.21)**	51 (.36)	**80 (.24)**	77 (.28)
Nothing follows	15 (.20)	**71 (.38)**	57 (.35)	**19 (.22)**	13 (.21)	**48 (.37)**	18 (.25)	**20 (.29)**
Average								
Accept	**83 (.21)**	23 (.33)	**38 (.33)**	79 (.22)	**88 (.20)**	47 (.36)	**79 (.26)**	75 (.29)
Nothing follows	15 (.20)	**75 (.34)**	61 (.33)	**19 (.22)**	11 (.20)	**51 (.37)**	19 (.27)	**23 (.30)**

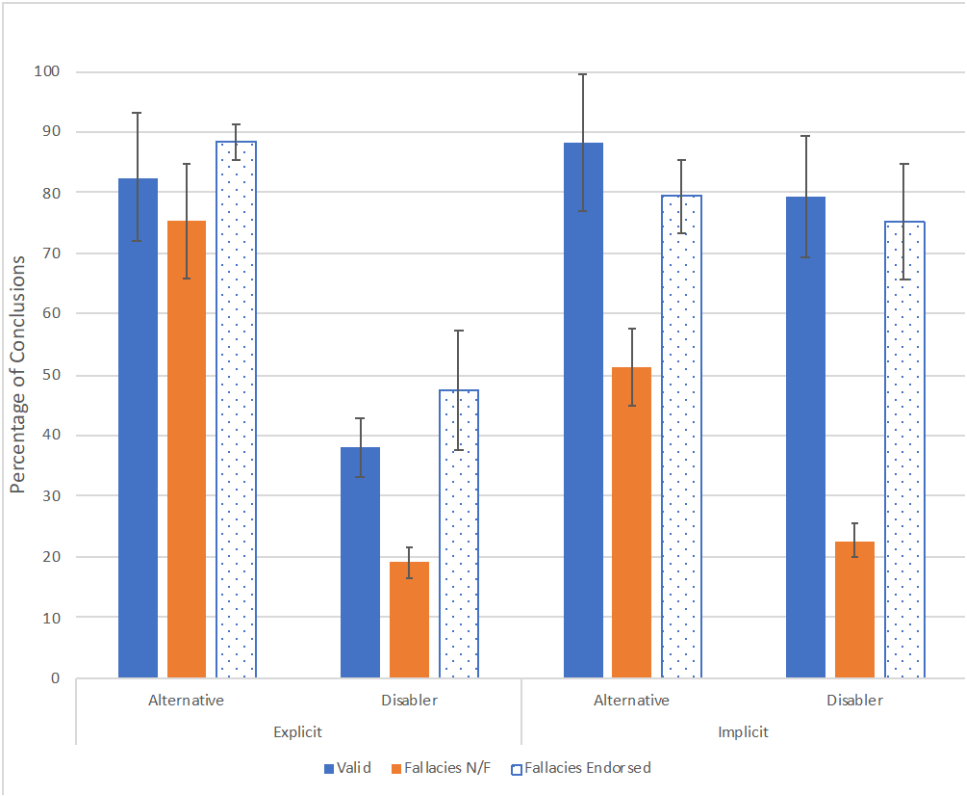
We carried out an analysis of variance (ANOVA) on the frequency of correct answers (valid) in a 2 (Condition: Explicit vs Implicit) by 2 (Counterexample: Alternative vs Disabler) by 2 (Inferences: Valid vs Fallacies) by 2 (Group: Few items vs Many items) design with the first three factors manipulated within-participants and the last between-participants. We computed the affirmation of the consequent for modus ponens, the negation of the antecedent for modus tollens and the "nothing follows" conclusion for the two fallacies (AC and DA) as correct inferences. Note that computing this response directly, as a measure of the suppression effect, is a stricter criterion than just looking for non-acceptance of the fallacies, which is consistent with two possible alternatives (the nothing follows and ¬A in the case of AC and B in the case of DA).

More correct inferences were made with Valid inferences than with Fallacies (72% vs 42%; $F(1, 61) = 57.46$, $p < .001$, $\eta 2 = .49$) and the same happened for Alternatives

compared to Disablers (74% vs 40%; $F(1, 61) = 205.99$, $p < .001$, $\eta 2 = .77$) (see Table 3). In general, results reveal a traditional trend that shows that Valid inferences are more frequently accepted than Fallacies. Note again that we compute "nothing follows" responses for Fallacies, which is the correct response from a material implication interpretation of the conditional and the logical response. As expected, considering Alternatives increases the correct inferences in Fallacies and considering Disablers reduces Valid inferences. This suppressing effect was greater for the Explicit Condition than for the Implicit Condition, with fewer valid inferences in the first (54% vs 60%; $F(1, 61) = 19.5$, $p < .001$, $\eta 2 = .24$). No effect of Group (few items vs many items) was found (58% vs 56%; $F(1, 61) = .34$, $p = .56$, $\eta 2 = .01$).

Figure 1

Mean percentage of logically correct responses for inferences (valid, fallacies) and fallacies endorsed (dotted bars), Condition (Explicit, Implicit) and Counterexample (alternative, disabler) in Experiment 1



Results also showed a significant interaction between Condition (Explicit vs Implicit) and Counterexample (Alternative vs Disabler) ($F(1, 61) = 61.23$, $p < .001$, $\eta 2 = .50$), between Condition (Explicit vs Implicit) and Inference (Valid vs Fallacies) ($F(1,61) = 35.02$, $p < .001$, $\eta 2 = .37$) and the interaction of Counterexample (Alternative vs Disabler) with Inference (Valid vs Fallacies) ($F(1,61) = 28.38$, $p < .001$, $\eta 2 = .25$).

The interaction showed that different results were obtained in the Implicit condition. The generation of synonyms made before the inference, which acts as a control, should not influence the process. Actually, the analysis for this condition shows no interaction between Counterexample and Inference ($F(1,61) = 1.23$, $p = .27$, $\eta 2 = .02$), but more correct responses for Alternatives than Disablers (64% vs 52% $F(1,61) = 37.12$, $p < .001$, $\eta 2 = .37$ and more correct Valid inferences than Fallacies (87% vs 30%; $F(1,61) = 125.44$, $p < .001$, $\eta 2 = .69$). Therefore, the content per se can provide the suppressing effect on inferences (see Figure 1).

The interaction between Condition and Counterexample shows that the suppressing effect is significant for the Explicit condition ($F(1,61) = 198.54$, $p<.001$, $\eta 2=.77$) and for the Implicit condition ($F(1,61) = 50.13$, $p<.001$, $\eta 2=.45$), but greater for the first. Actually, more correct inferences were made for the Explicit condition than for Implicit with alternatives ($F(1,61) = 11.69$, $p=.001$, $\eta 2=.16$) but fewer with disablers ($F(1,61) = 89.50$, $p<.001$, $\eta 2=.60$): which means a greater suppressing effect for the Explicit condition, as expected.

The same happened in the interaction between Condition and Inference. More inferences were endorsed with Valid inferences than with Fallacies in the Explicit condition ($F(1,61) = 8.25$, $p < .01$, $\eta 2 = .12$) and also in the Implicit Condition ($F(1,61) = 81.47$, $p < .001$, $\eta 2 = .57$). However, more correct valid inferences (fewer suppressing effects) were obtained in the Implicit Condition ($F(1,61) = 64.93$, $p < .001$, $\eta 2 = .52$) and

more correct inferences with Fallacies were obtained in the Explicit condition ($F(1,61) = 8.43$, $p < .01$, $\eta 2 = .12$).

Finally, the interaction between Inference and Counterexample showed that the difference between Valid inferences and Fallacies was greater for Disabling ($F(1,61) = 97.18$, $p < .001$, $\eta 2 = .61$) than for Alternative conditions ($F(1,61) = 21.75$, $p < .001$, $\eta 2 = .26$).

Discussion

Participants made inferences with two kinds of conditionals: contents that induced them to think of disabling conditions and contents that induced them to think of alternative conditionals. Fewer valid inferences were endorsed with disabling-content conditionals and fewer fallacies were accepted when the alternative-content conditionals were presented. Therefore, we could conclude that in the Implicit condition, the content of the conditional per se can create this suppressing effect of fallacies and valid inferences (given more correct fallacies and fewer valid inferences). The magnitude of the suppression of valid inferences and fallacies increased when we informed participants about a "disabling" or alternative condition and asked them to generate two or five explanations. Thus, Experiment 1 shows that the suppression effect was greater in the Explicit condition: when participants were informed that the antecedent happened but the consequent did not follow (or vice versa) and they looked for disabling or alternatives cases. Moreover, it did not make any difference whether participants were asked to generate two or five cases for the inference task.

Therefore, the main result in this study has been to show that the implicit condition produces suppression effects. Cariani and Rips (2017) questioned whether suppression could happen in an implicit procedure. The suppression effect was greater in the Explicit condition, but we cannot be sure whether this was caused by the explicit information

given about the existence of alternatives and disablers or because participants actively looked for those concrete cases, or by both. In Experiment 2 we try to answer this question

Experiment 2. Explicit information vs Looking for Counterexamples

In this second experiment, participants are always explicitly informed of a general disabling or alternative condition. We test whether asking them to look for disabling or alternative cases increases the suppression effect. We use the same Explicit condition as in Experiment 1 and create a new Explicit condition in which participants do not search for counterexamples; instead, after reading about the disabling or alternative condition, they carry out the control task of looking for synonyms. This control task is necessary because memory retrieval involves additional executive functions that could impact the later inference process. The two procedures' conditions for suppression are presented in Table 2 (second and third rows, respectively). In both conditions, participants are explicitly told that the consequent did not happen but the antecedent did (disabling) or that the consequent happened but not the antecedent (alternative). Therefore, the only difference between the two conditions is the generation task: participants either generate synonyms or counterexamples.

If the explicit information is responsible for the suppression effect, then searching for counterexamples should not increase that effect. As such, the suppression would be the same in both conditions (generating counterexamples or synonyms) since participants have the same explicit information telling them about the existence of counterexamples for the conditional. On the other hand, if thinking of particular cases influences representations, as the model theory maintains, an increase of the suppressing effect will occur in the counterexample condition compared to the synonyms condition. A final question is whether a more significant number of counterexamples will lead to an increase in suppression. Although the results in Experiment 1 did not show this effect, we again

asked half the participants to search for many counterexamples (5) and the other half for just a few (2).

Participants

The sample consisted of sixty-six adults between 18 and 27 years (M = 19.41; SD = 1.73): fifty-eight women with a mean age of 19.40 years (SD = 1.76) and eight men whose mean age was 19.50 years (SD = 1.60). All participants spoke Spanish as their first language and were recruited in colleges or universities in Granada. They were compensated with course credits. Before starting the experiment, they read a consent form complying with the University Research Ethics Committee guidelines.

Materials

The same as used in Experiment 1 (see Appendix B).

Procedure and design

The procedure was the same as in Experiment 1 with the following difference: in both conditions, participants were presented with the conditional, followed by explicit information about the alternative or disabling condition (see Table 2). In the Counterexamples condition, participants had to write two or five (depending on their group: few items vs. many items) counterexamples that could account for the facts described in the explicit information (see Table 2). By contrast, in the synonyms condition, participants were presented with a word and they had to write two or five (depending on their group) synonyms of that word. Everything else was identical to Experiment 1. We used a mixed design with Group (Few items vs Many items) manipulated between groups and Condition (Counterexamples vs Synonyms), Counterexample type (Alternative vs Disabler) and Inference (Valid vs Invalid)

manipulated within participants. The suppression effect was computed as in Experiment 1.

Results and discussion

As expected, fewer cases were generated in the few cases generation group than in the many cases group for both the counterexample (few cases: $M = 1.98$, $SD = .06$; many cases: $M = 4.12$, $SD = .82$; U-Mann Whitney test $Z = 6.79$, $\eta 2 = .65$, $p < .001$) and the synonyms (few cases: $M = 1.85$ $SD = .21$; many cases: $M = 3.34$ $SD = 1.05$; $Z = 5.82$, $\eta 2 = .50$, $p < .001$) (see Table 4).

Table 4

Experiment 2. Mean percentage of logically valid conclusions in bold (and standard deviations) for inferences (valid, fallacies), Condition (counterexample, synonyms), Counterexample type (alternative, disabler) and group (few items, many items)

	Counterexample				Synonyms			
	Alternatives		Disablers		Alternatives		Disablers	
	Valid	Fallacies	Valid	Fallacies	Valid	Fallacies	Valid	Fallacies
Few items								
Accept	**83 (.24)**	41 (.39)	**44 (.38)**	83 (.24)	**82 (.25)**	63 (.40)	**68 (.32)**	87 (.23)
Nothing follows	15 (.23)	**50 (.41)**	49 (.38)	**12 (.22)**	17 (.24)	**32 (.41)**	22 (.28)	**11 (.22)**
Many items								
Accept	**81 (.24)**	39 (.39)	**48 (.35)**	72 (.31)	**79 (.28)**	49 (.46)	**56 (.38)**	79 (.31)
Nothing follows	15 (.20)	**50 (.40)**	43 (.35)	**25 (.30)**	17 (.27)	**44 (.47)**	37 (.39)	**18 (.31)**
Average								
Accept	**82 (.24)**	40 (.39)	**46 (.36)**	78 (.27)	**80 (.26)**	56 (.43)	**62 (.35)**	83 (.27)
Nothing follows	15 (.21)	**50 (.40)**	46 (.37)	**18 (.26)**	17 (.26)	**38 (.44)**	30 (.33)	**15 (.26)**

We carried out an analysis of variance (ANOVA) on the frequency of correct logical answers in a 2 (Condition: counterexamples vs Synonyms) by 2 (Counterexample type: Alternative vs Disabler) by 2 (Inferences: Valid vs Fallacies) by 2 (Group: Few items vs

Many items) design, with the first three factors manipulated within-participants and the last between-participants.

As in Experiment 1, participants made more correct Valid inferences than Fallacies (68% vs 30%; $F(1, 64) = 49.16$, $p < .001$, $\eta 2 = .43$); also, Disabling conditionals reduced the Valid inferences while Alternative conditionals increased the "nothing follows" correct conclusions. Therefore, more correct conclusions were obtained for the Alternative conditionals compared to the Disabling conditionals (53% vs 37%; $F(1, 64) = 55.37$, $p < .001$, $\eta 2 = .46$). No effect of Group (generating 2 or 5 items) (48% vs 50%; $F(1, 64) = 0.90$, $p = .35$, $\eta 2 = .01$) or Condition (49% vs 49%; $F(1, 64) = .07$, $p = .80$, $\eta 2 < .01$) was found.

The results also showed three significant interactions, all with the factor Condition as a component: Condition (counterexamples vs Synonyms) and Inferences (Valid vs Fallacies) ($F(1, 64) = 7.06$, $p = .01$, $\eta 2 = .10$); Condition (Counterexamples vs Synonyms) and Counterexample type (alternative vs disabler) ($F(1, 64) = 12.95$, $p = .001$, $\eta 2 = .17$); and the same two factors with Group (Few items vs Many items) ($F(1, 64) = 4.67$, $p = .04$, $\eta 2 = .07$).

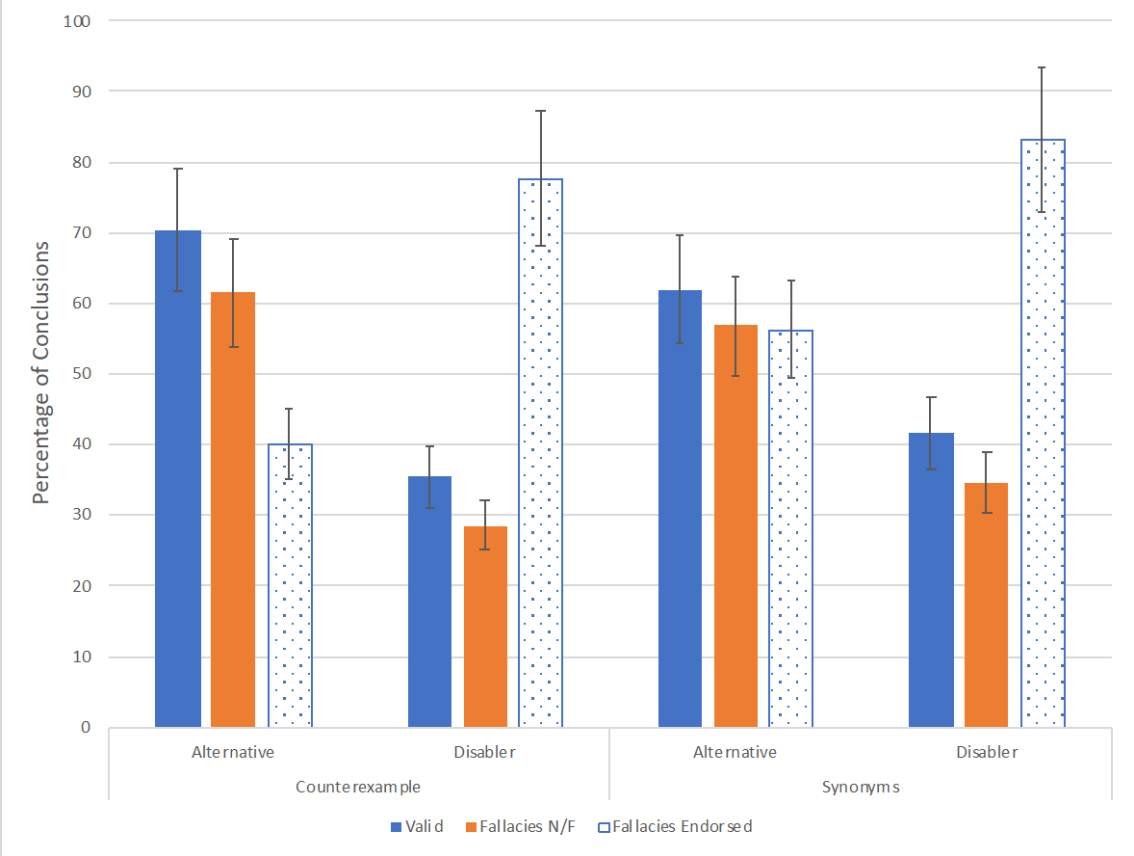
The first interaction shows that participants gave more correct responses to the valid inferences (MP and MT) than to the fallacies (DA and AC) in both conditions, as in Experiment 1. However, the suppression was stronger in the counterexample condition ($F(1, 64) = 26.85$, $p < .001$, $\eta 2 = .30$) than in the synonyms condition ($F(1, 64) = 51.35$, $p < .001$, $\eta 2 = .45$).

Condition and Counterexample type show that the suppressing effect is significant for both procedures (see Figure 2), the counterexample Condition ($F(1,64) = 66.44$, $p < .001$, $\eta 2 = .51$) and the synonyms condition ($F(1,64) = 26.34$, $p < .001$, $\eta 2 = .29$), but greater for the first. Again, as expected, the suppressing effect was greater: more correct

inferences were made for the Counterexample Condition than for the synonyms Condition with alternatives ($F(1,64) = 10.39$, $p = .002$, $\eta 2 = .14$) but fewer with disablers ($F(1,64) = 6.01$, $p = .017$, $\eta 2 = .09$).

Figure 2

Mean percentage of logically correct responses for inferences (valid, fallacies) and fallacies endorsed (dotted bars), Condition (Counterexamples, Synonyms) and Counterexamples type (alternative, disabler) in Experiment 2



To analyse the effect of the Group in the interaction, we analysed the two groups separately. In the Many items group, more correct conclusions were made for Alternatives than for Disablers (64%vs 37%; $F(1,32) = 20.78$, $p < .001$, $\eta 2 = .39$), and participants endorsed more Valid inferences than Fallacies (66% vs 43%; $F(1,32) = 12.14$, $p < .001$, $\eta 2 = .28$). No other significant difference was found. Similarly, in the Few items group, more correct conclusions were made for the Alternatives than for the Disablers (62% vs

34%; $F(1,32) = 40.32$, $p < .001$, $\eta 2 = .56$), and more were endorsed for Valid inferences than for Fallacies (69% vs 26%; $F(1,32) = 40.24$, $p < .001$, $\eta 2 = .56$). The interaction was due to the fact that only in the Few items group was the interaction between Condition (Counterexamples vs Synonyms) and Counterexample type (alternative vs disabler) significant ($F(1,32) = 14.28$, $p = .001$, $\eta 2 = .31$). The increase of the suppressing effect in the Without-Cases Condition reached significance only in the Few items group.

General Discussion

In this research, we tested the suppression effect of valid inferences and fallacies. To do so, we used alternative-content conditionals that induce us to think of alternative antecedents for obtaining a consequent, and disabling-content conditionals that lead us to think of disabling conditions that prevent the consequent. In Experiment 1, those contents that led people to think of alternatives and disabling conditions produced an effect of suppressing fallacies and valid inferences, respectively. This result is particularly interesting because Cariani and Rips (2017) maintained that the suppression of Modus Ponens in studies seems to require an explicit premise for alternative or disabling (contravening) conditions. They questioned the suppressing effect obtained in studies that varied the content of the conditional. Some of these studies used response scales as conclusions, instead of using the standard deduction instructions and response format with the three options (see Table 2). The response scales could encourage participants to treat the inferences as a probabilistic task, regarding the certainty of the conclusion instead of its necessity (p.581-582). Experiment 1 shows that the suppression effect was present in the implicit procedure with the standard deduction instructions and response format.

We also confirmed that the suppression effect was more significant in the Explicit Condition than in the Implicit one. In the explicit condition, we told participants that there were alternatives or disabling conditions and asked them to look for counterexamples before making the inference. In this case, the number of generated instances (few or many) did not make a difference. To make the Explicit and Implicit procedure conditions similar in complexity, we created a control condition where participants had to retrieve from memory synonyms instead of counterexamples. In both conditions, participants had a task that required them to retrieve contents from long term memory; however, those contents only related to the inferences in one of the conditions (explicit condition). In the implicit condition in Experiment 1, the synonyms generation task preceded the conditional and the inferences. Considering the differences between the Implicit and Explicit conditions in Experiment 1 (see Table 2), one may ask: is it the presence of explicit information that increases the suppression effect or does searching for disabling and alternative cases have an additional suppression effect? In Experiment 2, we compared the Experiment 1 Explicit condition with a new condition. The only difference between the conditions in the second experiment was that in one condition, participants searched for counterexamples (alternatives and disablers), whereas in the other condition, they had to search for synonyms. We created the synonyms task to control the possible effects of retrieving content from long term memory. Once more, results showed the suppression effect in the two Explicit Conditions. However, when participants not only received the explicit information but also had to search for counterexamples (counterexample condition), the endorsement of valid inferences decreased when participants searched for disabling conditions (without affecting fallacies). When participants retrieved alternative cases, the correct conclusions for fallacies increased (without affecting valid inferences). We found that the increased suppression was

significant only when participants searched for a few cases and not for many. We had not predicted this lack of improvement in the many items group. One possibility is that the need to look for many counterexamples would force participants to go outside the mental set of possible related ones and find less prototypical cases, maybe with lower suitability as real counterexamples, thus reducing the benefit obtained when they only have to look for two.

Another possibility is related to the fluency effect: the first counterexamples are easily retrieved in the few items condition because of the greater strength of association, but when participants need to search for additional ones and have difficulty finding them (up to five items), they might get the impression that there are not many counterexamples available for that conditional. In any case, the results clearly show that 1) looking for explicit alternatives and disablers improves the suppression of fallacies and valid inferences, but 2) having many cases does not produce more suppression than having few; actually, the opposite happened. As we mentioned in the introduction, deductive theories from different approaches have attempted to integrate and explain the results of initial studies on the suppression effect. They have tried to explain how disabling information (A & ¬B) and alternatives (¬A & B) will influence people's inferences. They should also explain that the suppression effect may arise from different sources:

1. From participants' general knowledge accessed by the meaning of the conditional
2. From the cases explicitly mentioned in the problem
3. From participants actively generating cases

As we have seen, mental rule theories base their explanation on pragmatic effects (see Braine & O'Brian, 1998; Rips, 1994). In their model of suppression, Cariani & Rips (2017) also proposed the pragmatic component as a key to explaining how suppression occurs: semantically, participants consider possibilities from a basic interpretation of the

conditional (strict interpretation). In addition, they adjust, adding and discarding possibilities when they acquire new evidence from additional premises (i.e., the second conditional in the traditional suppression procedures). Conversational rules are the base of the pragmatic component. In the description of their model, they do not explicitly say how the content would lead to activation of the pragmatic component when no additional premises are included, as happened in the Implicit Procedure Condition. The model in its present form cannot predict that in Explicit conditions, the suppression effect increases when participants search for concrete cases, as in Experiment 2. One difference between this model and the mental model theory is how the conditional is represented, depending on its meaning.

In the mental model theory, through the modulation effect, a particular set of initial representations is created, depending on the meaning of the conditional (see Johnson-Laird & Byrne, 2002; Quelhas et al., 2010, 2017). For example, as compared to a factual conditional (such as "if she watered the plants, they bloomed"), a counterfactual conditional (such as "if she had watered the plants, they would have bloomed") induces an increase of MT and DA inferences because the initial representation for counterfactuals includes the model of "she did not water the plants and they did not bloom" (Byrne, 2016 for a review). Therefore, participants are willing to accept "she did not water the plants" when they know that the plants did not bloom (MT) or to accept the reverse (DA). Espino & Byrne (2020) demonstrated that the background knowledge conditions can produce a suppression effect even with counterfactual conditionals. They used the traditional explicit procedure of additional conditions to suppress the MT valid inference and the explicit alternative condition to suppress the DA fallacy. They explained the result by the fact that people represent conditionals in the additional procedure as a conjunction of the antecedents of the two conditionals and the alternative procedure as a

disjunction. As we used disabling conditions instead of the traditional explicit procedure of additional conditions, we cannot test their proposal.

The model theory assumes that people represent mental models and explains how the content leads them to represent additional information as a new mental model to be integrated by the modulation effect based on their knowledge (Johnson-Laird & Byrne, 2002). Shared knowledge can induce us to think that if we find a friend, our earlier plans might change (for example, after reading "if Ana finds a friend, she will go to the theatre," and knowing that "Ana found a friend", we can suppress the valid conclusion "Ana went to the theatre"). However, the chances of including an explicit negation in the abstract model (found-a-friend and did not-go-to-theatre) increase when we explicitly tell people about this instance. This is what happened in our explicit condition. The problem with negation is that a mental footnote such as negation can be easily lost (Johnson-Laird & Byrne, 2002). When participants were allowed to create their particular cases, they could obtain a concrete mental model such as "found-a-friend and went to a party," which would help to fix a more permanent mental model (instead of "found-a-friend *not-theatre*", "found-a-friend *party*"). The search for counterexamples has an essential role in the mental model theory because it allows the construction of mental models (De Neys et al., 2003a; Markovits & Quinn, 2002) by fleshing out operations (Johnson-Laird & Byrne, 2002; Khemlani et al., 2018). Given a conditional, considering counterexamples consists of fleshing out the implicit models into explicit ones that can suppress inferences. However, the theory would not predict an advantage for having many concrete mental models since a higher working memory load is not usually helpful (Johnson-Laird & Byrne, 2002). Our results are consistent with this theory.

Theories based on supposition and probabilistic logic explained the suppression effect based on the reduction of believability in a conditional when participants received

additional information (Oaksford & Chater, 2020; Over, 2017; Stevenson & Over, 1995). In particular, the Suppositional conditional theory assumes that people understand a conditional "if A, then B" considering only "A" but not "not-A" cases to compute the probability of "B" (Evans, 2007; Evans & Over, 2004). When given new information, people revise the credibility of the first conditional, which explains suppression. From this approach, the suppression effect for our implicit condition can be explained by the effect of the conditional content. Thus, thinking about a disabling conditional's content leads them to consider the "A *not-B*" case, reducing the probability of their accepting "B" and, therefore, a reduction of MP valid inferences would be expected. On the other hand, the content of an alternative conditional that leads them to think of the "not-A *B*" case does not reduce the probability of their accepting "B". Thus, consequent in conditional (6) is less likely to be accepted than consequent in conditional (5), and therefore in the first case, suppression of MP is predicted. Previous studies have also shown that giving explicit information about the frequency or the existence of disabling or alternative conditions increases the suppression (Geiger & Oberauer, 2007; Markovits et al., 2010). This could explain the increase of suppression in the explicit condition in Experiment 1 when we explicitly told participants about alternatives or disabling conditions.

However, it is not clear how to explain the results regarding the search for alternatives and disablers; participants had already been explicitly informed of their presence. For example, for disabling conditionals, participants were told that the antecedent happened, but not the consequent. This explicit information should fix the reduction of credibility in the conditional. We expected that later in the trial when participants searched for counterexamples, they would obtain additional evidence that reduced the probability of the conditional. If this happened, why was there no effect of the number of alternatives?

There was no more suppression in the many cases condition than in that of the few cases, in either Experiment.

Differences between probabilistic approaches and the mental model theory could lie in how statistical information is processed (Markovits et al., 2017). Although they might make similar predictions, Brisson et al. (2018) propose that the account based on probability could induce the use of different strategies from those of mental model theories. The mental model theory would explain that the manipulations in the present study (the content of the conditional, given explicit information, and the search for counterexamples) increase the probability that participants will suppress valid inferences by producing counterexamples based on the disabling conditions and reject fallacies when considering alternatives (Byrne et al., 1999; Juhos et al., 2015).

Markovits et al. (2017) maintain that although the probabilistic approach (the p-validity model; see Evans et al., 2015; Singmann et al., 2014) is in many respects very similar to the mental model description of the counterexample, different predictions could be made from it. The probabilistic approach evaluates the likelihood of a conclusion considering the full context of available knowledge. In contrast, the counterexample search approach maintained by the mental model theory implies a narrower focus: a more concrete search for cases. If reasoners base their inferences on statistics, a broader contextual effect would be expected compared to those based on a counterexample search (Markovits et al., 2017; p.1183).

The present study's objective was to test whether the content of conditionals, explicit information, search for cases and search for counterexamples contribute to influencing how inferences are made. We have shown that these factors increase the suppression effects. We believe that these theories can integrate or explain our results ad hoc, but it is challenging to make exact predictions from the beginning. For example, following

Markovits et al. (2017), we could attribute the suppression effect to the statistical approaches based on general knowledge and explicit information, but this is clearly not expected from the generated cases. From the model theory, we could expect a suppression effect based on the generated cases and the meaning (based on the modulation effect, Johnson-Laird & Byrne, 2002). Assuming that with the content of the conditionals factor, participants have already established a believability criterion or have created a mental model, both approaches could have predicted the lack of effect of another factor (the explicit information and/or the search for counterexamples). The additive effect found in the three factors we study here provides, in our view, an important empirical fact that could help theories detail in more depth the algorithm for integrating evidence during the process of deduction with conditionals.

Appendix A

Mean of counterexamples (alternatives or disablers) generated for each conditional tested for the selection of the 6 conditionals (3 alternatives and 3 disablers) for Experiments 1 and 2

Conditional	Alternatives generated	Disablers generated
1*	3.33	1.14
2	1.66	2.14
3	1.83	1.14
4**	1	3
5**	.83	2.57
6	1.66	2.57
7*	4.43	2.5
8	3.57	3.33
9*	3.71	2.66
10**	2.42	4.33
11	3.28	2.5
12	3	3.5

**Conditionals selected as alternatives*

***Conditionals selected as disablers*

Appendix B

Conditionals used in the task (synonyms in brackets) and *the original ones in italic*

Disabler sentences

1. If Ana finds a friend, then she will go to the theatre (big); *Si Ana encuentra una amiga, entonces irá al teatro (grande)***
2. If Sebastian puts the coffee pot on the stove, then the coffee will rise (happy); *Si Sebastián pone la cafetera en el fuego, entonces subirá el café (feliz)***
3. If Rafael goes to the airport by car, then he will arrive in time to catch his flight (sensitive); *Si Rafael va en coche al aeropuerto, entonces llegará a tiempo para coger el avión (sensible)***
4. If you strike a match, then it will be lit (rich); *Si se frota una cerilla, entonces se encenderá (rico)*
5. If you press the right switch, then the light will turn on (tenacious); *Si se pulsa el interruptor correcto, entonces la luz se encenderá (constante)*
6. If Vera turns on the air conditioning, then she will be cold (good); *Si Vera enciende el aire acondicionado, entonces tendrá frío (bueno)*

Alternative sentences

7. If María jumps into a swimming pool, then she will get wet (beautiful); *Si María salta a una piscina, entonces se mojará (bonito)***
8. If Beatriz's phone is dropped, then it will break (kind); *Si a Beatriz se le cae el móvil, entonces se le romperá (simpático)***
9. If Cristina drinks coffee at night, then she will have difficulty sleeping (easy); *Si Cristina bebe café por la noche, entonces tendrá dificultad para dormir (fácil)***

10. If Teresa eats salt, then she will be thirsty (intelligent); *Si Teresa come sal, entonces tendrá sed (inteligente)*
11. If Tiago reads without glasses, then he will have a headache (expressive); *Si Tiago lee sin gafas, entonces tendrá dolor de cabeza (expresivo)*
12. If Daniel pours water on a camp fire, then the fire will go out (calm); *Si Daniel echa agua en la hoguera, entonces el fuego se apagará (tranquilo)*

*As the materials were in Spanish, it is important to take into account that in the case of synonyms, most of them are polysemic, unlike in English.

**Conditionals selected from a pilot study

Appendix C

Results by inference in the two experiments

Table C1

Mean frequencies of acceptances for each inference (AC,MP,MT,DA) (with "nothing follows" in parentheses) for Condition (explicit, implicit), Counterexample Type (alternatives, disablers) and Group (few items, many items) in Experiment 1. ***In bold the logically correct response.***

	Alternatives				Disablers			
	MP	MT	AC	DA	MP	MT	AC	DA
Explicit								
Few items	**2.69** (0.28)	**2.28** (0.66)	.53 **(2.47)**	.59 **(2.31)**	**1.06** (1.94)	**.97** (1.97)	2.38 **(0.59)**	2.44 **(0.53)**
Many items	**2.55** (0.32)	**2.39** (0.58)	.81 **(2.06)**	.77 **(2.19)**	**1.13** (1.84)	**1.39** (1.58)	2.39 **(0.55)**	2.32 **(0.61)**
Average	**2.62** (0.30)	**2.33** (0.62)	.67 **(2.27)**	.68 **(2.25)**	**1.10** (1.89)	**1.18** (1.78)	2.38 **(0.57)**	2.38 **(0.57)**
Implicit								
Few items	**2.78** (0.22)	**2.66** (0.31)	1.21 **(1.78)**	1.44 **(1.50)**	**2.50** (0.50)	**2.22** (0.72)	2.19 **(0.75)**	2.19 **(0.75)**
Many items	**2.74** (0.26)	**2.42** (0.52)	1.61 **(1.35)**	1.42 **(1.52)**	**2.42** (0.52)	**2.39** (0.58)	2.42 **(0.52)**	2.23 **(0.71)**
Average	**2.76** (0.24)	**2.54** (0.41)	1.42 **(1.57)**	1.43 **(1.51)**	**2.46** (0.51)	**2.30** (0.65)	2.30 **(0.63)**	2.21 **(0.73)**

Table C2

Mean frequencies of acceptances for each inference (AC,MP,MT,DA) (with "nothing follows" in parentheses) for Condition (explicit, implicit), Counterexample Type (alternatives, disablers) and Group (few items, many items) in Experiment 2. ***In bold the logically correct response.***

	Alternatives				Disablers			
	MP	MT	AC	DA	MP	MT	AC	DA
With-Cases								
Few items	**2.97** (0.27)	**2.30** (0.88)	1.39 **(1.67)**	1.18 **(1.70)**	**1.33** (1.12)	**1.24** (1.36)	2.21 **(0.30)**	2.27 **(0.33)**
Many items	**2.85** (0.21)	**2.21** (0.76)	1.21 **(1.64)**	1.15 **(1.58)**	**1.70** (0.91)	**1.21** (1.36)	2.18 **(0.64)**	2.00 **(0.73)**
Average	**2.91** (0.24)	**2.26** (0.82)	1.30 **(1.65)**	1.17 **(1.64)**	**1.52** (1.02)	**1.23** (1.36)	2.20 **(0.47)**	2.14 **(0.53)**
Without-Cases								
Few items	**2.39** (0.30)	**2.12** (0.49)	1.85 **(0.82)**	1.82 **(0.70)**	**2.33** (0.67)	**1.91** (1.00)	2.88 **(0.30)**	2.76 **(0.52)**
Many items	**2.48** (0.30)	**2.09** (0.67)	1.42 **(1.27)**	1.39 **(1.24)**	**1.97** (1.00)	**1.73** (1.21)	2.58 **(0.52)**	2.45 **(0.58)**
Average	**2.44** (0.30)	**2.11** (0.58)	1.64 **(1.05)**	1.61 **(0.97)**	**2.15** (0.83)	**1.82** (1.11)	2.73 **(0.41)**	2.61 **(0.55)**

Capítulo 3

How children and adults keep track of real information when thinking counterfactually

How children and adults keep track of real information when thinking counterfactually

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Abstract

Thinking about counterfactual conditionals such as “if she had not painted the sheet of paper, it would have been blank” requires us to consider what is conjectured (She did not paint and the sheet was blank) and what actually happened (She painted and the sheet was not blank). In two experiments with adults (Study 1) and schoolchildren from 7 to 13 years (Study 2), we tested three potential sources of difficulty with counterfactuals: inferring, distinguishing what is real vs conjectured (epistemic status) and comprehending linguistic conditional expressions (“if” vs “even if”). The results showed that neither adults nor schoolchildren had difficulty in the comprehension of counterfactual expressions such as “even if” with respect to “if then”. The ability to infer with both of these develops during school years, with adults showing great ability. However, the third source factor is critical: we found that the key to young children’s difficulty with counterfactual thinking was their inability to differentiate real and conjectured information, while adults showed little difficulty with this.

Keywords: counterfactuals; semifactuals; conditional reasoning; deductive development; epistemic status; mental models

You can easily imagine a mother talking about her son and saying to her young daughter:

(i) "If Carlos had worn knee pads to skate, his knees would not have been injured"

But, can the young daughter infer what really happened just from hearing the sentence? Understanding counterfactual conditionals requires her to think of two possibilities (Byrne, 2005, 2016; Johnson-Laird & Byrne, 1991):

A fact: Carlos did not wear knee pads and his knees were injured

A conjecture: Carlos wore knee pads and his knees were not injured

Moreover, she needs to keep in mind not only that there are two possibilities but also that one of them is real and the other is just a "conjecture". This ability to think about which is the real one and which is the conjectured one is called 'epistemic status' about the possibilities (Byrne, 2016). Here, we study the development of children in tracking that epistemic status and how it contributes to the whole ability to reason counterfactually from subjunctive conditionals.

There are few studies on how adults track the epistemic status (see Ruiz-Ballesteros & Moreno-Ríos, 2017). In contrast, there has been plenty of research providing evidence that people represent both situations (real and conjectured), with priming (see Byrne, 2005, 2016), with comprehension and with inference tasks (McCloy & Byrne, 2002; Moreno-Ríos et al., 2008; Ruiz-Ballesteros & Moreno-Ríos, 2017). In most cases, counterfactual expressions have been formulated using subjunctive conditionals, but not in all (e.g. Markovits, 2014).

In the text that follows, we review some contradictory results in the literature regarding the development of thinking about "how things could have been" and the experimental strategies used to test this ability. After that, we present how a deductive reasoning framework can help us to study children's difficulty with counterfactuals, not

only in making predictions about what is represented but also whether that representation is real or conjectured.

The development of counterfactual thinking

Until recently, it was unquestioned that primary schoolchildren (from 6 to 12; Beck et al., 2006; Rojas-Barahona et al., 2010) and even pre-schoolers (from 3 to 5; Guajardo et al., 2009; Roldán-Tapia et al., 2017) were able to reason with counterfactual conditionals in the same way and with the same meaning, as adults. However, some studies suggest that their ability could improve during the school years (see Rafetseder et al., 2013; Rafetseder & Perner, 2018), and even adults seem to show difficulty in particular situations (e.g. Markovits, 2014; Ruiz-Ballesteros & Moreno-Ríos, 2017).

The discrepancy could be due to the researcher's assumption that if pre-schoolers gave a correct response to a counterfactual conditional, it is because they understand these expressions. However, it is also possible to be correct without understanding the counterfactual conditionals as adults do. Children might understand the counterfactual conditional expression (i) as an indicative conditional, called basic conditional, based on their common knowledge (Rafetseder et al., 2010):

(ii) "If Carlos wore knee pads to skate, his knees were not injured'"

This was a basic conditional interpretation that would lead to what was called "Basic Conditional Reasoning" (Rafetseder et al., 2010). Actually, readers could complete the consequent "not injured", just based on their knowledge about the antecedent: "if Carlos wore knee pads to skate, his knees were …?" Researchers found that after presenting children with counterfactual conditionals such as (i), and adding "Carlos did not wear knee pads", children concluded "Carlos's knees were injured" ("modus ponens" inference). Basic conditionals are usually interpreted as biconditionals, and therefore, the logical predictions for basic conditionals are the same as for counterfactual conditionals.

As those inferences were consistent with adult counterfactual inferences, researchers thought that young children had the ability to think counterfactually. We think that it is possible that researchers failed to realise that the inferences were produced because children understood the counterfactual expression (i) as the basic conditional (ii), as we mentioned previously. If this is what happened, children's responses to the counterfactual expressions were correct but they may not have understood them in the same way as adults. To be confident about children's counterfactual comprehension, the experimental conditions need to be able to discriminate between counterfactual and basic conditional interpretations.

Discriminate conditions: alternative situations and semifactual conditionals

At least two strategies can be used to prevent the interpretation of counterfactuals as just basic conditionals.

One way was provided by Rafetseder, Cristi-Vargas, and Perner (Rafetseder et al., 2010). In their "discriminate responses condition", a piece of contextual information was added and a basic conditional interpretation of a counterfactual (ii) led to a wrong answer and, thus, a different one from that obtained using a counterfactual interpretation. For example,

> "Yesterday, early in the morning, Carlos was running in the schoolyard and he fell on the ground and hurt his knees. After that, he went skating with his friends".

They asked, "If Carlos had worn knee pads to skate, would his knees have been healthy or injured?" The basic conditional interpretation 'If Carlos wears knee pads to skate, his knees were healthy' would lead to a wrong response as children have to consider that there is another situation that annuls that relation, that is, Carlos's knees were injured even though he wore knee pads to skate because he previously fell on the ground when

he was running. Only adolescents and adults could integrate the contextual information to make a Mature Conditional Interpretation that would lead to what Rafetseder, Schwitalla, and Perner (Rafetseder et al., 2013) called Counterfactual Reasoning.

The second way to create a discriminate response condition for a basic interpretation of counterfactual conditionals is by using semifactual conditional expressions such as:

(iii) "Even if Carlos had worn knee pads to skate, his knees would have been injured".

As we have seen before, subjunctive conditionals like (i) have generally been proposed by linguists and philosophers (e.g. Carpenter, 1973; Fillenbaum, 1974) to envisage the two situations (the conjectured and the real). Semifactual conditionals (iii) are a subtype of counterfactual conditionals, also constructed with the subjunctive mood but usually expressed using concessive terms such as "even if-then", "if-then still", "if-then also" instead of 'if-then' (Byrne, 2005; Gómez-Veiga et al., 2010; McCloy & Byrne, 2002; Moreno-Ríos et al., 2008). These expressions appear to cancel an expected causal link between antecedent and consequent: wearing knee pads usually prevents knees being injured but here this causal link is cancelled (Rodríguez Rosique, 2001; Schwenter, 2001). In this case, the interpretation of semifactuals differs from that of counterfactuals. The real situation in (iii) is that "Carlos did not wear knee pads, and his knees were injured". That is, the antecedent is false (not knee pads) but the consequent remains true (knees injured) instead of false as happens with counterfactuals (Goodman, 1983).

Interestingly, a basic conditional interpretation of the conditional (iii) (following a basic conditional reasoning strategy) with the concessive expression "even if Carlos had worn knee pads to skate, his knees would have been…?" would lead people to conclude "injured" unlike what would be concluded with "if then" expressions: "not injured". However, people who use a mature interpretation of the counterfactual "if then" in the discriminate conditions proposed by Rafetseder et al. would conclude "injured" in either

case because they will obtain a similar representation from the semifactual expression "even if" in (iii) and from the discriminate condition with "if": that is, the compound of the counterfactual expression in (i) and the additional contextual information saying that his knees were already injured.

Using semifactual conditionals, Moreno-Ríos and García-Madruga (Moreno-Rios & García-Madruga, 2002) compared the inferences made by primary schoolchildren from 7 to 11 years old, preadolescents (13-14 years old) and adults. They found that only preadolescents made similar inferences to those of adults. Meanwhile, schoolchildren made inferences as if they understood semifactual conditionals as basic conditionals. Results showed that schoolchildren's ability to make inferences with these conditionals increases until the age of around 14 years.

However, the limitations with counterfactuals of very young children obtained in the previous studies are not uniquely determined by the discriminative structure of the problems. Some interesting studies have shown that children around five years old were able to interpret counterfactual conditionals in the discriminate condition. This was shown by McCormack, Ho, Gribben, O'Connor, and Hoerl (McCormack et al., 2018) and by Nyhout and Ganea (Nyhout & Ganea, 2019) (see also Nyhout et al., 2019). They used two very simple tasks with few objects and the conditionals were about physical causation: the effects on the objects of simple actions. The question was formulated using "counterfactual expressions" in (McCormack et al., 2018) but including the "if… still" expression in (Nyhout et al., 2019) and (Nyhout & Ganea, 2019). The authors did not mention this fact, but using this expression, the conditional was converted into a semifactual by the use of a concessive. Actually, philosophers of language have debated which is the best semifactual expression, with some championing "even if" (Bennett, 1982; Goodman, 1983) and others 'if...still' (Barker, 1991). Moreover, "even if", "if

...still" and "if …also" have the same inferential effects (see Experiment 3, Spanish "aunque/también" in (Moreno-Ríos et al., 2008)). Therefore, Nyhout and Ganea (Nyhout & Ganea, 2019) and Nyhout et al. (Nyhout et al., 2019) could be helping children to understand the necessity of the conclusion by using "still" in their formulation, and therefore joining the two strategies for discriminating conditions mentioned above. We cannot know which one of the two strategies was responsible for the results in these experiments. Besides, the grammatical structure of the counterfactual expressions could be playing a role in the difficulty of counterfactual understanding.

Previous studies have tried to disentangle the difficulty of the morphosyntactic expression based on the properties of some languages. Yarbay-Duman, Blom, and Topbas (Yarbay Duman et al., 2015) separated two sources of difficulty in counterfactual thinking in Turkish-speaking children: the morphosyntactic complexity of using the subjunctive conditional from the cognitive complexity of considering two different things. Children with some linguistic impairment showed the morphosyntatic complexity effect: they had greater difficulty with counterfactual thinking with subjunctive conditionals than indicative conditionals. In any case, it seems that the use of discriminative conditions is not the only explanation for why schoolchildren have difficulties with some counterfactual problems.

In this study, we used the two strategies previously mentioned (context and "even if") to ensure that people were understanding counterfactuals as such, and not as basic conditionals. We used 'discriminate conditions', such as the one in which Carlos previously fell on the ground when he was running and hurt his knees. To conclude "knees injured", the information provided by the context is needed only in the "if" condition (counterfactuals). It would be unnecessary and reiterative in the "even if" condition (semifactuals) if its grammatical meaning (in any case, the knees were injured) is

accessed. Testing adults and children, we can detect whether the grammatical use of "even if" can help them to improve their results, which would imply that they are not actually accessing the grammatical meaning of the counterfactual. If so, we will have a clue that they are using that "morphosyntatic information".

How people reason with counterfactuals

The study of counterfactual reasoning in children has not been driven by contrasting different theories (see Rafetseder et al., 2010, 2013). One reason could be that the main theories of conditional reasoning agree about the dual meaning of counterfactuals (Kulakova & Nieuwland, 2016). Thus, for the mental model theory, each possibility is represented as a mental model: an iconic representation of a situation that captures its basic structure. It can also contain symbolic elements that codify abstract features of the situation, such as negations (¬) or other "mental footnotes" of counterfactual, obligation, belief, etc. (see Bucciarelli & Johnson-Laird, 2005).

As we have seen before, counterfactual thinking requires us to consider a real situation and another conjectured one (Byrne, 2005, 2016; Johnson-Laird & Byrne, 1991). It can be induced using counterfactual expressions "if A, then B", such as (i) in which something different to what is said (Byrne, 2016): (conjectured:) 'Carlos wore knee pads and his knees were healthy (not-injured)'; A B actually happened:
(real:) 'Carlos did not wear knee pads and his knees were injured'; ¬A ¬B.
Therefore, the real situation from counterfactuals has a false antecedent and consequent. However, in the real situation of semifactual conditionals (iii), the antecedent is false but the consequent remains true:

(real:) "Carlos did not wear knee pads, and his knees were injured": ¬A B.

As we have seen, children in the study by Rafetseder et al. (Rafetseder et al., 2013) seemed not to use a counterfactual representation while younger children in McCormack

et al. (McCormack et al., 2018) and Nyhout and Ganea (Nyhout & Ganea, 2019) did. It is possible that in Rafetseder et al. (Rafetseder et al., 2013), children only represented the conjectured situation according to the basic conditional reasoning strategy. However, it is also possible that children in all these studies would be representing both the real and the conjectured possibilities, but in Rafetseder et al.'s study, those representations could be based on a wrong conditional derived from the basic conditional interpretation as they did not consider the contextual information.

In a similar way, the suppositional theory (Evans, 2007; Evans et al., 2005) maintains that the listeners interpret a pragmatic implication: in the "if" condition (counterfactuals) they understand that the speaker intends to convey the idea of "not-A and not-B" (Evans et al., 2005), and in the "even if" conditional (semifactuals), the idea that the speaker conveys is "not-A and B" (Feeney & Handley, 2011; Handley & Feeney, 2004). The clearest difference between the mental model theory and the suppositional theory is that only the former establishes that there is a codification of the epistemic status (what is real and what conjectured) as a mental footnote, keeping that information in mind.

A complete understanding of counterfactuals requires distinguishing what is real from what is conjectured and to study this, we need a theory of counterfactuals that makes predictions about how people keep track of the epistemic status. The mental model theory provides us with a clear and useful framework to test the components of counterfactual development. However, there is controversy regarding the epistemic status about what is real and what conjectured. On the one hand, the theory maintains that, due to working memory limitations, people tend to easily forget the mental footnotes, which causes frequent errors in deduction (see Johnson-Laird, 2006; Johnson-Laird & Byrne, 2002). On the other hand, it has been proposed that the epistemic labels are not so labile (Ferguson, 2012; Ferguson & Cane, 2015). They propose a "permanent label" hypothesis,

suggesting that the mental footnotes which allow us to keep track of what is real and what conjectured are not easily forgotten. They support the idea that both situations (the real and the conjectured) are equally understood (Santamaría et al., 2005) and accessible (Ferguson, 2012; Ferguson & Cane, 2015), remaining equally available. Contrary to the "permanent label hypothesis", the mental model theory predicts that people would tend to lose labels of the "epistemic status", which leads to different predictions: inferences which require accessing the content of the models (e.g. the elements "A B") will be more accurate than those that require accessing the real and presupposed labels of those contents.

Therefore, from the mental model theory, two predictions can be derived. First, an improvement with age in the ability to distinguish real and conjectured situations (epistemic status): children's cognitive development is related to an increase in working memory efficiency (Gathercole et al., 2004) and therefore fewer mental footnotes will be lost. Also for this reason, the same developmental effect is expected for the epistemic status. Second, if the 'permanent label' (Ferguson, 2012; Ferguson & Cane, 2015) hypothesis does not hold, only the representations stay and children lose the label indicating what is conjectured and what real, so more errors are expected in detecting the epistemic status than in the inference process: when footnotes are lost, the mental model remains, and therefore although people cannot distinguish what is real and what is conjectured, they can still use the model to make inferences. There is also a specific prediction deriving from how counterfactuals and semifactual conditionals are represented: "the knees were injured" (B) should be more frequently accepted with "Even if" because the fact is present in the two possibilities (conjectured: A B and real: ¬A B), but with "If then", it is only present in one (conjectured: A B; real: ¬A ¬B). However, no differences between the two conditionals are predicted for concluding about the

antecedent “Carlos wore knee pads” (A), given that in the representations of both conditionals this element is present just one time.

It is possible that the ability to codify the epistemic status adequately, that is, keeping track of what information is real and what conjectured, could be one of the causes of developmental differences. Ruiz-Ballesteros and Moreno-Ríos (Ruiz-Ballesteros & Moreno-Ríos, 2017) showed, in accordance with the standard mental model theory predictions, that even adults, in some demanding tasks in which different conditionals had to be integrated, lost track of what information was real and what conjectured, confusing logical truth (conjectured situation) with empirical truth (real situation) (Moshman, 1990).

Lastly, one of the difficulties in comparing children and adults is that frequently, different tasks are used (see discussion in Royzman et al., 2003). In the following two experiments, we will try to understand the nature of the difficulty in thinking counterfactually, using the same task. We will test this ability in adults and children. This will allow us to distinguish between basic and counterfactual reasoning, while tracking whether they keep the epistemic label of the information (real and conjectured), as well as whether they can use the linguistic knowledge about subjunctive-concessive expressions (‘if’ and ‘even if’).

Study 1

We test the comprehension of counterfactuals by using stories in which a character utters a sentence with a counterfactual conditional. Only if participants understand it will they be able to answer the final questions correctly. A sample story is: Yesterday, early in the morning, Carlos was running in the schoolyard and he fell on the ground and hurt his knees. Later in the evening, *Carlos’s mother saw him skating. Afterwards, she said: “If he had worn kneepads to skate, his knees would have been …”*

… injured or healthy? (inferential question).

To test the epistemic question, we say: Remember that *the mother said: "if Carlos had worn kneepads to skate…" According to this evidence, did the mother see Carlos wearing his kneepads? Yes or No*

The story does not say explicitly whether the mother saw the kneepads (just that she saw him skating), but comprehension of the counterfactual expression informs them the fact ("if Carlos had worn his kneepads…" which means that actually he was not wearing them).

If participants make a basic conditional interpretation of the counterfactual, they will represent only one mental model (A B). By contrast, if they make a mature counterfactual interpretation, they will represent two mental models with epistemic labels about what is conjectured (A B) and what is real (¬A ¬B) and this includes the contextual information (he previously fell on the ground). Also, the labels that provide us with the information about whether the model is conjectured or presupposed/real can be lost with time. Table 1 shows the representation for the mature interpretation, with those labels and after losing them, as well as the basic interpretation predicted by the mental model theory (first and second columns).

As was previously shown, children's ability to think counterfactually has to do with 1) the meaning of "counterfactual expressions" but also with 2) the ability to think with two possibilities, one of them false. Our key question here is whether it has also to do with 3) keeping the information about their epistemic status (what is real and what conjectured). In this study, we test adults' sensitivity to these three factors when they think using counterfactual conditionals. Regarding the first, counterfactual conditionals are expressed using subjunctive "If it had happened…" expressions and semifactuals with concessive subjunctive "Even if it had happened…" conditional expressions. We test whether adults use the information provided by the concessive subjunctive grammatical

expressions ("even if") as an aid to their inferred answers. In our example, the initial information creates a discriminate condition by stating a fact:

"Yesterday, early in the morning, Carlos was running in the schoolyard and he fell to the ground and hurt his knees. Later in the evening, Carlos's mother saw him skating."

The following two sentences lead to the same conclusion:

a) "If Carlos had worn knee pads to skate, would his knees have been …healthy or injured (correct)?"

b) "Even if Carlos had worn knee pads to skate, would his knees have been …healthy or injured (correct)?"

Both expressions lead to the same conclusion: "Carlos's knees were injured", the first because of the contextual information and the second because of that information plus the morphosyntactic aid of "even if". Therefore, only in the "even if" conditional could the inferential question (which will be our first question in the experiment) be correctly solved with the sentence on its own, without the need to consider the fact of the incident in the schoolyard (context; See Inferential Question prediction in Table 1, for Mature I.). Therefore, the improvement of inferences will be a sign that the morphosyntaxis of the subjunctive concessive conditional 'even if' was used to make the inference.

Table 1

Predictions (correct responses in bold) for the Inferential and Epistemic questions in Experiments 1 and 2, for the Mature (with and without labels) and Basic interpretations of counterfactuals with "if" and "even if" counterfactuals based on their initial representations. See text for details.

Counterfactual Interpretations	**Representations *[label]***			**Predictions to Questions:**	
				Epistemic (real)	**Inferential**
Mature Interpretation					
If then	*[conject.]*	Kneepad	¬Injured(*)		¬Injured (**Injured***)
	[real]	¬Kneepad	Injured	**¬Kneepad**	
Even if	*[conject.]*	Kneepad	Injured(*)		**Injured**
	[real]	¬Kneepad	Injured	**¬Kneepad**	
Mature Interpretation (labels lost)					
If then		Kneepad	¬Injured(*)	Kneepad/**¬Kneepad**	¬Injured (**Injured***)
		¬Kneepad	Injured		
Even if		Kneepad	Injured(*)	Kneepad/**¬Kneepad**	**Injured**
		¬Kneepad	Injured		
Basic Interpretation					
If then		Kneepad	¬Injured	Kneepad	¬Injured
Even if		Kneepad	Injured	Kneepad	**Injured**

(*cancelled by the contextual information = previously injured)

Regarding the second factor, we test whether more correct responses are given with the second expression ("even if"). From the mental model theory, the counterfactual and semifactual conditional expressions lead people to initially represent two facts: one real and another one conjectured. When the right inference is to conclude "Injured", it will be easier with semifactual conditionals, in which the two situations have the same correct conclusion (Injured), than with 'if' counterfactual conditionals, in which only one possibility is consistent with the correct one (Injured). It is therefore with "even if" that

the response accuracy should be greater. To avoid a wrong conclusion about the conjectured (Not Injured) with "if then", participants need to consider the contextual information (e.g. the knees were already injured) so as to avoid a Basic conditional interpretation and obtain a Mature conditional interpretation. This is only with "if then"; it is not necessary with "even if" (see Table 1; Mature interpretation, last column on right).

Regarding the third factor, participants have to differentiate between real and conjectured situations. In this case, as we asked for the antecedent, "even if" and "if" counterfactual conditionals have the same two alternative options, based on the mental model theory: Kneepads for the conjectured case and not Kneepads for the real one (see Table 1: Mature I., Representations Column). Therefore, no differences in the difficulty of detecting the real case are expected between the two conditionals.

The new task was based on Rafetseder et al.'s (Rafetseder et al., 2013) Exp.2 task but adapted to study the epistemic status. As in their study, an inferential question was presented: "If Carlos had worn knee pads to skate… Would his knees have been healthy or injured?" However, in the present task we also looked for how they distinguish between the inferential and the real state.

There are some differences from the original task. In particular, in half the problems we used "even if" expressions instead of expressions with just "if": "Even if Carlos had worn knee pads to skate…". In addition, in Rafetseder et al.'s task, the causal link between the action (e.g. a girl walked into a room with mud on her shoes) and the result is made explicit (e.g. the floor was dirty), whereas in our task the result can only be inferred from the question itself. Finally, we included a measure of the epistemic status. In order to test it, all the stories included a new character: a police officer who was present and witnessed all the situations described. Thus, participants were asked about what really happened, as in "Did the police officer see Carlos wearing knee pads?"

Predictions about responses for the epistemic and inferential questions are summarised in Table 1, based on the mental model representations. The frequency of responses is expected to be higher when there is only one predicted response. We predicted that:

− Adults would infer according to an appropriate comprehension of the counterfactual conditional (Mature Interpretation rather than a basic conditional one).

− They would identify and differentiate correctly the real and the conjectured situation with some limitations derived by the loss of "mental footnotes" (Table 1, see the two first rows: Mature Int. and Mature Int. labels lost).

− The use of the semifactual conditional "even if" will facilitate the inferential question, referring to the consequent, in comparison with the counterfactual "if" (Table 1, Inference Predictions). However, differences would not be shown in the identification of real and conjectured situations, tested by asking about the antecedent, because they both have the same representation for the antecedent (Table 1, Epistemic Predictions).

Method

Participants

Fifty-four adults between 20 and 30 years old (M_{age}= 24.36; *SD*= 2.44), thirty-five women (M_{age}= 24.28; *SD*= 2.41) and nineteen men (M_{age}= 24.57; *SD*= 2.62), participated. They were all volunteers and spoke Spanish as their first language. The sample was composed of all the students enrolled on a course of developmental psychology who accepted the invitation to participate in the study, choosing this activity from among others, to received course credits. Participants read and filled out a consent form for this study complying with the University Research Ethics Committee guidelines (Comité de ética en investigación humana de la Universidad de Granada specifically approved this study: 178/CEIH/2016). The procedure and the task for this Study, as well as for Study 2 with

children, were also approved by the same committee.

Materials

Nine stories were created, based on Rafetseder et al. (Rafetseder et al., 2013) contents to test inferential accuracy and epistemic status in counterfactual reasoning. [In that study, most of the original problems used alternatives to the antecedent but one story implied an alternative to the consequent. We looked for a balance that equalized the numbers of these two kinds of story. The distinction, although interesting, is not included in the paper in order to focus reading on the objectives of the study]. The stories were adapted, controlling factors such as negations and pragmatic implications. Also included in the stories was a character who witnessed the different situations. This allowed us to test the two different epistemic statuses (differentiating conjectured and real situations). Rafetseder and colleagues asked two questions using a different structure: "What would have happened if Susi had taken her shoes off? Would the floor be clean or dirty?" However, we used only one question, as outlined previously, presenting half the stories with "if" counterfactual expressions, and the other half with "even-if" semifactual expressions (see example below).

The workbooks started with a short introduction, which asked participants to take the role of an investigator, using some information provided by a police officer. After this, a practice trial with a story was presented, followed by the 8 experimental stories. Each one consisted of two tasks (questions): the "inferential accuracy" task tested whether participants give correct responses to the counterfactual conditional. The second one, the "epistemic status" task, tested whether they could differentiate real and conjectured situations.

The following is an example of a trial. The manipulation of the conditional can be seen in bold for **even if conditionals** and in brackets (for if conditionals):

*The police officer saw through a window of the room that a child was awake because his alarm clock had just sounded. His sister went into his bedroom to take a toy. Later, the police officer said: "**Even if** (If) his sister had entered silently…"*

Inferential Question

Would the child have been … awake (correct) or asleep? (Spanish original version: "¿El niño habría estado…despierto o dormido?")

Epistemic Status Question

*Remember, the police officer said: "**Even if** (If) his sister had entered silently …" According to this evidence, did the police officer see his sister going in silently? Yes / No (correct) (Spanish original version: "Recuerda que el policía dijo: "**Aunque** (Si) su hermana hubiera entrado en silencio…De acuerdo con esta pista, ¿el policía vio que la hermana entró en silencio? Sí / No")*

The presentation order of the different factors in the eight stories was randomised: the kind of conditional expression (if, even if), the order of the alternative responses, as well as the order of the stories and the correct response to the epistemic status question (yes/no). In half of the cases, the epistemic question was formulated in a complementary way, changing the correct responses between yes and no (e.g. did the police officer see her sister entering noisily? Yes / No). Eight different workbooks with the randomised factors mentioned, were constructed.

Procedure and design

The Conditional ('if' vs 'even if') factor was manipulated within-participants. The dependent variable was accuracy in the questions.

The participants were tested individually in a quiet room in a 10 min. session. The experimenter read the stories and the conditional statement aloud and asked the

participants first the inferential accuracy question and then the epistemic status question. In the first, they had to complete the conditional with one of the alternatives proposed and in the second, to think about what actually happened, answering yes or no.

Results

The data for both experiments are available at http://sl.ugr.es/dataGS_etal.

Inferential response

We carried out an ANOVA using as independent variable Conditional, with the number of correct responses as dependent variable. As we predicted, the results showed a correct counterfactual understanding with a mean of 89% correct responses. Moreover, as expected, we found a main effect of the Conditional, giving more correct responses with "even if" than with "if" (92% vs 85%; $F(1,53)= 4.93$, $p < .05$, $\eta 2=.09$), as Table 2 shows.

Epistemic status

A second analysis of Conditional was carried out with epistemic status. The epistemic status difficulty (72% correct responses) contrasted with the inferential accuracy previously referred to (89% correct responses) (see Table 3). As predicted, the analysis of conditional between Even if (70%) and if (75%) did not show effects ($F(1,53)= 2.17$, $p =.15$, $\eta 2=.04$).

However, more correct responses in the epistemic status task were provided by those that responded correctly to the inferential question than by those that did not (90% vs 10%; $\chi 2(1)= 194.92$; $p < .0001$).

Discussion

The results show that, in general, adults present a high ability to conclude correctly from counterfactual conditionals in the inferential question. An interesting and novel result is that adults use the grammatical aid "even if" to give their inferential response. The mental model theory predicts the effect, given that the two mental models in "even if" lead to the correct conclusion ("B"/ Injured in Table 1), while there is only one in the "if then" condition (see Table 1), which needs to consider the contextual information (Mature Counterfactual Interpretation) to establish "B" as the conjectured conclusion. In this way, the study demonstrates the existence of two aid sources in counterfactual reasoning: comprehension of the situation and linguistics ("even if").

Based on the mental model theory, a correct response to the epistemic question requires having a complete representation of counterfactuals that includes the conjectured and the presupposed model as well as their labels. These labels or mental footnotes are easily forgotten (Johnson-Laird, 1983; Johnson-Laird & Byrne, 2002), but when this happens, the mental model remains. It is for this reason that more correct responses are expected in inferences than in detecting epistemic status: the inference can be made by just looking at the elements in the models, but the epistemic question also requires accessing the label of what is true. Accordingly, in this study adults showed some difficulties, with 72% correct responses, this being consistent with other previous results with counterfactuals (Ruiz-Ballesteros & Moreno-Ríos, 2017; Thompson & Byrne, 2002). Also, correct responses to the epistemic inference require discarding the representation derived from what is expressed (the conjectured model) and looking for what is real (the real model) to give a response. It follows that if someone could discard the conjectured model, it is very probable that they could also access it in the inferential question. Thus, most of the correct responses to the epistemic question (what really

happened), were preceded by a correct inference based on the conjectured model (90% vs 10%).

Study 2

In the present study, we test children with the same task as adults. The aim of this study was to evaluate the development of counterfactual reasoning, trying to identify also the factors that make deduction in children difficult in the cases detected by Rafetseder et al. (Rafetseder et al., 2013). In particular, the study disentangles two potential factors that could be responsible for the development of counterfactual reasoning during the school years: one deductive, the consideration of counterfactual possibilities (inferential responses), and the epistemic status: identifying real and conjectured situations. As far as we know, this last aspect had not been studied previously with children.

Following the mental model theory, counterfactuals and semifactuals, unlike other conditionals, require the construction of multiple mental models, which is cognitively demanding. Children have to create two mental models and inspect models and their elements to make deductions (see Johnson-Laird, 1983, 2006; Johnson-Laird & Byrne, 2002). Also, to identify what is real and what conjectured, they have to keep the mental footnote attached to each model.

Two proposals are contrasted here. On the one hand, the mental model theory establishes that mental footnotes are very easily lost. It was found that the working memory capacities of children from 4 to 15 years old increase linearly (Gathercole et al., 2004). Therefore, due to predictable processing limitations, we would expect an increase with age in both deductive and epistemic detection abilities, but with a particularly poor ability to detect the epistemic status. On the other hand, previous research with adults has supported the hypothesis that the epistemic labels are permanent (Ferguson, 2012; Ferguson & Cane, 2015). However, the results in Study 1 question this prediction, at least

with that kind of inference task. Therefore, if children can make a mature interpretation, we would expect to fit the predictions of a Mature interpretation without epistemic labels (see Table 1). Of course, it is also possible that some children could interpret counterfactuals just as basic conditionals, and therefore their responses would fit predictions in the last row of Table 1.

Additionally, we aimed to dissociate the ability to think about counterfactual situations from the ability to interpret counterfactual conditional expressions. As shown in Study 1, the mental model theory predicts that the comprehension of "even if A, B" will lead people to draw more correct conclusions of "B" ("Injured" in Table 1) than with "if A, B", based on the way these conditional expressions are represented (see Table 1). Adults seem to use the concessive expression "even if" as assistance to increase the number of correct responses with respect to "if then" subjunctive expressions. This result could show that the linguistic component contributes to good counterfactual reasoning or at least to a good performance in discriminate conditions. The question is whether this happens equally in children.

The mental model theory maintains that the core meaning of conditionals "if A, then B" leads people to obtain an initial representation (A B; Johnson-Laird & Byrne, 2002). Results in the study of the development of conditionals show that children from the age of seven and adults use the same initial representation (A B; Gauffroy & Barrouillet, 2009). Therefore, we would expect that children would represent the initial mental model in the same way as adults, and therefore, like adults, they would benefit by using "even if" when they have to conclude "B" from "A". Our hypothesis is that 'even if' will facilitate the inference question of "B" (Injured in Table 1) compared to "if" but that they will not show differences in the epistemic question (about "kneepads" in Table 1), because they have the same representations.

Finally, because the two components of counterfactual reasoning could be related to other cognitive activities or abilities, we took other potentially related measures, such as reading, comprehension and intelligence. It has to be emphasised that linguistic abilities relating to reading ability should not affect the present task, considering that the stories are read by the experimenter. However, children with higher development in these skills, such as good readers, are likely to have more opportunities than poor readers to be exposed to stories with counterfactual scenarios.

Method

Participants

Ninety-six children aged from 7;9 (years; months) to 12;7 (M_{age}= 10;1; *SD*= 1;3) from a school in Granada participated in this study. There were 49 girls (M_{age}= 10;1; *SD*= 1;3) and 47 boys (M_{age}= 10;1; *SD*= 1;4). They were organised into three age-groups: 7-9 years (29 children; Range= 7;9-9;0), 9-11 years (38 children; Range= 9;1-10;9) and 11-13 years (29 children; Range= 11;0-12;7). All participants spoke Spanish as their first language. The sample was composed of all the students from third grade in a school who accepted the invitation to participate in the study. They participated only if their parents gave written consent for this study, complying with the ethical protocol from the University Ethics Committee (Comité de ética en investigación humana de la Universidad de Granada specifically approved this study: 178/CEIH/2016).

Materials

Two scales of the Reading Processes Evaluation Battery (PROLEC) (Cuetos Vega et al., 2007) were used: the pseudo-words reading (for reading coding) task and the text comprehension task. The first consists of reading different pseudo-words. The second involves two short texts (90 words approximately) and two long texts (130 words

approximately). Each had four inferential questions, avoiding answers based only on passive data recall from memory.

Raven's Progressive Matrices (Raven, 1975) is a widely known test of general fluid intelligence. Participants had to select the option which followed the sequence with a total of 60 matrices grouped in five categories (A, B, C, D and E) from the easiest to the most difficult.

Finally, we used the counterfactual reasoning task employed in Study 1, following the same procedure, but in this case, the responses of the children were recorded.

Procedure and design

Two factors were manipulated: Conditional ("if" vs "even if") within-participants and Age group (from 7 to 9 years, from 9 to 11 years and from 11 to 13 years) between-participants. Response accuracy in the two inferential and epistemic status question tasks was computed.

The counterfactual reasoning task was carried out in the same conditions as in the first study, that is, individually with an approximate duration of 10 minutes, but in this case in a quiet classroom and recording the responses of the children. In the same session, the PROLEC test was also administered individually, starting with the reading task and followed by the comprehension task. RAVEN was administered in a separate session in groups of four children with a duration of 30 min. approximately. The administration of the tasks was counterbalanced in the following way: half the children did the RAVEN test before the other two tasks and the other half did it afterwards. Also, half the children did the reasoning task before the PROLEC test, and the other half the other way round.

Results

Inferential response

We carried out an ANOVA with Conditional (within-subject variable) and Age (between-subject variable) as the independent variables, and Inferential accuracy as the dependent variable. According to our hypothesis, the results showed more correct responses with "even if" than with "if" in the inferential task (85% vs 68%; F(1,95)= 39.48, p<.001, η2=.30). Differences were also found with Age group (69% vs 77% vs 85%; F(2,93)= 4.42, p<.05, η2=.09), revealing a developmental trend in the ability to reason with counterfactual conditionals, as Table 2 shows. The interaction between the two variables was not significant (F(2,93)= .08, p=.92, η2=.002).

Table 2

Percentage of correct responses in Inferential response in Studies 1 with adults and 2 with children. Means and standard deviations in brackets by Adults, Children's Age groups and Conditional (even if and if).

Age Group	Even if	If	*M*
From 7 to 9 years	77 (.27)	61 (.29)	*69 (.28)*
From 9 to11 years	86 (.21)	68(.27)	*77 (.24)*
From 11 to 13 years	94 (.11)	76 (.26)	*85 (.19)*
M	*85 (.22)*	*68 (.28)*	
Adults	92 (.13)	85 (.20)	89 (.16)

Epistemic status

Regarding epistemic status, we carried out a 2 (Conditional) by 3 (Age Group) analysis of variance (ANOVA), using Epistemic status accuracy as dependent variable.

The results showed more correct responses with "if" than with "even if" (57% vs 45%; $F(1,93)= 15.41$, $p < .001$, η2=.14). Moreover, there were differences in Age group

(45% vs 48% vs 60%; $F(2,93) = 4.67$, $p < .01$, $\eta 2 = .09$), showing a developmental lineal trend (polynomial contrast $p<.01$). The interaction between the two factors was not significant ($F(2,93)= 1.30$, $p = .28$, $\eta 2 = .03$).

However, unlike adults, children do not identify or differentiate correctly between real facts and conjectured facts (see Table 3). The binomial test showed that with "if then", only older children gave responses above chance (63%, binomial test $p=.007$, given a probability = .5), but not the youngest or the intermediate age group (51% and 57%, binomial test, $p=.92$ and $p=.09$ respectively). With "even if" expressions, even older children gave responses by chance (57%, binomial test, $p=.16$) and the younger children systematically identified what was presented in the conditional as what actually happened (the youngest age group; 39%, binomial test, $p=.02$; and the intermediate age group 39%, binomial test, $p=.01$).

Table 3

Percentage of correct responses in epistemic status in Studies 1 with adults and 2 with children. Means and standard deviations in brackets by Adults, Children's Age groups and Conditional (even if and if).

Age Group	Even if	If	*M*
From 7 to 9 years	39 (.24)	51 (.25)	*45 (.24)*
From 9 to 11 years	39 (.26)	57 (.23)	*48 (.24)*
From 11 to 13 years	57 (.25)	63 (.26)	*60 (26)*
M	*45 (.26)*	*57 (.25)*	
Adults	70 (.24)	75 (.25)	72 (.25)

Correct responses to the epistemic question were more frequent when correct responses were also given to the inference question for all three age groups (youngest children 62% vs 38%; $\chi 2(1)= 5.5$; $p<.05$; intermediate age-group children 74% vs 26%;

$\chi 2(1)= 34.29$; $p<.0001$ and older children 85% vs 15%; $\chi 2(1)= 67.69$; $p<.0001$). This result is to be expected if labels are lost more easily than models, and therefore, children who accessed the label (and responded correctly to the epistemic question) did so because they already had the models (and responded correctly to the inference question).

Correlation

We tested the relationship between the participants' execution in the inferential and epistemic tasks in relation to age (in days), intelligence, comprehension and reading ability measures (note that the stories were read by the researcher and not by the children).

Results show that reasoning abilities correlate with age (Inferential response $r=.23$; $p<0.05$; and Epistemic status $r=.30$; $p<0.01$) and Intelligence with Inferential response ($r=.23$; $p<0.05$). No correlation was found between the two measures of reasoning, consistent with the distinct nature of the two components ($r=.09$; $p>0.05$). No other significant correlation was found (see Table 4).

Table 4

Correlations between age (A), inferential response (IR), epistemic status (EE), comprehension (C), reading ability (RA) and intelligence (I) in Study 2.

	A	IR	EE	C	RA	I
A	-					
IR	.23*	-				
EE	.30**	.09	-			
C	-.06	.20	.04	-		
RA	-.01	.11	.01	-.02	-	
I	.09	.23*	.08	.17	.06	-

Note: *p< .05 **p< .01

General discussion

Teachers at school commonly use expressions that require children to understand counterfactual and semifactual conditionals, such as: "if Hitler had won the Second World War, European citizens lives would have been different" and "but even if Hitler had won…". The ability to think about what might have happened is essential not only in school but also in everyday life. This is not a simple ability, which may be the reason why there has been a controversy about the age at which children can think counterfactually. Some researchers have found it in children of 6 years old (McCormack et al., 2018; Nyhout et al., 2019), others suggest children of around 3-4 years old possess this ability, as shown with their tasks (Guajardo et al., 2009; Nyhout & Ganea, 2019), and others maintain that this ability is developed during the school years from 6-12 (Rafetseder et al., 2010, 2013). Even adults seem to show difficulty in particular situations (e.g. Markovits, 2014; Ruiz-Ballesteros & Moreno-Ríos, 2017).

In our research, we did not try to provide a complete account of children's counterfactual reasoning, but just contribute to explaining the difficulties found by Rafetseder et al. in previous studies with schoolchildren when they had to make simple inferences in some very common problems they faced. This was the aim and focus of our research.

To look for possible factors, some studies have used indicative conditionals to create contrary-to-fact situations, such as "if a feather was thrown at a window, then the window was broken" (see e.g. Markovits, 2014; Markovits & Vachon, 1989). However, counterfactual thinking has been more frequently evaluated using subjunctive conditionals, such as "If A had happened, B would have happened", or using the concessive subjunctive, "Even if A had happened, B would have happened". Development of reasoning with counterfactual conditionals could be influenced by the

ability to use and understand these morphosyntactic components (Yarbay Duman et al., 2015). In the present study, we found that this does not seem to be the factor responsible for children's difficulty in reasoning with counterfactuals as, like adults, they used the morphosyntactic information to improve their inferences. They made more correct conclusions when the question was expressed with "even if" semifactuals than with "if then" counterfactuals. Predictions from the mental model theory are consistent with the increase of correct acceptances of the consequent ("B"), because it is present in the two mental models of "even if", but only in one of the "if then" models (see predictions in the inferential question -"Injured"- in Table 1).

The second, and closely related, factor studied here was the inference factor: the ability to think with possibilities (deductive component). Older children, probably with less limited working memory capacity, could draw more correct conclusions than younger children in the "inference question" (Barrouillet, 2015; Gauffroy & Barrouillet, 2011), but even the youngest children could make counterfactual inferences. If we concentrate on the 'if' conditionals, we have a similar condition to that used by Rafetseder et al. (Rafetseder et al., 2013) with very similar and, in fact, slightly better results. Unlike in Rafetseder et al.'s studies, in most of our stories, the real state was not stated explicitly but had to be inferred, and therefore a potential effect of that information on responses, that was present in previous studies, was weakened in the present one. Even so, our findings with the present task suggest, as do Rafetseder et al.'s, that children do not give similar responses to those of adults until the age of 12 (85%, with adults 89%). However, this does not mean that younger children are not able to answer counterfactual questions correctly, with our participants giving 69% accuracy at age 9. Our results are consistent with the proposal of development in multiple stages, as has been proposed previously (Beck & Riggs, 2014; Markovits, 2014). It is difficult to interpret the different findings

in performance in the study of counterfactual reasoning as many features have been proposed as possible causes, such as the use of language or drawings, the executive demands of the task, having a visual support and the kind of cause (physical or not), among others. Here it is important to remember that children of about 5 years could correctly interpret the counterfactual conditional, even in the discriminate condition, when adequate simple and concrete objects were presented in the task (McCormack et al., 2018; Nyhout et al., 2019; Nyhout & Ganea, 2019). Therefore, the difficulty shown by schoolchildren is not due to an inability to think counterfactually per se, but it could be related to their difficulty in following counterfactual alternatives during the comprehension of stories with characters and actions.

The third factor studied is the epistemic component: the ability to codify and access correctly the information about what is real and what is conjectured. The mental model theory maintains that the epistemic status has to be represented as mental footnotes added to one possibility, but these are easily discarded during the inference process (to increase working memory resources; see (Johnson-Laird & Byrne, 2002)). People can then access a particular possibility and make the inferences correctly, but they are more prone to error in finding its mental footnote (which model is the conjectured and which the real one) to draw conclusions about the epistemic status. However, some authors have suggested a 'permanent label' hypothesis based on some previous results (Ferguson, 2012; Ferguson & Cane, 2015). They defend the theory that the two labels are not lost: the epistemic status remains. These studies have mainly used comprehension tasks rather than inference tasks and obtained processing measures online (Ferguson & Cane, 2015), with priming tasks (Santamaría et al., 2005). It is possible that in these conditions the epistemic information has not yet been lost. Our results support the standard theory and the ease of forgetting the epistemic status, contrary to what is suggested by the 'permanent label'

hypothesis. In accordance with this, adults showed a good ability to think counterfactually about the conjectured situation. However, their ability was not so good when using the epistemic information (mistakes were made in 30% of cases; Study 1). This result is consistent with previous results (Ruiz-Ballesteros & Moreno-Ríos, 2017).

A notable result is that schoolchildren showed clear difficulties in this same ability to follow what is presupposed and what conjectured, this being the main source of difficulty in reasoning with counterfactuals. Although this ability improves with development, children's responses were close to random in some conditions. The youngest children scored under 50%, showing that they have serious difficulty in retaining the epistemic mental footnotes. In fact, the youngest group of children and even those under 11 years old, interpreted the semifactual "even if Carlos had worn the knee pads" as if Carlos actually wore knee pads (61% versus 39%). The improvement with age in this ability as well as in the deductive one could be due to the increase in processing resources and working memory capacity (Gathercole et al., 2004): older children can handle more accurately and retain the mental models, their elements, and footnotes but show difficulties as adults because of the footnotes loss.

The differences between counterfactual "if then" and "even if" have also proved interesting. While inferences were better with "even if", as was mentioned and predicted from the mental model theory, no differences were predicted detecting the epistemic status with "if" compared to "even if". Actually, this was the result found in adults, but children made fewer correct responses in "even if" than in "if" problems. One possibility is that the young children do not interpret the linguistic expression "even if" with two models, considering only the conjectured model. However, results with the inferential question suggest that they represent "even if" and "if then" problems in different ways.

One important question that has not been raised here is that Rafetseder et al. (Rafetseder et al., 2010) used the terms basic conditional reasoning and counterfactual reasoning to distinguish not only the ability to consider contextual information that leads to establish the conclusion, but they also made the assumption that younger children who used basic conditional reasoning did not need to represent two mental models but just one, while only older children and adults who used counterfactual reasoning needed to represent the two models (p. 339). However, there is a possibility that even the young children in Rafetseder et al.'s study (who used a basic conditional reasoning strategy) would have been interpreting the conditional as a counterfactual, but forming a "wrong" conjectured conditional without having considered the contextual information (as was shown in Table 1 in the basic interpretation row). Thus, they would have represented both real and wrongly conjectured possibilities. If this were the case, we would say that even young children can think with two models and this could explain why other studies found no limitation in children of around five years old in counterfactual reasoning tasks. Even so, we think that thinking counterfactually requires construction of the correct conjectured model. Neither Rafetseder et al.'s (Rafetseder et al., 2013) results (p.401) nor ours can clearly discard the fact that children represent only one model, in fact in the present article we have left this possibility open to readers. However, further research is needed to find out more about this question. In any case, children's difficulty can be located in their poor ability to distinguish "what is real" from "what is conjectured" which is even lower with "even if" expressions.

Therefore, we could conclude that schoolchildren's difficulty, as found in previous studies with counterfactuals, has at least two potential sources: the deductive component associated with thinking about different possibilities (De Neys & Everaerts, 2008; Markovits, 2014) that is required to create the real situation ("Carlos did not wear knee

pads") negating the conjectured situation ("If Carlos had worn knee pads"), and the epistemic component (what really happened and what was conjectured). Also, we have seen that, for deduction, they do not seem to have great difficulties using and understanding the meaning of the linguistic expressions, and their ability to consider alternatives increases. However, they show a substantial limitation in understanding what is real and what conjectured.

Other cognitive abilities such as literacy and comprehension could be related to the two components of counterfactual thinking studied here. We have seen that intelligence correlates with the inferential component but not with the epistemic knowledge component. Interestingly, the inference and the epistemic components did not correlate, which supports their independence of each other. As it was shown, in other studies pre-schoolers could solve counterfactual tasks with few objects and simple actions. In the present study, schoolers had some difficulties with counterfactuals tested with other tasks. They had to read stories about people and actions, keeping track of the epistemic status of the possibilities. The working memory load and the need to attribute mental representations states in these tasks could have made the counterfactual inferences more difficult. Unfortunately, we did not test other cognitive components such as direct measures of working memory or of theory of mind, which we think could be interesting for future studies.

In short, the focus of children's difficulty with reasoning counterfactually seems to be the epistemic status. The results of this paper suggest that a good candidate factor to improve counterfactual thinking could be directing children's attention to what is real and what conjectured in an explicit way, helping them to keep track of the epistemic status. However, it is unlikely that linguistic expressions used to express the counterfactual are

an important factor, at least during school years. More research will help us examine how we could improve this important kind of reasoning.

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Appendix

Example of the stories and percentage of correct responses (standard deviations in brackes). In bold the correct response.

Imagine that you are a great detective whose mission is to investigate different cases. To do so, you have the support of your colleague Raúl who saw what happened and who will give you some information about it.

Hi, detective!

Today we have a lot of work. In each of the stories we have listened to part of the conversation between the police officer Raúl and other people will be our information. Pay attention to the words said by the policeman because he won't repeat them. Will you be able to figure out what happened in each situation? Here are the cases, remember to pay attention to the information:

0. The police officer was at a birthday party and he saw a boy leaving the hall running. The police officer says that the boy is afraid of the sound of balloons bursting. You have to pay great attention to the police officer's words because he gives you some information: remember that he says "the boy is afraid of the sound of balloons bursting". Keeping in mind this information, could we say that there were balloons in the hall? Yes / No

Story 1- The police officer saw through a window that a child was in his bedroom and had a blank sheet of paper because his pen did not have ink. When he went out of his bedroom his sister went in and took the sheet and the pen. Later, the police officer says: "If/Even if his sister had used the pen…"

Counterfactual question- Would the sheet of paper have writing on it or would it be **blank**?' Adults: 94 (*SD*= 23); Children: 78 (*SD*= 42)

Epistemic status question- Remember, the police officer said: "If/Even if his sister had used the pen …" According to this evidence, did the police officer see his sister using the pen? Yes / **No** Adults: 70 (*SD*= 46); Children: 49 (*SD*= 50)

Story 2- The police officer saw that a girl was on the beach playing with a bucket. Her bucket was broken and had a hole in the bottom. Later, the police officer said: "If/Even if the girl had poured water into her bucket…"

Counterfactual question- Would the bucket have been…full or **empty**? Adults: 89 (*SD*= 32); Children: 84 (*SD*= 36)

Epistemic status question- Remember, the police officer said: "If/Even if the girl had poured water into her bucket…" According to this evidence, did the police officer see the girl pouring water into the bucket? Yes / **No** Adults: 63 (*SD*= 49); Children: 24 (*SD*= 43)

Story 3- The police officer saw that a girl was walking while eating an ice-cream. Then, the ice-cream fell on her shirt. She was walking near a puddle when a car passed. Later, the police officer said: "If/Even if the car had passed carefully…"

Counterfactual question- Would the girl's shirt have been…clean or **dirty**? Adults: 80 (*SD*= 41); Children: 70 (*SD*= 46)

Epistemic status question- Remember, the police officer said: "If/Even if the car had passed carefully…" According to this evidence, did the police officer see the car splash the girl? **Yes** / No Adults: 70 (*SD*= 46); Children: 48 (*SD*= 50)

Story 4- The police officer saw that the floor of a boy's house was wet because his mother had just washed it. When she finished, the boy came home from school and stepped in a puddle that was close to the door. Later, the police officer said: "If/Even if the boy had gone in barefoot…"

Counterfactual question- Would the floor have been…**wet** or dry? Adults: 85 (*SD*= 36); Children: 73 (*SD*= 45)

Epistemic status question- Remember, the police officer said: "If/Even if the boy had gone in barefoot…" According to this evidence, did the police officer see the boy go in barefoot? Yes / **No** Adults: 85 (*SD*= 36); Children: 54 (*SD*= 50)

Story 5- The police officer saw through a window that a girl was at home and the TV was turned off because it was broken. Her mother came into the hall to watch her favorite program. Later, the police officer said: "If/Even if her mother had turned on the TV…"

Counterfactual question- Would it have been…on or **off**? Adults: 89 (*SD*= 32); Children: 74 (*SD*= 44)

Epistemic status question- Remember, the police officer said: "If/Even if her mother had turned on the TV…" According to this evidence, did the police officer see the mother turning on the TV? Yes / **No** Adults: 65 (*SD*= 48); Children: 50 (*SD*= 50)

Story 6- The police officer who was at a swimming pool saw that a boy had an airbed. The airbed was deflated because it had been pricked. Later, the police officer said: "If/Even if his father had used an air pump…"

Counterfactual question- Would the airbed has been…inflated or **deflated**? Adults: 89 (*SD*= 32); Children: 79 (*SD*= 41)

Epistemic status question- Remember, the police officer said: "If/Even if his father had used an air pump…" According to this evidence, did the police officer see the father using the air pump? Yes / **No** Adults: 59 (*SD*= 50); Children: 35 (*SD*= 48)

Story 7- The police officer saw through a window of the room that a child was awake because his alarm clock had just sounded. His sister went into his bedroom to take a toy. Later, the police officer said: "If/Even if his sister had entered silently…"

Counterfactual question- Would the child have been … **awake** or asleep? Adults: 93 (*SD*= 26); Children: 76 (*SD*= 43)

Epistemic status question- Remember, the police officer said: "If/Even if his sister had entered silently …" According to this evidence, did the police officer see that his sister went in silently? Yes / **No** Adults: 87 (*SD*= 34); Children: 87 (*SD*= 33)

Story 8- The police officer was in a garden and saw that a child's father went out shopping. When he came back, the car door was open because he had forgotten to close it. After that, the father went out and the mother went to the car to fetch some bags. Later, the police officer said: "If/Even if the mother had forgotten the car key…"

Counterfactual question- Would the car have been…**open** or closed? Adults: 91 (*SD*= 29); Children: 80 (*SD*= 40)

Epistemic status question- Remember, the police officer said: "If/Even if the mother had forgotten the car key…" According to this evidence, did the police officer see the mother with the car key? **Yes** / No Adults: 80 (*SD*= 41); Children: 58 (*SD*= 50)

Capítulo 4

Alternatives or syntactic negation? Adults' and children's preferences for constructing counterfactual possibilities

Alternatives or syntactic negation? Adults' and children's preferences for constructing counterfactual possibilities

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Abstract

Reasoning with counterfactuals such as “if his sister had entered silently, the child would have been awake”, requires considering what is conjectured (“his sister entered silently”) and what is the counterfactual possibility (“his sister did not enter silently”). In two experiments, we test how both adults (Study 1) and children from 8 to 12 years (Study 2) construct counterfactual possibilities about the cause of an effect (“the child was awake because…”). We test specifically whether people construct the counterfactual possibility by recovering alternatives, for example, “the alarm clock sounded” or by using the syntactic negation using propositional symbols (“his sister did not enter silently”). Moreover, as children show difficulty in thinking with abstract contents, we test whether they construct the counterfactual possibility more readily by recovering concrete alternatives (“the alarm clock sounded”) rather than abstract alternatives (“he had trouble sleeping”). Results showed that children, as well as adults, recovered the alternative as the cause of the effect rather than the negation. Moreover, children, unlike adults, created the counterfactual possibility more frequently by recovering concrete situations rather than abstract situations.

Keywords: Counterfactual reasoning, Negation, Concreteness, Epistemic status, Conditionals, Alternatives, Mental models

Counterfactual thinking requires thinking about false possibilities, that is, what could have happened in a different situation. Imagine a situation in which a friend, Eva, studied psychology but, what if Eva had chosen to study art instead of psychology?

Counterfactuals such as

(1)"If Eva had studied art, she would have worked at the Louvre Museum"

are conditional expressions that establish a hypothetical relation between cause and effect. Many studies have shown that, as the mental model theory proposes (Johnson-Laird & Byrne, 1991), understanding a counterfactual makes us think about two situations. One of them is the situation that corresponds to the counterfactual conjecture ("Eva studied art and worked at the Louvre Museum"; (A, B)) and the other refers to the real or presupposed fact ("Eva did not study art and did not work at the Louvre Museum"; (Not-A, Not-B)) (Byrne, 2016; Byrne, 2017).

[Conjectured]	Eva studied art (A)	Worked at the L.M. (B)
[Presupposed-fact]	Eva did not study art (¬A)	Did not work at the L.M. (¬B)

However, the mental model theory also establishes that we do not just have to consider both possibilities, but also need to keep track of their epistemic status by codifying it as labels (see [conjectured] and [presupposed-fact] labels above) (Johnson-Laird & Byrne, 2002). This means recognising which one of them is the real possibility and which one the conjectured possibility. Keeping track of the epistemic status is a difficult aspect of thinking counterfactually, as demonstrated by studies with children (Gómez-Sánchez et al., 2020) as well as with adults (Ruiz-Ballesteros & Moreno-Ríos, 2017).

Counterfactuals such as (1) require negating the antecedent in order to create the counterfactual possibility: "Eva did not study art" and, as far as we are aware, it is not

known how people construct it. Thus, the main aim of this paper is to establish what people think about when they are given this statement. Do they construct the negation of the antecedent using propositional symbols ("she did not study art") or do they represent an alternative fact (e.g. "she studied psychology")? Do children construct it in the same way as adults? Does it make a difference having a concrete ("she studied painting") or an abstract ("she studied art") situation? In this paper we try to disentangle these questions. Other aims are to examine the development of counterfactual reasoning and the ability to keep track of the epistemic status.

First, we briefly summarize the findings on the development of counterfactual reasoning, how people understand counterfactuals and the difficulty in distinguishing the epistemic status. Following this summary, we review the effect of negation found in some recent studies with inferences (Byrne, 2017; Espino & Byrne, 2018; Moreno-Ríos & Byrne, 2018), and how reasoning with negation changes during development (Markovits, 2013; Markovits & Lortie-Forgues, 2011). We then outline the task that allows us to test our predictions about the effect of each kind of situation (concrete and abstract) on creating counterfactual possibilities. Furthermore, we examine the ability to reason with counterfactuals in adults and children, as well as their ability to distinguish real and conjectured possibilities. We report the results of two experiments, one with adults (Study 1) and another with children (Study 2). Finally, we discuss the findings in relation to previous literature.

The development of counterfactual thinking

There is no agreement on when counterfactual thinking is fully developed in children, with some research finding this ability in school children (Gómez-Sánchez et al., 2020; McCormack et al., 2018; Nyhout et al., 2019) and others suggesting that even pre-schoolers are able to reason counterfactually in the same way as adults do (Guajardo et

al., 2009; Nyhout & Ganea, 2019; Roldán-Tapia et al., 2017). However, there is no clear explanation about the differences found between studies. A number of factors could be responsible for these differences, such as demands on executive functions (Beck et al., 2009; Beck & Riggs, 2014), the structure, clarity and difficulty of the task or whether the task implies physical rather than agents as causes (McCormack et al., 2018; Nyhout et al., 2019; Nyhout & Ganea, 2019). Differences found in counterfactual thinking abilities could also be related to differences in the conceptualisation of counterfactual thinking, such as how broad or narrow the author's view of counterfactuals is (e.g. whether it includes hypothetical future, timeless conditionals or just alternatives to past events) (Beck & Riggs, 2014; Buchsbaum et al., 2012; Rafetseder et al., 2010; Weisberg & Gopnik, 2013) or a misunderstanding in what the task is measuring (Rafetseder et al., 2010, 2013).

According to the latter, some researchers have shown that children's success in these tasks was because they interpreted the counterfactual ("If Eva had studied art she would have worked at the Louvre Museum") as a basic conditional ("If Eva studied art, then she worked at the Louvre Museum"; see Rafetseder et al., 2013 for further details). Rafetseder et al. (2013) avoided this problem by ensuring that in their task basic conditional reasoning resulted in a different answer from a strategy that required counterfactual thinking. They found a developmental trend in thinking counterfactually: children gave very similar responses to adults at around 12 years old, and this ability continues to develop during adolescence (Markovits, 2014; Moreno-Rios & García-Madruga, 2002).

Recently, it has been proposed that one of the causes of children's difficulty to reason with counterfactuals could relate to the ability to codify correctly the epistemic status, that is keeping track of which possibility is real and which one is conjectured (Gómez-Sánchez et al., 2020). However, this difficulty is not surprising considering that even

adults in some demanding tasks lose track of that epistemic status, such as in Ruiz-Ballesteros and Moreno-Ríos' study (2017). In their task participants had to integrate information from different conditionals. They found that people discarded the epistemic status information during the integration of conditionals, leading to a more economical process. This could also be applied to children, as Gómez-Sánchez et al.'s study (2020) found. Due to the high working memory load, they could lose the mental footnotes about which situation is the real one and which the conjectured one. Consequently, they could still access the two models but not their mental footnotes.

The development of counterfactual thinking could be also related to the following factors: First, to processing resources and executive functions such as inhibition and attention (Beck et al., 2009; Byrne, 2005; De Neys & Everaerts, 2008; Drayton et al., 2011; Ferguson & Cane, 2015; Gathercole et al., 2004) finding also some mixed results on the role of working memory (Beck et al., 2009; Drayton et al., 2011), and second to the consideration of alternatives (Moreno-Rios & García-Madruga, 2002; Rasga et al., 2016). The ability to consider alternatives as well as working memory capacity increase with age (Barrouillet et al., 2009; Santamaría et al., 2013). Counterfactual reasoning requires the consideration of false alternatives, having to temporarily inhibit our knowledge and imagine an alternative situation was true (Byrne, 2016; Rafetseder et al., 2010). Therefore, due to developmental issues we expect a developmental trend in children's ability to think counterfactually, and particularly, in their ability to keep track of epistemic status. As we explained before, the mental footnotes are easily forgotten and these are essential for answering the epistemic question correctly (i.e., what is real and what conjectured). Nevertheless, when the mental footnotes are forgotten, the mental model remains, enabling a correct answer to the inferential question.

As we have seen, to create the counterfactual possibility from (1) it is necessary to negate the antecedent ("she did not study art"). Hence, the construction of negation in counterfactuals could be another key element in the explanation of the difficulty children have with counterfactuals.

Developmental differences in reasoning with negation

Developmental differences need to be understood within the context of the challenges that arise for all people when reasoning with negation. People usually represent a sentence such as "there is not a circle" as "not-circle", that is, the representation of negation may include symbolic annotations to capture negation such as "not" (e.g., Byrne & Johnson-Laird, 2009; Johnson-Laird & Byrne, 2002; Khemlani et al., 2012, 2014; Moreno-Ríos & Byrne, 2018). However, in a situation in which there is an alternative such as a triangle, the negation of "there is not a circle" leads people to think about the "triangle". That is, when there is a potential alternative, it is easier to represent the negation by recovering that alternative. This happens in binary contexts such as "there is not a light figure". In these cases it is easier to represent the negation by thinking of the alternative ("dark figure") than by thinking of the negation in an abstract way ("not light figure") as it only has one potential alternative: its antonym (Espino & Byrne, 2018; Mayo et al., 2004).

Similarly, Espino and Byrne (2018) found an inferential effect in binary contexts that they called "inference-to-alternates": a tendency to draw affirmative conclusions that refer to an alternate even from a negative minor premise. In our study, we predict a similar effect but related to the recovery of the cause responsible for the effect (see Study 1). In more complex situations, where the negation refers to more than one possibility (e.g. circle, triangle and square) people can use the symbolic annotations to economise the process (Espino & Byrne, 2018; Orenes et al., 2014).

This brings us on to the developmental differences in the ability to use negations. Previous studies have shown that schoolchildren use concrete cases for negating the antecedent and that the ability to create more abstract negations develops in adolescence and adulthood (Markovits, 2013; Markovits & Lortie-Forgues, 2011). Thus, schoolchildren would find difficult to create abstract negation (not-circles), thinking instead about concrete categories (triangles). However, adolescents and adults can construct the negation of the antecedent in an abstract way, thinking in not-A abstract cases (not-circles) (Markovits & Lortie-Forgues, 2011). Frequently, negation is not explicit but included in the context. That is what happens in the case of counterexamples.

Counterexamples and negation

A conditional such as "If Daniella makes a noise, Charles is awake" (If A, then B) expresses a relation between a cause (A; making a noise) and an effect (B; being awake). However, this causal relation can be different if there are counterexamples for it. There are two kinds of counterexamples (see, Cummins, 1995; De Neys & Everaerts, 2008):

a) Alternatives (Not-A, B) which are causes, different from the original one (e.g., an alarm clock ringing), that are capable of producing the same effect cited in the relation (Charles is awake). That is, Charles may be awake (B) even if Daniella does not make a noise (not-A).
b) Disablers (A, Not-B) which prevent the effect from occurring (Charles being awake) despite the presence of the cause (Daniella makes a noise), because something breaks the causal relation (e.g., Charles wears earplugs). That is, Daniella making a noise (A) does not cause Charles to be awake (Not-B).

As we have seen, counterfactual conditionals such as "If Daniella had made a noise, Charles would have been awake" tell us that something different to what is said ("Daniella

made noise and Charles was awake"; AB) actually happened ("Daniella did not make noise and Charles was not awake"; Not-A Not-B).

The mental model theory suggests that these possibilities are represented as a mental model of reality: an iconic representation of a possibility as the image of a girl making a noise and a boy awakes. As we have mentioned previously, the mental model theory also establishes that there is a codification of their epistemic status as mental footnotes. However, people tend to easily forget these mental footnotes which causes frequent errors in deduction (see Johnson-Laird, 2006; Johnson-Laird & Byrne, 2002). These mental models can also contain abstract features such as negations (the girl not making a noise or "it is false that the girl made a noise"), and obligation or belief (Bucciarelli & Johnson-Laird, 2005; Vargas et al., 2011). Thinking counterfactually requires negating the antecedent to create the counterfactual possibility (presupposed fact: "Daniella did not make a noise"), but how do people think about negation?

As we have seen in the previous section, negation shows differences depending on different aspects such as the kind of content (e.g. concrete or abstract) or the age of the child. Similarly, the construction of negation also shows differences depending on the nature of the counterexamples. If the counterexample is an alternative then the negation will correspond to an element from the story (the alternative). However, if the counterexample is a disabler then the negation will not correspond to any element from the story. Consider the next two stories to explain how negation differs with both types of counterexample:

Alternative story:

(2) A child was awake because his alarm clock had just sounded. His sister went into his bedroom to take a toy. Later, the police officer said: "If his sister had entered silently, the child would have been awake"

Disabler story:

(3) A girl was on the beach playing with a bucket. Her bucket was broken and had a hole in the bottom. Later, the police officer said: "If the girl had poured water into her bucket, the bucket would have been empty".

In alternatives stories such as (2), the negation of the antecedent "if his sister had entered silently" can be made either by a) constructing a syntactic negation using propositional symbols such as "not" ("the sister did not enter silently") or b) discarding the mentioned action and taking the alternative action explicitly mentioned in the story ("the alarm clock sounded"). However, in disabler stories such as (3) the negation of the antecedent ("the girl did not pour water into her bucket") has no alternative explicit negation to recover from the story. Hence, for disablers the negation has to be made in a more abstract way, being forced to use the symbolic annotations ("she did not pour water").

Nevertheless, even with the presence of an explicit negation in alternative stories, it is possible to have a concrete (e.g., an alarm clock) or an abstract alternative (e.g., having trouble sleeping) (see the materials section for more information). We compare these two types of alternatives in order to test whether children, but not adults, recover as cause of the effect (why the child is awake) a concrete alternative (the alarm clock) more than an abstract one (trouble sleeping; Markovits & Lortie-Forgues, 2011). However, since there is no explicit alternative that can be used to negate the antecedent in disabler stories, these stories will be used as a control. Consequently, introducing a concrete (e.g. pick white stones up) or an abstract action (e.g. be occupied) in disabler stories should not have any effect since those actions do not correspond to the negation of the antecedent. That is, in disabler stories the concreteness of the cause remains constant (the hole in the bucket) unlike alternative stories.

One of the most common difficulties in comparing cognitive abilities between children and adults is that results of the studies are usually obtained with different tasks, and it is not clear to what extent differences found can be due to the tasks (Royzman et al., 2003). Therefore, our experiments used the same task to examine the ability to reason counterfactually and to keep track of the epistemic status. This task also allows us to test whether people construct the negation of the antecedent in counterfactuals either using an alternative (e.g. "the alarm clock sounded") or using the abstract negation by itself with symbolic annotations (e.g. "the sister did not enter silently"). Moreover, we also test whether the concreteness of the situation (concrete vs. abstract) has an effect depending on the kind of counterexample (alternative vs. disabler). In general, we predict that adults, as well as children, will negate the antecedent by recovering the alternative or the disabler instead of using symbolic annotations ("not"). Moreover, we predict an effect of concreteness for children with alternatives resulting in the recovery of the concrete alternative ("alarm clock") more than the abstract one ("trouble sleeping") to create the counterfactual situation ("his sister did not enter silently").

STUDY 1 - ADULTS

We test how adults construct counterfactual possibilities depending on the kind of counterexample (alternative vs. disabler) and the concreteness (concrete vs. abstract) of the counterexample. In Study 2 we examine whether there are differences between adults' and children's construction of counterfactual possibilities. Espino and Byrne (2018) showed that people tend to make affirmative inferences from negative premises in binary context (e.g., to act vs. not to act). The effect was called "inference-to-alternatives". We predict a similar effect with the negation of causal antecedents in counterfactual conditionals. The comprehension of counterfactuals requires a person to consider the

negation of the antecedents. If people represent negation in stories by thinking about an alternative possibility instead of negating the antecedent, then we expect participants asked about the cause to explain the consequence, to create the counterfactual possibility by recovering the alternative possibility. This means that participants will recover the alternative possibility to explain the consequence (from here "predicted cause"; e.g. the alternative or the disabler provided in the story) instead of the syntactic negation of the antecedent using propositional symbols ("not") for all counterexamples types.

In the study we present alternative and disabler stories about causal events that lead to a consequence. Participants have to identify the causal event for that consequence. Alternatives stories, unlike disabler stories, provide an alternative situation that corresponds to the syntactic negation of the antecedent which causes the same consequence. However, disablers do not provide an explicit situation different from "the girl did not pour water" that corresponds to it (see Figures 1a and 1b). As concreteness only impacts on alternatives but not on disablers, recovering a concrete negation should be easier than recovering an abstract negation in alternative stories but not in control disablers stories. Nevertheless, due to adults' ability in thinking with abstract negation we do not predict significant differences in contrast to our expectations in relation to children.

Therefore, we summarize our prediction as follow:

1- If the concreteness has an impact on how people think counterfactually and also has a relation with the kind of counterexamples (alternatives and disablers), then we would expect more responses referring to the predicted cause with concrete situations than with abstract situations in alternative stories.

2- Nevertheless, we do not expect to find differences in disabler stories (that act as a control for the alternative stories), because the manipulation of the concreteness

does not correspond to an alternative cause (see the materials section and Figures 1a and 1b).

3- Furthermore, we test adults' ability to reason with counterfactual conditionals as well as their ability to keep track of the epistemic status. Based on previous results, and the mental model theory, we predict that adults will show a good ability to make inferences from counterfactual conditionals, as well as a good ability to distinguish the epistemic status.

Figure 1a

Causes in the alternative stories that can lead to the response, taking as example the alternative story about the child who is awake: "If his sister had entered silently, the child would have been…"

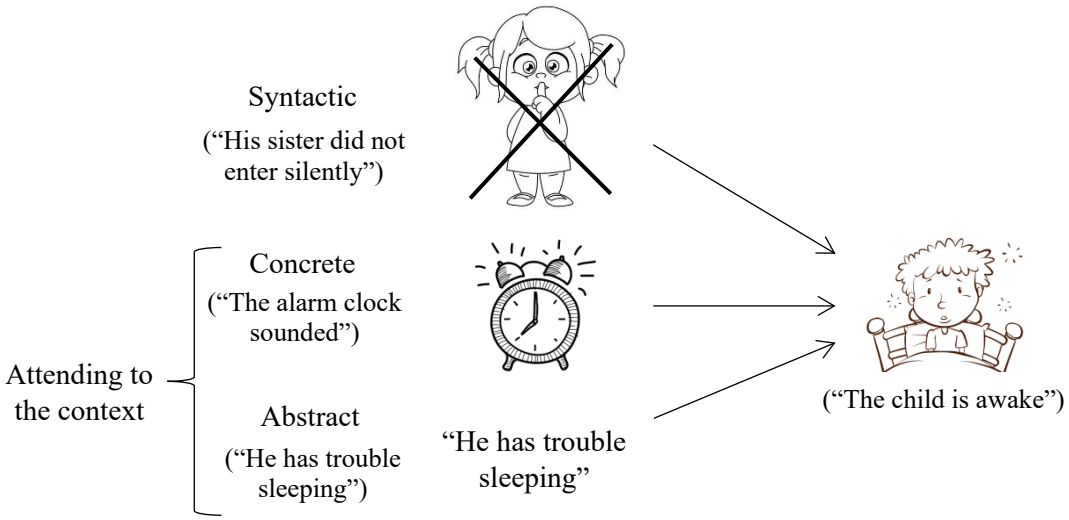
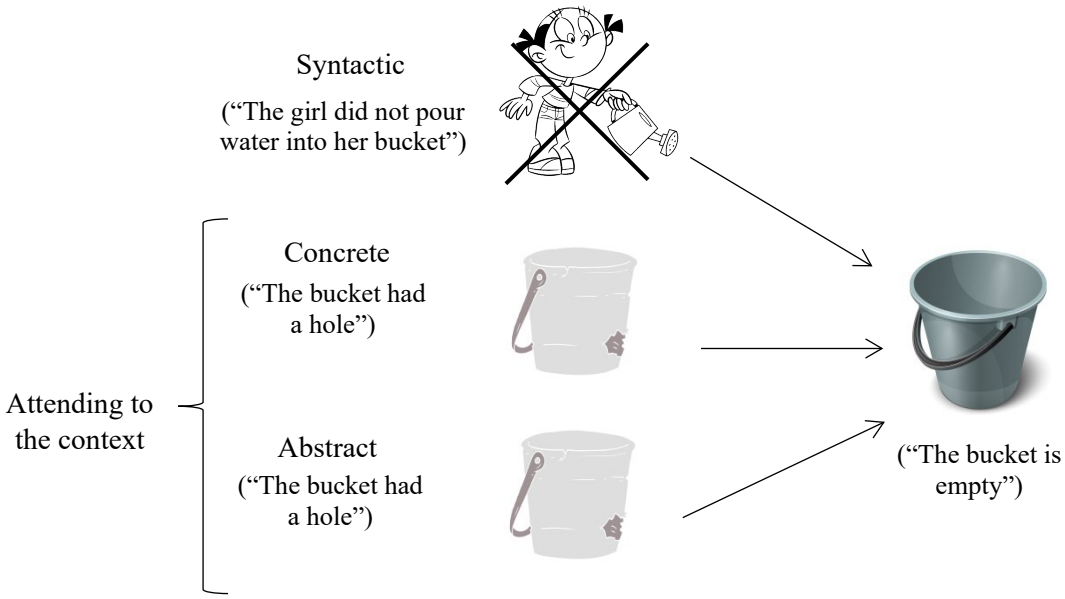


Figure 1b

Causes in the control disabler stories that can lead to the response, taking as example the disabler story about the empty bucket "If the girl had poured water into her bucket, the bucket would have been …".



Method

Participants

The sample consisted of fifty-five adults aged between 18 and 27 years (M_{age}= 21.25 years; *SD*= 2.29). Fifty-two were women and three were men. All participants were native Spanish speakers and were recruited in colleges or universities in Granada. Participants read a consent form complying with the University Research Ethics Committee guidelines. The procedure and the task for this study, as well as for Study 2 with children, were also approved by the same committee.

Materials

Nine stories were created, based on the materials in Gómez-Sánchez et al., (2020) and Rafetseder et al. (2013) to test inferential accuracy, epistemic status and identification

of the cause of the consequent in counterfactual reasoning. The stories were adapted to test the hypotheses in this study.

Two kinds of story were used depending on the kind of counterexample (alternative or disabler). In the disabler stories such as (3), the presence of the action mentioned in the antecedent (pouring water into a bucket) does not produce any consequence (the bucket stays empty). To infer that the correct answer is empty people have to remember that the bucket had a hole. In the second kind of story, alternative stories such as (2), the action mentioned in the consequent happens (the child is awake), even though the antecedent does not happen (the sister does not make noise). This happens because a different antecedent (e.g. the alarm clock) causes the same effect (the child is awake).

In addition, we manipulated the concreteness of the action (concrete vs. abstract) in order to test whether providing a concrete action improves accuracy in the alternative condition, without showing differences in the control disabler condition. The difference between both is shown in the example below.

The participants were presented with a questionnaire which started with a short introduction, asking participants to take the role of an investigator, using the information provided by a police officer, and having to infer what happened in each story. After completing a practice trial where one story is presented, participants were presented with the 8 experimental stories. Each one consisted of three tasks (see an example below):

1. The ‘inferential accuracy’ task, tests whether when participants are given an antecedent, they conclude the consequent determined by the story should be accepted (e.g. The child was awake; the bucket was empty).
2. The ‘epistemic status’ task, tests whether they can differentiate real and conjectured situations.

3. The ‘causal question’ task, tests which cause participants tend to report as being responsible for the outcome mentioned in the story (consequent).

The following is an example of an alternative story (translated from the original Spanish). The manipulation of the concreteness can be seen in bold for the **concrete situation** and in brackets for the (abstract situation).

The police officer saw through a window of the room that a child was awake because **his alarm clock had just sounded** (he had trouble sleeping). His sister went into his bedroom to take a toy. Later, the police officer said: ‘If his sister had entered silently…’

1. Inferential Question: Would the child have been … awake(correct) or asleep?
2. Epistemic Status Question: Remember, the police officer said: ‘If his sister had entered silently …’ According to this evidence, did the police officer see that his sister went in silently? Yes / No(correct)
3. Causal question: The police officer believes the child was awake because…

The following is an example of a disabler story (translated from the original Spanish). The manipulation of the concreteness can again be seen in bold for the **concrete situation** and in brackets for the (abstract situation). In this kind of story, as the concreteness is not related to the information needed to answer the questions and, consequently, the concreteness of the cause remains constant, we do not expect differences.

The police officer saw that a girl was on the beach playing with a bucket. Her bucket was broken and had a hole in the bottom. The girl was **picking white stones up** (occupied). Later, the police officer said: ‘If the girl had poured water into her bucket…’

1. Inferential Question: Would the bucket have been…full or empty(correct)?

2. Epistemic Status question: Remember, the police officer said: 'If the girl had poured water into her bucket…' According to this evidence, did the police officer see the girl pour water into the bucket? Yes / No(correct)
3. Causal question: The police officer believes the bucket was empty because…

Procedure and design

The participants were tested in small groups (4 people) in a quiet room in a session that lasted 15 minutes. The experimenter read the stories and the conditional statement out loud and asked the participants the inferential accuracy question, the epistemic status question and, finally, the causal question, in that order. Participants had to mark their response on an answer sheet. In the first (inferential) question, they had to choose between the alternatives proposed (e.g. awake or asleep), in the second (epistemic) question they had to think about what actually happened, answering yes or no, and in the third one (causal question) they had to write down what caused the result (e.g. why was the child awake).

Responses to the causal question were coded according to which cause was reported as responsible for the consequent. Hence, responses were classified as syntactic negation of the antecedent (she did <u>not</u> enter silently), predicted cause (the alternative or the disabler), or other causes not presented in the story, such as inventions.

We employed an experimental design with Counterexample (alternative vs. disabler) and Concreteness (concrete vs. abstract) as within-participants variables in all the questions. The dependent variables were inferential accuracy, epistemic status accuracy and frequency of the predicted cause.

Results

Inferential response

As can be seen in Table 1, adults showed a correct counterfactual understanding, with a mean of 92% correct responses. Moreover, there was no difference between alternatives and disablers (91% vs. 93%) nor between concrete and abstract negation (both 92%).

We carried out a 2x2 ANOVA with Counterexample (alternative vs. disabler) and Concreteness (concrete vs. abstract) as independent variables and Inferential accuracy as dependent variable. The results showed no differences depending on the kind of counterexample ($F(1,54) = .31$, $p = .58$, $\eta^2 = .006$) nor on the concreteness ($F(1,54) = .04$, $p = .84$, $\eta^2 = .001$). Both variables did not interact ($F(1,54) = .36$, $p = .55$, $\eta^2 = .007$).

Table 1

Percentages of correct responses in Inferential response and Epistemic status, means and standard deviations in brackets for Counterexample (alternative, disabler) and Concreteness (concrete, abstract) in Study 1

		Alternative	Disabler	*M*
Inferential response	Concrete	90 (.22)	93 (.18)	*92 (.20)*
	Abstract	92 (.19)	92 (.19)	*92 (.19)*
	M	*91 (.21)*	*93 (.19)*	
Epistemic status	Concrete	82 (.29)	69 (.37)	*76 (.33)*
	Abstract	71 (.38)	77 (.32)	*74 (.35)*
	M	*77 (.34)*	*73 (.35)*	

Epistemic status

As can be seen in Table 1, the epistemic status difficulty (75% correct responses) contrasted with the inferential accuracy previously referred to (92% correct responses). As in the inferential response, there was no difference between alternatives and disablers (77% vs. 73%) nor between concrete and abstract negation (76% vs. 74%). A second 2x2

ANOVA was carried out to examine performance on the epistemic status question. The analysis showed no main effects (Counterexample: $F(1,54) = .45$, $p = .51$, $\eta^2 = .008$; Concreteness: $F(1,54) = .09$, $p = .77$, $\eta^2 = .002$), but an interaction ($F(1,54) = 7.10$, $p = .01$, $\eta^2 = .12$) which was the result of participants giving correct responses for the 'alternative' stories more than the 'disabler' stories for the concrete situations (82% vs. 69%; $F(1,54) = 5.28$, $p = .025$, $\eta^2 = .09$); but for the abstract situations there was no difference between 'alternative' and 'disabler' stories (71% vs. 77%; $F(1,54) = 1.00$, $p = .32$, $\eta^2 = .018$).

Causal question

We categorised the responses to the causal questions as referring to the syntactic negation of the antecedent (e.g. the girl did not pour water; the sister did not enter silently, etc.), referring to the actual cause referred to in the story (e.g. the bucket had a hole, the alarm clock sounded, he had trouble sleeping, etc.), and finally other different causes not present in the story, such as inventions. We excluded participants who responded inconsistently across the two scenarios they were given for each condition. The number of remaining participants in the alternative concrete condition was 30 (25 selected the predicted cause and 5 the syntactic negation of the antecedent), 35 in the alternative abstract condition (27 predicted cause, 7 negation of the antecedent and 1 other causes), 40 in the disabler concrete condition (34 predicted cause and 6 negation of the antecedent) and finally 37 in the disabler abstract condition (31 predicted cause and 6 negation of the antecedent).

As can be seen in table 2, the predicted cause was the most designated cause (70%) regardless of its concreteness in both types of counterexamples.

Table 2

Percentages of causes of the consequent reported (negation of the antecedent, predicted cause and others), means and standard deviations in brackets for Counterexample (alternative, disabler) and Concreteness (concrete, abstract) in Study 1

	Alternative		Disabler (Control)		
	Concrete	Abstract	Concrete	Abstract	*M*
Predicted cause	65 (.35) 'Alarm clock'	67(.37) 'Trouble sleeping'	74 (.36) 'Hole'	72 (.36) 'Hole'	*70 (.36)*
Negation of the antecedent	24 (.34) 'Did not enter silently'	28 (.36) 'Did not enter silently'	24 (.35) 'Did not pour water'	23 (.35) 'Did not pour water'	*25 (.35)*
Others	11 (.21)	5 (.15)	2 (.10)	5 (.15)	*5 (.15)*

Four chi-square tests were performed to examine whether adults provided as cause of the consequent ("why the boy was awake"; "why the bucket was empty") either negations of the antecedent ("the sister did not enter silently"; "the girl did not pour water") or predicted causes ("the bucket had a hole"; "the alarm clock sounded", etc.). The chi-square tests showed adults more frequently referred to the predicted cause as the cause of the consequent than the syntactic negation of the antecedent: alternative stories with a concrete situation (X^2 (1, 30) = 13.33, p <.001), alternative stories with an abstract situation (X^2 (2, 35) = 31.77, p <.001), disabler stories with a concrete situation (X^2 (1, 40) = 19.60, p <.001), and disabler stories with an abstract situation (X^2 (1, 37) = 16.89, p <.001).

We also carried out a third ANOVA using as independent variables Counterexample (alternative vs. disabler) and Concreteness (concrete vs. abstract), with the frequency of the predicted cause (e.g. the bucket had a hole; alarm clock; trouble sleeping) as dependent variable. The results showed a main effect of Counterexample with

participants identifying more predicted causes in disabler than in alternative stories (73% vs. 66%; $F(1,54) = 4.52$, $p = .038$, $\eta^2 = .08$). However, we did not find a main effect of Concreteness ($F(1,54) = .02$, $p = .88$, $\eta^2 = .00$) or an interaction ($F(1,54) = .17$, $p = .68$, $\eta^2 = .003$).

Discussion

The results show that adults have good counterfactual thinking abilities (92% accuracy). As was expected, their ability to answer questions about epistemic status was not as good (75% accuracy). Consistent with previous findings, it seems that people can lose track of the footnotes (e.g. Gómez-Sánchez et al., 2020; Ruiz-Ballesteros & Moreno-Ríos, 2017). Accuracy decreases because these mental footnotes are required to distinguish real and conjectured possibilities. However, when people make an inference given the antecedent, they accept the consequent without problem, because they do not need to recover their footnotes (which situation is the real one and which the conjectured one).

Responses to the epistemic status question also revealed that in concrete situations adults find it easier to know what actually happened from an alternative story than a disabler story. We used the disabler condition as a control condition to discard a possible effect of abstract content versus concrete content in relation to the ability to detect causal facts when the abstractness has nothing to do with that causal fact. Therefore, in the disabler stories there is no concrete situation that could lead them to know that "the girl did not pour water". They have to think about it in an abstract way, independently of the story (concrete or abstract). In contrast, in the alternative condition the abstractness versus concreteness in the story was related to the causal fact. Results showed that an abstract cause is as difficult in the control disabler condition as it is in the abstract alternative condition ("the girl did not enter silently" because "the boy had trouble sleeping"). But a

more concrete cause "the alarm clock sounded" was recovered more easily (frequently) than the abstract cause.

The most novel result was the one that concerns how adults construct the negation of the antecedent in order to think with counterfactuals. As far as we know it is something that has not been studied before. Results support our hypothesis in adults, in that they more frequently report the predicted cause (the alternative or the disabler) as the cause of the consequent than the syntactic negation of the antecedent (using "not"). The effect is found with both kinds of counterexamples. It means that adults construct the negation of the antecedent by thinking of the alternative and affirmative situation (e.g. alarm clock, hole in the bucket) instead of by recovering the syntactic negation of the antecedent (she did not enter silently; she did not pour water).

STUDY 2 – CHILDREN

In the second study we tested children with the same task as adults. The aim of this study was to establish a developmental view of the findings with adults in Study 1. Hence, we evaluated the development of counterfactual thinking, as well as of the ability to keep track of epistemic status. Moreover, we tested how children construct the counterfactual possibility, as we did with adults. We therefore expect that children will recover the predicted cause (the alternative or the disabler) as the cause of the consequent more than the syntactic negation of the antecedent using propositional symbols ("not").

Considering the increase with age in the ability to create alternatives (Barrouillet et al., 2009; Santamaría et al., 2013), as well as in working memory efficiency (Beck et al., 2009; Drayton et al., 2011; Ferguson & Cane, 2015; Gathercole et al., 2004), we predict a developmental trend in the ability to think counterfactually, as well as in the ability to distinguish the epistemic status (real and conjectured situation). The mental model theory maintains that one source of error when inferring is the easy loss of labels in the mental

models, particularly in load conditions of working memory (Johnson-Laird, 1983; Johnson-Laird & Byrne, 2002). The limitation in younger children's working memory span could led them to use an economical representation of counterfactuals by omitting the epistemic labels. Therefore, we predict more errors detecting the epistemic status than thinking counterfactually because children lose the mental footnotes about which situation is the real one and which the conjectured one.

Furthermore, if children represent negation by thinking about another possibility instead of negating the antecedent as adults do (Espino & Byrne, 2018; Study 1), and they are not able to think about negation in an abstract way, as some studies propose, then we predict the same effect we found with adults: to recover as the cause of the consequent to a lesser extent the syntactic negation of the antecedent compared to the predicted cause.

Finally, by manipulating concreteness (concrete vs. abstract situation) we predict that children will report the abstract situation as the cause of the consequent to a lesser extent than the concrete situation in alternatives stories but not in control disabler stories. This prediction is based on the findings about the construction of negation using concrete cases in schoolchildren and the development of the ability to create abstract negation in adolescence and adulthood (Markovits, 2013; Markovits & Lortie-Forgues, 2011). When we ask about the cause of an event in alternative stories (e.g. the boy was awake because…), children should find it easier to recover a concrete and imaginable situation or cause (the alarm clock) rather than an abstract one (trouble sleeping; see Figure 1a) to explain why the boy was awake, due to their poor ability to think about abstract negation. However, we do not predict any differences with disablers because, as we said before, they act as control.

Method

Participants

One hundred and forty-three children aged between 8 and 12 years (M_{age}= 10.33; *SD* 1.15) from three schools in Granada participated in this study. There were 53 girls with a mean age of 10.44 years (*SD*= 1.19) and 90 boys with a mean age of 10.26 years (*SD*= 1.13). They were organised into their two year groups: 2nd (73 children; M_{age}= 9.35; Age range: 8.00-10.22) and 3rd (70 children; M_{age}= 11.35; Age range: 10.34-12.95). All participants spoke Spanish as their first language. They participated in the study only if their parents gave written consent, complying with the ethical protocol from the University Ethics Committee for this study.

Materials

We used the same counterfactual reasoning task employed in Study 1(adults).

Procedure and design

We manipulated the same factors within-participants as in Study 1 with adults: Counterexample (disabler vs. alternative), Concreteness (concrete vs. abstract) and Cause (negation vs. predicted cause). We added a fourth between-participants variable: Year group (2 vs. 3).

The task was carried following the same procedure as in Study 1.

Results

Inferential response

We carried out a 2x2x2 ANOVA using as independent variables counterexample (alternative vs. disabler), concreteness (concrete vs. abstract) and year group (2^{nd} vs. 3^{rd}) with inferential accuracy as dependent variable. Consistent with our hypothesis, the results showed a main effect of year group (78% vs. 87%; $F(1,141) = 8.54$, $p = .004$, $\eta^2 = .06$), revealing a developmental trend in the ability to reason with counterfactual conditionals. They also showed a main effect of counterexamples with more correct responses in disabler than in alternative stories (85% vs. 79%; $F(1,141) = 7.55$, $p = .007$, $\eta^2 = .05$). We did not find a main effect in concreteness ($F(1,141) = .48$, $p = .49$, $\eta^2 = .003$).

Finally, the results did not show significant interactions (counterexample and concreteness: $F(1,141) = 1.92$, $p = .17$, $\eta^2 = .01$; counterexample and year group: $F(1,141) = .01$, $p = .92$, $\eta^2 = .00$); concreteness and year group: $F(1,141) = .03$, $p = .87$, $\eta^2 = .00$ and counterexample, concreteness and year group: $F(1,141) = 1.45$, $p = .23$, $\eta^2 = .01$).

Table 3

Percentages of correct responses in Inferential response and Epistemic status, means and standard deviations in brackets by year group, counterexample (alternative, disabler) and concreteness (concrete, abstract) in Study 2

		Alternative		Disabler	
	Year group	Concrete	Abstract	Concrete	Abstract
Inferential response	2^{nd}	78 (.32)	71 (.35)	79 (.31)	83 (.25)
	3^{rd}	84 (.28)	83 (.28)	90 (.20)	89 (.22)
Epistemic status	2^{nd}	62 (.35)	60 (.34)	61 (.37)	58 (.34)
	3^{rd}	67 (.32)	65 (.34)	71 (.31)	69 (.33)

Epistemic status

For the epistemic status question, we carried out a 2 (counterexample: alternative vs. disabler) by 2 (concreteness: concrete vs. abstract) by 2 (year group: 2nd vs 3rd) ANOVA, using Epistemic status as dependent variable.

The results showed a main effect of year group (60% vs. 68%; $F(1,141) = 5.57$, $p = .020$, $\eta^2 = .04$), showing a developmental trend in the ability to distinguish real and conjectured situations. However, we did not find either any other main effects (counterexample: $F(1,141) = .41$, $p = .52$, $\eta^2 = .003$; concreteness: $F(1,141) = .77$, $p = .38$, $\eta^2 = .005$) or interactions (counterexample vs. year groups: $F(1,141) = 1.10$, $p = .30$, $\eta^2 = .008$; concreteness vs. year group: $F(1,141) = .002$, $p = .96$, $\eta^2 = .00$; counterexample vs. concreteness: $F(1,141) = .004$, $p = .95$, $\eta^2 = .00$; counterexample vs. concreteness vs. year group: $F(1,141) = .004$, $p = .95$, $\eta^2 = .00$).

Causal question

We categorised responses and participants as in Study 1. The number of remaining participants in the alternative concrete condition was 90 (81 in the predicted cause, 6 in the syntactic negation of the antecedent and 3 in the other causes), 56 in the alternative abstract condition (47 predicted cause, 7 negation of the antecedent and 2 other causes), 99 in the disabler concrete condition (92 predicted cause, 4 negation of the antecedent and 3 other causes) and finally 105 in the disabler abstract condition (98 predicted cause, 5 negation of the antecedent and 2 other causes).

A chi-square test was carried out to test whether children provided as cause of the consequent (why the boy was awake; why the bucket was empty) either more negations of the antecedent (“the sister did not enter silently”; “the girl did not pour water”) or predicted causes (“the bucket had a hole”; “the alarm clock sounded”; “the child had trouble sleeping”, etc.). The chi-square test showed children more frequently suggested

the predicted cause as the cause of the consequent than the negation of the antecedent in all cases: alternative stories with a concrete situation (X^2 (3, 90) = 120.36, p <.001), alternative stories with an abstract situation (X^2 (3, 56) = 131.99, p <.001), disabler stories with a concrete situation (X^2 (3, 99) = 148.61, p <.001), and disabler stories with an abstract situation (X^2 (3, 105) = 166.85, p <.001).

We also carried out a third ANOVA using as independent variables counterexample (alternative vs. disabler), concreteness (concrete vs. abstract) manipulated within-participants and year group (2^{nd} vs. 3^{rd}) manipulated between participants, with the frequency of the predicted cause (e.g. the bucket had a hole; alarm clock; trouble sleeping) as dependent variable.

Results showed a main effect of counterexample, giving more predicted responses with disablers than with alternatives (80% vs. 66%; $F(1,141) = 35.64$, $p \leq .001$, $\eta^2 = .20$). There was a main effect of concreteness with more predicted causes when the situation was concrete (alarm clock) compared to abstract (trouble sleeping; 76% vs. 70%; $F(1,141) = 7.96$, $p = .005$, $\eta^2 = .05$). However, we did not find a main effect of year group (70% vs. 75%; $F(1,141) = 1.92$, $p = .168$, $\eta^2 = .01$). Moreover, there was neither an interaction between counterexample and year group ($F(1,141) = .04$, $p = .844$, $\eta^2 = .00$) nor between concreteness and year group ($F(1,141) = .00$, $p = .986$, $\eta^2 = .00$) or counterexample, concreteness and year group ($F(1,141) = .00$, $p = .996$, $\eta^2 = .002$). Nevertheless an interaction was found between counterexample and concreteness ($F(1,141) = 13.06$, p <.001, $\eta^2 = .09$). As expected, there was no effect of concreteness in disablers but there was in alternatives, giving more predicted causes with concrete situations than with abstract (73% vs. 58%, $F(1,142) = 16.17$, $p \leq .001$, $\eta^2 = .10$).

Table 4

Percentages of causes of the consequent reported (negation of the antecedent, predicted cause and others), means and standard deviations in brackets by counterexample (alternative, disabler), concreteness (concrete, abstract) and year group (2nd vs 3rd) in Study 2

		Alternative		Disabler		
		Concrete	Abstract	Concrete	Abstract	*M*
2nd	Predicted cause	70 (.35)	56 (.33)	77 (.31)	78 (.33)	*70 (.33)*
	Negation of the antecedent	18 (.28)	24 (.31)	14 (.27)	12 (.26)	*17 (.28)*
	Others	12 (.26)	20 (.27)	9 (.23)	10 (.22)	*13 (.25)*
3rd	Predicted cause	75 (.34)	61 (.33)	82 (.28)	84 (.28)	*75 (.31)*
	Negation of the antecedent	19 (.28)	21 (.28)	10 (.22)	14 (.26)	*16 (.26)*
	Others	6 (.17)	18 (.24)	8 (.20)	2 (.13)	*9 (.19)*

Note: see Table 2 to know what responses were computed in each case.

General discussion

In the present studies, we examined the development of counterfactual reasoning and the ability to distinguish real and conjectured situations, as well as the ability to keep track of them (epistemic status). Counterfactual reasoning requires negating the antecedent to create the counterfactual possibility, however as far as we are aware it is not known how adults and children think about negation in order to negate the antecedent, and this was our most important aim.

As expected, we found high accuracy (92%) in adults' ability to make inferences from counterfactual statements. As predicted, children's performance showed a developmental trend in this ability (78% in 8-10 years old children and 87% in 10-12 years old children), that could be due to an increase in the ability to consider alternatives and increases in working memory capacity. This finding is consistent with results from earlier studies that indicate that 6 to 7 year-olds can indeed reason counterfactually

(McCormack et al., 2018; Nyhout et al., 2019; Rafetseder & Perner, 2018), but revealing counterfactual thinking as a developmental ability, that improves until adolescence (Gómez-Sánchez et al., 2020; Rafetseder et al., 2013).

Regarding the epistemic status, we found that adults showed more difficulty than in the inferential task with a mean of 72% correct responses. This finding is consistent with previous results (Gómez-Sánchez et al., 2020; Ruiz-Ballesteros & Moreno-Ríos, 2017; Thompson & Byrne, 2002). According to the mental model theory, responding correctly to the epistemic status question requires not only having a complete representation of counterfactuals that includes the conjectured and the presupposed model, but also keeping in mind their labels in order to keep track of their epistemic status. These labels or mental footnotes are easily forgotten (Johnson-Laird, 1983; Johnson-Laird & Byrne, 2002), causing a decrease in the number of correct responses. Children's performance on the epistemic status questions also showed a developmental trend (60% vs. 68%) and as with the adult group, their performance was worse than on the inferential task. In a previous study, Gómez-Sánchez et al. (2020), using similar stories (with some important differences regarding the variables manipulated here, such as concreteness and counterexample availability), also found higher scores in the inference responses than in the epistemic status and a developmental improvement with age in the epistemic responses. This ability could be crucial for achieving correct counterfactual reasoning (Gómez-Sánchez et al., 2020).

Finally, in respect of the causal question, we found the expected effect. More predicted causes were reported (e.g. the bucket had a hole, the child had trouble sleeping, etc.) as being the cause of the consequent than the syntactic negation of the antecedent using propositional symbols (e.g. the girl did <u>not</u> pour water; the sister did <u>not</u> enter silently, etc.). We observed this effect in both studies, which implies that adults and

children construct the counterfactual possibility in the same way. These results are consistent with previous research, showing that people construct negation ("there is not a light figure") by recovering another possibility ("a dark figure") instead of by thinking on the syntactic negation ("not light figure") (Espino & Byrne, 2018; Khemlani et al., 2012; Mayo et al., 2004; Moreno-Ríos & Byrne, 2018). The inference-to-alternative effect (Espino & Byrne) was obtained only with binary possibilities but not with non-binary possibilities (there is a red figure). In our study, the alternative stories contain two possible causes. As with the binary categories, the negation of one, seems to lead people to think of the other. It is possible that effect could disappear with more possible causes.

Something that was not expected was observing more predicted causes in disablers than in alternatives stories, especially as we found this effect in both studies. Although both kinds of stories are not comparable as they are different, it could be related to the salience of the cause: in alternatives the cause is something (e.g. an alarm clock; trouble sleeping) that does not get as much attention as in the disabler stories, where something unusual happened (e.g. a bucket with a hole). It could also be related to the structure of the counterexample. In disabler stories there is no competing alternative that catches attention, whereas in the alternative stories an explicit alternative is mentioned. However, more research is needed in order to find what causes this result.

We also found that children, unlike adults, gave the predicted cause more with concrete situations than with abstract situations, which could be explained by their poor ability in thinking with abstract concepts. Moreover, as hypothesized, the manipulation of concreteness had an impact on alternative stories but not in control disabler stories. This happens because alternative stories provide an explicit situation that corresponds to the negation of the antecedent, and the manipulation of its concreteness affected the recovery of the cause, as expected. In other words, when we asked children why the child was

awake they reported the predicted response with concrete situations ("because the alarm clock sounded") more than with abstract situations ("because he had trouble sleeping"). However, this effect was not found in disabler stories because they acted as control, with the concreteness of the cause remaining constant (compare Figures 1a and 1b). This result is in accordance with the developmental differences in their ability to negate, as schoolchildren find difficulty in thinking abstractly (Markovits, 2013; Markovits & Lortie-Forgues, 2011).

The findings of the present studies bring to light several difficulties that could cause children's difficulty in thinking with counterfactuals, such as keeping in mind which is the real situation and which the conjectured one, and having to negate the antecedent in an abstract way. However, the most novel result is the one related to how adults and children construct negation. More research is needed in order to know to what extent these difficulties are responsible for their performance in counterfactual thinking and whether the construction of negation of the antecedent can be generalised to other kind of contents.

Appendix

*Example of alternative and disabler stories with **concrete situations in bold** and (abstract situations in brackets). * indicates the correct response.*

Imagine that you are a great detective whose mission is to investigate different cases. To do so, you have the support of your colleague Raúl who saw what happened and who will give you some information about it.

Hi, detective!

Today we have a lot of work. In each of the stories we have listened to part of the conversation between the police officer and other people. You will need that information to answer some questions. Pay attention to the words said by the policeman because he won't repeat them. Will you be able to figure out what happened in each situation? Here are the cases, remember to pay attention to the information:

1. The police officer was at a birthday party and he saw a boy leaving the hall running because he is afraid of the sound of balloons bursting. You have to pay great attention to the police officer's words because he gives you some information: remember that he says "the boy is afraid of the sound of balloons bursting". Taking into account this information, could we say that there were balloons in the hall? *Yes / No

ALTERNATIVES

Story 1- The police officer saw through a window of the room that a child was awake because **his alarm clock had just sounded** (he had trouble sleeping). His sister went into his bedroom to take a toy. Later, the police officer said: 'If his sister had entered silently…'

1. Inferential Question: Would the child have been … *awake or asleep?

2. Epistemic Status Question: Remember, the police officer said: 'If his sister had entered silently …' According to this evidence, did the police officer see that his sister went in silently? Yes / *No
3. Causal Question: The police officer believes the child was awake because…

Story 2- The police officer saw that a girl was walking while eating an ice-cream. **Then, a chocolate scoop fell on her shirt and stained it**. (She is very careless and always wears scruffy clothes…) She was walking near a mud puddle when a car approached. Later, the police officer said: "If the car had avoided the puddle…"

1. Counterfactual Question: Would the girl's shirt have been…clean or *dirty?
2. Epistemic Status Question: Remember, the police officer said: *"If the car had avoided the puddle... "* According to this evidence, did the police officer see the car splash the girl? *Yes / No
3. Causal Question: The police officer believes the girl's shirt was dirty because…

Story 3- The police officer saw that the stairs of a boy's house were wet because **his mother had just washed it** (, where they live, it rains every day)**.** When **she finished**, the boy came home from school and stepped in a puddle that was close to the door. Later, the police officer said: *"*If the boy had gone in barefoot…"

1. Counterfactual Question- Would the stairs have been…*wet or dry?
2. Epistemic Status Question- Remember, the police officer said: *"*If the boy had gone in barefoot…" According to this evidence, did the police officer see the boy go in barefoot? Yes / *No
3. Causal Question: The police officer believes the stairs were wet because…

Story 4- The police officer saw that the father came back from shopping. The car door was open because **the seat belt was trapped in the door** (he has an awful memory and always forgets to close the car). The child went to the car to fetch some bags. Later, the police officer said: "If the child had left the car key…"

1. Counterfactual Question- Would the car have been…*open or closed?
2. Epistemic Status Question- Remember, the police officer said: "If the child had left the car key…" According to this evidence, did the police officer see the child with the car key? *Yes / No
3. Causal Question: The police officer believes the car was open because…

DISABLERS

Story 5- The police officer saw that a girl was on the beach playing with a bucket. Her bucket was broken and had a hole in the bottom. The girl was **picking white stones up** (occupied). Later, the police officer said: 'If the girl had poured water into her bucket…'

1. Inferential Question: Would the bucket have been…full or *empty?
2. Epistemic Status Question: Remember, the police officer said: 'If the girl had poured water into her bucket…' According to this evidence, did the police officer see the girl pour water into the bucket? Yes / *No
3. Causal Question: The police officer believes the bucket was empty because…

Story 6- The police officer, who was in a swimming pool, saw that a child had a lilo. The lilo was deflated because it had a hole. His father was **there playing cards** (nearby). Later, the police officer says, 'If the father had used the air pump...'

1. Inferential Question: Would the lilo have been…inflated or *deflated?

2. Epistemic Status Question: Remember, the police officer said: ‘If the father had used the air pump…’ According to this evidence, did the police officer see the father using the air pump? Yes / *No
3. Causal Question: The police officer believes the lilo was deflated because…

Story 7- The police officer saw through the window that a boy was in his room and had a blank sheet of paper because his pen was out of ink. When the boy left his room, his sister came in and took the paper and pen. The sister **found the story of the three little pigs** (remembered she had homework). Later, the police officer says, ‘If the sister had used that pen...’

1. Inferential Question: Would the paper have been…*blank or painted?
2. Epistemic Status Question: Remember, the police officer said: ‘If the sister had used that pen…’ According to this evidence, did the police officer see the sister using that pen? Yes / *No
3. Causal Question: The police officer believes the paper was blank because…

Story 8- The police officer saw that a girl was in her room. The light in the room was off because there was no light bulb. The girl was **jumping on the bed** (thinking about what to do for the weekend). Later, the policeman says, ‘If the girl had flipped the switch....’

1. Inferential Question: Would the light have been…on or *off?
2. Epistemic Status Question: Remember, the police officer said: ‘If the girl had flipped the switch…’ According to this evidence, did the police officer see the girl flipping the switch? Yes / *No
3. Causal Question: The police officer believes the light was off because…

Capítulo 5

Discusión general

El objetivo fundamental de esta tesis doctoral ha sido estudiar el razonamiento deductivo, así como la consideración de alternativas para poder alcanzar conclusiones válidas. Más concretamente, nos hemos centrado en algunos factores que podrían influir en este tipo de razonamiento para, más tarde, estudiar un tipo de construcciones concretas que requieren de la generación de alternativas: los enunciados contrafácticos. De forma general, podríamos decir que se han perseguido tres objetivos principales que guardan estrecha relación al compartir como núcleo el análisis del efecto de las alternativas en la deducción. Por un lado, evaluar el razonamiento inferencial con condicionales, tratando de determinar qué factores podrían influir en la elaboración de las cuatro inferencias básicas. Por otro lado, analizar el desarrollo evolutivo del razonamiento contrafáctico, tratando de localizar algunos factores que podrían ser causantes de las limitaciones encontradas en este tipo de razonamiento en niños. Por último, analizar el papel que la negación ocupa en la construcción de la posibilidad contrafáctica.

A continuación, se recogen los resultados más relevantes obtenidos en los estudios empíricos de esta tesis, discutiéndolos en base a los resultados hallados en otros trabajos de investigación. Con el objetivo de facilitar la lectura y que la información sea lo más clara posible se va a organizar en 3 bloques, derivados de los tres objetivos generales de esta tesis.

Razonamiento inferencial con condicionales

A lo largo de la introducción hemos visto cómo las inferencias con condicionales están sujetas a un proceso evolutivo complejo y cómo diferentes factores pueden influir en la realización de todas ellas, inferencias válidas y falacias. El efecto de muchos de estos factores en la supresión de inferencias había sido puesto a prueba, aunque algunos generaban dudas (Cariani & Rips, 2017). En nuestro estudio 1, a través de dos experimentos con personas adultas pusimos a prueba tres de estos factores: el propio

contenido del condicional, información adicional al condicional y generación de contraejemplos. Además, quisimos identificar si el número de contraejemplos generado afectaba a la magnitud de la supresión, así como si la inclusión de los tres factores mostraba un efecto aditivo en la supresión.

En la tarea usada para ambos experimentos utilizamos condicionales de dos tipos. Por un lado, alternativas, que nos llevan a pensar en condiciones o antecedentes alternativos que llevan a la misma conclusión o consecuente. Por ejemplo, "si María salta a una piscina, entonces se moja" nos hace pensar en otras formas en las que María puede mojarse: que se le caiga la bebida encima, que se duche, que la empujen a la piscina, que llueva…Y, por otro lado, disablers, con los que se inhibe una relación entre antecedente y consecuente, evitando que este último se dé. Por ejemplo, ante "si Sebastián pone la cafetera en el fuego, entonces el café sube" existen numerosas condiciones disabler que pueden "romper" esa relación entre antecedente (cafetera en el fuego) y consecuente (que suba el café): que el fuego no esté encendido, que no haya echado el café, que no le haya puesto suficiente agua, que no lo deje el tiempo necesario en el fuego…

En el experimento 1 confirmamos el efecto de supresión propio de estos dos tipos de contraejemplos, con las alternativas suprimiendo las falacias (AC y NA) y los disablers suprimiendo las inferencias válidas (MP y MT). Es decir, cuando se presentaba el condicional tipo alternativa "si María salta a una piscina, entonces se moja" y, por ejemplo, la premisa "María no saltó a una piscina", los participantes generalmente no concluían "no se mojó" (lo que sería la falacia NA: ¬A∴¬B; ver Tabla 1 de la introducción). Por el contrario, bloqueaban esa falacia concluyendo que no se podía saber si se mojó o no. Esto es debido a la disponibilidad de alternativas (lluvia, bebida que se le cae, ducha, etc.), pues saben que no solo saltar a una piscina hace que se moje, sino que también puede mojarse de otras maneras (ver Tabla 3 de la introducción como ejemplo).

Por otro lado, cuando se presentaba el condicional disabler "si Sebastián pone la cafetera en el fuego, entonces sube el café" y la premisa "Sebastián puso la cafetera en el fuego" la disponibilidad de disablers hacía que no concluyeran "el café subió" (MP: A∴B). Al igual que en el caso de las alternativas, los participantes tienen presentes esos posibles disablers (no haber encendido el fuego, no haberla dejado el tiempo suficiente, no haberle echado el café, etc.), y no les permiten asegurar que el café suba, concluyendo por tanto que "no se puede saber si el café subió o no".

Asimismo, también encontramos diferencias en cuanto a la condición, mostrándose un mayor efecto de supresión en la condición explícita frente a la implícita. No obstante, en ambas condiciones se produjo la supresión. En la condición implícita únicamente se proporcionaba el condicional ("si Sebastián pone la cafetera en el fuego, entonces sube el café"). Sin embargo, en la condición explícita los participantes contaban, además, con información adicional al condicional ("sin embargo, sabemos que Sebastián puso la cafetera en el fuego, pero el café no subió") y con la búsqueda activa de contraejemplos (alternativas o disablers) ("escribe 2 posibles explicaciones a este hecho"). Estos resultados muestran que el propio contenido del condicional en sí mismo (condición implícita) puede suscitar el efecto de supresión, algo que había sido recientemente cuestionado (Cariani & Rips, 2017). No obstante, puesto que en los resultados de la condición explícita no podíamos discernir a cuál de los factores (información adicional o búsqueda de contraejemplos) podía deberse el aumento de la magnitud del efecto, diseñamos un segundo experimento con el objetivo de arrojar luz sobre este resultado.

De esta forma, en el experimento 2 comparamos la condición explícita del experimento 1 previamente descrita con una nueva condición explícita. En esta nueva condición suprimimos la búsqueda de contraejemplos y la reemplazamos por una búsqueda de sinónimos ("escribe 2 sinónimos de feliz") que no debería producir

supresión, con el objetivo de proporcionar una complejidad similar en ambas condiciones. Los resultados de este segundo experimento mostraron nuevamente un efecto de supresión en ambas condiciones. Sin embargo, este efecto se vio incrementado cuando los participantes tenían que buscar activamente contraejemplos. No obstante, esta mejora solo se vio reflejada cuando los participantes solo tenían que buscar dos contraejemplos, frente a cuando tenían que buscar cinco. Esta falta de efecto en el grupo de "muchos"(5) podría estar relacionada con el efecto de fluencia: cuando se tienen que buscar pocos contraejemplos, el acceso a ellos puede ser relativamente fácil y rápido, lo que puede hacer pensar que existen numerosos contraejemplos disponibles. Sin embargo, la búsqueda de muchos, en este caso de 5, es bastante más difícil y la dificultad para alcanzar el número propuesto podría hacer pensar que no existen muchos contraejemplos.

Tal y como hemos visto en la introducción, la TMM propone que, en la creación de las posibilidades a partir de un condicional, se produce un proceso o efecto de modulación (Johnson-Laird & Byrne, 2002; Quelhas et al., 2010, 2017; Quelhas & Johnson-Laird, 2017). Con este efecto de modulación se defiende la importancia del conocimiento a la hora de generar las posibilidades, pues estas tienen su base en él. Por ejemplo, como hemos visto previamente, el condicional "si María salta a una piscina, entonces se mojará" podría llevarnos a pensar, gracias a nuestra experiencia y conocimientos previos, que existen numerosas alternativas que pueden causar el mismo resultado (que María se moje). Es por ello que el efecto de supresión, disponiendo únicamente del contenido del condicional, sería esperable no solo con alternativas, sino también en el caso de los disablers, tal y como encontramos en los dos experimentos.

Por otro lado, la información adicional al condicional ayuda a considerar la existencia de alternativas y disablers: "Sin embargo, sabemos que María no saltó a una piscina, pero se mojó". No obstante, aunque útil, esta información se presenta haciendo uso de

negaciones sintácticas o explícitas a través del uso del "no". Esto lleva a una representación más abstracta y costosa del contraejemplo en comparación con la generación de un contraejemplo "real", lo que queda también reflejado en los modelos que construimos (No-piscina Mojada). Es por ello que la búsqueda activa de contraejemplos (se le cayó bebida encima, le llovió, la empujaron a la piscina, etc.), puede facilitar la generación de los modelos (De Neys et al., 2002) y su mantenimiento en mente al ser más concretos (Lluvia Mojada), permitiendo con ello facilitar la supresión.

Es importante destacar que la búsqueda de un mayor número de contraejemplos (en nuestro caso 2 frente a 5) no supone un mayor efecto de supresión, sino todo lo contrario. Esto podría explicarse porque una alta demanda de la memoria de trabajo puede dificultar el proceso, así como por el efecto de fluencia previamente mencionado. Esta relación entre el número de contraejemplos disponibles y el efecto de supresión ha sido fuente de estudio en varias ocasiones. Sin embargo, no existen resultados consistentes, con algunos encontrando que la mera disponibilidad de uno lleva a la supresión (Markovits & Quinn, 2002) y otros sí encontrando diferencias en función del número de contraejemplos disponibles (De Neys et al., 2003a; Geiger & Oberauer, 2007).

De esta forma, podemos decir que una aportación interesante de este estudio radica en que, aunque en condiciones y con contenidos diferentes, se demostró el efecto de supresión de los 3 factores puestos a prueba: contenido del condicional, información adicional y búsqueda de contraejemplos, en contra de lo que Cariani y Rips (2017) planteaban. Asimismo, se ponen en relación todos los factores en un solo estudio, mostrando que su conjunción conlleva un efecto aditivo o sumatorio en cuanto a la supresión. Es por ello que estos hallazgos representan un avance en el conocimiento del razonamiento deductivo, complementando y ampliando los resultados previos. No

obstante, futuros estudios podrían comprobar los efectos encontrados, haciendo especial hincapié en el relativo a la aportación conjunta de todos los factores.

Desarrollo evolutivo de la consideración de alternativas en el razonamiento contrafáctico y factores

Tal y como se ha visto a lo largo de la introducción, existe controversia en cuanto a la habilidad de los más pequeños para razonar con condicionales de tipo contrafáctico. Algunos encuentran esta habilidad profundamente desarrollada en niños y niñas en edad preescolar con tareas básicas (Guajardo et al., 2009; Nyhout & Ganea, 2019) y otros lo hacen alrededor de los 8 años en tareas que, parece, requieren de una mayor habilidad (Rafetseder et al., 2013, 2021). Sin embargo, no existe un acuerdo acerca de qué factores podrían ser los causantes de las dificultades y diferencias halladas. En el estudio 2 tratamos de analizar algunos factores que podrían ser claves en este tipo de razonamiento: la estructura gramatical, la consideración de posibilidades y el mantenimiento de las etiquetas mentales. Algunos estudios ya han demostrado que este último factor supone una gran dificultad incluso en personas adultas (Ruiz-Ballesteros & Moreno-Ríos, 2017). Sin embargo, no había sido investigado en niños y niñas.

Tal y como hemos mencionado a lo largo de la introducción, se ha tomado la TMM como marco de trabajo al tratarse de la única teoría que permite establecer hipótesis concretas respecto a todos los objetivos propuestos. Si nos centramos en los objetivos generales 2 y 3 referidos a los condicionales de tipo contrafáctico, tomar esta teoría como marco queda aún más justificado. Esto es así puesto que, en las aproximaciones probabilísticas, este tipo de condicionales son concebidos de la misma forma que los condicionales básicos, por lo que no sería posible establecer hipótesis que conllevaran la distinción entre ambos.

Como hemos visto a lo largo de esta tesis, los condicionales de tipo contrafáctico hacen referencia a algo que podría haber ocurrido, pero que realmente no lo hizo, utilizando construcciones subjuntivas del tipo "si hubiera ocurrido…, entonces habría ocurrido…". Es importante mencionar que, en algunas ocasiones, el uso de este tipo de condicionales, como los empleados en los estudios 2 y 3, se ha confundido en la literatura con el de otras construcciones que, aunque plantean una situación contraria a la realidad ("si tiras una pluma a un cristal, el cristal se rompe"), no utilizan este tipo de estructuras gramaticales. Sin embargo, esta diferenciación es importante.

En el experimento 1 analizamos, desde el marco de la teoría de los modelos mentales, la capacidad de razonamiento contrafáctico en personas adultas, prestando especial atención a su habilidad para mantener el estatus epistémico. Además, pusimos a prueba el carácter lingüístico a través del uso de la concesiva "aunque" pues, como vimos en la introducción, podría suponer una ayuda a la hora de razonar con contrafácticos. Tal y como esperábamos, los resultados mostraron una correcta habilidad inferencial (89% respuestas correctas). Sin embargo, la detección del estatus epistémico, es decir, la habilidad para distinguir situación real e hipotética ("si hubiera echado agua", denota que en realidad no echó agua) supuso mayor dificultad (72% respuestas correctas), siendo este resultado consistente con otros estudios (Ruiz-Ballesteros & Moreno-Ríos, 2017).

Esta diferencia de resultados entre habilidad inferencial y distinción entre situación real e hipotética puede ser explicada por la TMM. Para dar la respuesta correcta al contrafáctico, únicamente debemos tener presentes los dos modelos o posibilidades (A B; ¬A ¬B en el caso de contrafácticos). Sin embargo, para el estatus epistémico, además, se requiere mantener la nota mental que cada uno de esos modelos tiene y que hace referencia a qué modelo es cada uno de ellos (hipotético y real, respectivamente). Debido a las exigencias de la tarea, estas notas mentales son fácilmente descartadas durante el

proceso (Johnson-Laird & Byrne, 2002), manteniendo una correcta habilidad inferencial pero presentando mayor dificultad en la identificación de situación real e hipotética.

Asimismo, encontramos que el uso de "aunque" facilitó la respuesta inferencial tanto en personas adultas como en niños y niñas. Esto era esperable puesto que, tal y como se puede observar en la Tabla 4 de la introducción, el consecuente en los modelos real e hipotético con condicionales semifácticos permanece siendo el mismo (B), lo que podría facilitar el razonamiento al tratarse de la respuesta correcta. Sin embargo, con contrafácticos, el consecuente varía dependiendo del modelo (¬B en modelo real; B en modelo hipotético).

Los datos presentados en el experimento 2 muestran que el razonamiento contrafáctico podría seguir un proceso evolutivo y que parece ser en torno a los 12 años cuando los niños y niñas dan respuestas similares a las personas adultas. No obstante, esto no quiere decir que niños y niñas de menor edad no cuenten con la habilidad para pensar con contrafácticos. De hecho, algunos estudios muestran esta habilidad en niños/as bastante más pequeños/as, aunque con tareas más simples (McCormack et al., 2018; Nyhout et al., 2019). Es importante destacar que, como mencionábamos, las tareas con las que se evalúa este tipo de razonamiento muestran importantes diferencias: uso de dibujos o actuación, tareas de papel y lápiz, causa física o debida a un agente, diferente demanda de funciones ejecutivas, etc. En nuestro estudio nosotros evaluamos esta habilidad utilizando la misma tarea con niños/as, adolescentes y personas adultas.

Los resultados con escolares han proporcionado especialmente un avance en la investigación sobre el razonamiento contrafáctico, al confirmar la dificultad que encuentran en el estatus epistémico: los niños y niñas de menor edad fueron incapaces de distinguir situación real e hipotética, es más, recuperaron lo hipotético como si fuera real; solo los más mayores, mostraron alguna capacidad para hacerlo, aunque con una gran

limitación dando respuestas muy próximas al azar. No obstante, debemos recordar que, incluso las personas adultas, mostraron algo de dificultad. Por los resultados hallados, podríamos decir que podría tratarse de uno de los aspectos clave en la dificultad que los niños y niñas experimentan al pensar con condicionales de este tipo. Aunque esta habilidad, al igual que la inferencial, parece mostrar un patrón evolutivo, incluso aquellos pertenecientes al mayor grupo edad muestran un elevado porcentaje de error (40%). Estos resultados, unidos a los encontrados en personas adultas, podrían demostrar la importancia de funciones ejecutivas como la inhibición, la atención y la memoria de trabajo en este tipo de razonamiento (Beck et al., 2009; Gathercole et al., 2004).

De esta forma, podríamos concluir que el razonamiento contrafáctico muestra dos aspectos claves para su correcta adquisición. Por un lado, la habilidad para considerar la posibilidad contrafáctica y, con ello, la creación de los dos modelos que el contrafáctico requiere (real e hipotético); y, por otro lado, el mantenimiento de las notas mentales que indican el carácter epistémico de cada una de ellas (cuál es la real y cuál es la hipotética). Esto podría tener importantes implicaciones sobre todo en el ámbito educativo. Por ejemplo, en algunas asignaturas como historia los maestros pueden plantear en clase cómo podrían haber sido las cosas si un acontecimiento hubiera sido diferente en el pasado ("¿qué habría pasado si los alemanes hubieran ganado la segunda guerra mundial?"). Este tipo de planteamientos es muy útil, pues promueve el desarrollo de la imaginación y la actitud crítica, permitiendo al alumnado entender el contraste pasado-presente e imaginar situaciones alternativas a la realidad, con la consecuente reflexión acerca de las mismas. No obstante, como hemos visto en este estudio, deberíamos ser precavidos a la hora de utilizar este tipo de construcciones pues los niños y niñas, e incluso adolescentes, podrían confundir lo real con lo hipotético y recordar posteriormente hechos hipotéticos como reales. Esto, además, podría trasladarse de manera práctica, no solo a las aulas, sino

también al ámbito familiar, pues las personas adultas a menudo utilizamos construcciones de este tipo con niños y niñas de, incluso, menor edad. Es por ello que los resultados obtenidos sugieren la importancia de enfatizar que no se deberían utilizar este tipo de construcciones o, al menos, deberíamos ser cautos al hacerlo, pues suponen un esfuerzo y dificultad añadidas.

El papel de la negación en el razonamiento contrafáctico

En la última parte de esta tesis, se intentó ir más allá en el razonamiento contrafáctico, tratando de investigar cómo personas adultas y niños/as construyen la posibilidad contrafáctica. Como hemos visto a lo largo de la introducción, esta requiere de la negación y su construcción parece mostrar diferencias evolutivas. Así, los más pequeños la representan a través de aspectos concretos, mientras que las personas en edad adulta también pueden representarla haciendo uso de elementos abstractos, como el uso del "no" (Markovits et al., 2010; Markovits, 2013). Es por ello que cabría esperar diferencias a la hora de construir la posibilidad contrafáctica. No obstante, estas diferencias deberían mostrarse únicamente en las historias de tipo alternativa, pues la manipulación de la concreción de la negación afecta directamente a la alternativa a recuperar para construir la posibilidad contrafáctica (concreta: despertador; abstracta: problemas para dormir; sintáctica: "no entró en silencio"). Sin embargo, las historias de tipo disabler se diseñaron como control, pues el uso de elementos concretos o abstractos no afectaba a la alternativa causante del resultado (concreta: "cogiendo piedras blancas"; abstracta: "estaba ocupado"; comparar Figura 1a y Figura 1b del capítulo 4 para más información).

En el experimento 1, al igual que ocurrió en el estudio 2, las personas adultas mostraron una correcta habilidad para razonar con contrafácticos (92% correctas) y mayor dificultad para distinguir situación real e hipotética (75% correctas). Esta diferencia, como comentábamos anteriormente, podría deberse a la pérdida de las

etiquetas mentales con el objetivo de agilizar el proceso inferencial debido a la alta demanda de funciones ejecutivas como la atención y la memoria de trabajo, siendo consistente con otros estudios (Ruiz-Ballesteros & Moreno-Ríos, 2017).

Los resultados con niños y niñas en el experimento 2 también siguieron la línea del estudio 2, mostrando un desarrollo evolutivo en ambas habilidades y una mayor dificultad en la detección del estatus epistémico, aunque la puntuación media fue ligeramente más baja en este estudio. Esta diferencia en las medias podría deberse a la propia tarea al igual que ocurre con otros estudios, pues ambas muestran importantes diferencias en cuanto a las variables utilizadas, entre otros aspectos. No obstante, consideramos que lo importante es que la tendencia en los resultados mantiene la misma dirección.

Sin embargo, el objetivo principal de este último estudio era investigar cómo tanto personas adultas como niños y niñas construían la negación del antecedente para la posibilidad contrafáctica. Los resultados mostraron que ambos, parecen hacerlo recurriendo a la situación afirmativa, independientemente de que sea alternativa o disabler, en lugar de a la negación sintáctica utilizando "no". Estos resultados podrían estar relacionados con los de otros estudios que encuentran que las personas construyen la negación a través de la recuperación de una posibilidad opuesta, en lugar de a través del uso de la negación sintáctica (Espino & Byrne, 2018; Moreno-Ríos & Byrne, 2018). Por ejemplo, ante "no es de noche", se interpreta "es de día".

Nosotros no utilizamos categorías naturales ni contenidos de clases binarias (claro/oscuro, fácil/difícil…). No obstante, las situaciones que describimos en las historias sí corresponden a dos posibilidades derivadas de la propia formulación del problema y su contexto, por ejemplo, una persona está despierta porque (1) suena el despertador o (2) porque otra persona hace ruido. Aunque difieren, ambos estudios hacen

referencia a posibilidades binarias, por lo que sería interesante que futuras investigaciones evaluaran la posible relación entre contenidos binarios y posibilidades dobles.

La referencia a la alternativa o al disabler como responsable del resultado ("el niño estaba despierto porque…"; "el cubo estaba vacío porque…") mostró un resultado inicialmente no predicho en ambos experimentos: tanto personas adultas como niños/as hicieron más referencia al disabler que a la alternativa como causa, independientemente de su concreción. Una explicación a este hecho podría residir en la saliencia de la causa: en el disabler se trata de algo inusual e inesperado (que un cubo tenga un agujero, que una lámpara no tenga bombilla, etc.) y que, por lo tanto, podría captar más fácilmente la atención de los participantes. Sin embargo, en las alternativas es algo relativamente cotidiano (que suene un despertador, que alguien se olvide las llaves del coche, etc.) No obstante, es importante mencionar que ambos tipos de historia son diferentes y, por tanto, las diferencias podrían deberse a múltiples factores derivados de las mismas. Futuras investigaciones podrían confirmar este efecto, así como analizar posibles factores causantes de tales diferencias.

Como era de esperar por el carácter evolutivo de la construcción de la negación, los niños y niñas, a diferencia de las personas adultas, construyeron la negación del antecedente recuperando en mayor proporción situaciones concretas que abstractas. Como hemos visto a lo largo de la introducción, los más pequeños muestran dificultad al pensar en la negación de manera abstracta. Por ello, la disponibilidad de una alternativa específica y, además, el hecho de que esta sea concreta y generalmente imaginable favorecería su representación. Las personas adultas, sin embargo, no muestran dificultad a la hora de construir la negación de manera abstracta, es por ello que no se esperaban diferencias significativas.

En relación con lo anterior, y yendo un paso más allá, es importante mencionar que la manipulación de la concreción mostró el efecto previsto: diferencias significativas en el caso de las historias de tipo alternativa, pero no en las de tipo disabler. Como hemos mencionado previamente, las historias disabler las utilizamos a modo de control pues la concreción no tenía efecto en la posible causa alternativa al resultado (ver Figura 1b del capítulo 4), a diferencia de las historias de tipo alternativa (ver Figura 1a del capítulo 4). Es por ello que, en estas últimas, los niños y niñas se apoyaron en la alternativa concreta e imaginable para construir la posibilidad contrafáctica, tal y como era esperable en base a los hallazgos relativos a la representación de la negación previamente mencionados (Markovits, 2013; Markovits & Lortie-Forgues, 2011).

Es importante destacar que algunos estudios han mostrado un efecto de orden en la presentación de problemas en función de su concreción. De esta forma, presentar problemas de tipo abstracto antes que concretos parece tener un efecto negativo en los últimos, en el caso de adolescentes (Markovits & Vachon, 1990). Sin embargo, que se presenten primero los problemas concretos no ha mostrado este efecto (Markovits & Lortie-Forgues, 2011). A pesar de estos hallazgos, consideramos que este problema no debería darse en nuestro estudio pues se llevó a cabo una aleatorización de las historias. No obstante, puesto que únicamente tratamos de controlar este efecto, pero no lo medimos, sería interesante que futuros estudios lo hicieran. De esta forma, podrían tratar de confirmar si este efecto se produce, o no, en el caso de problemas con condicionales de tipo contrafáctico, así como en el caso de historias con contraejemplos de tipo alternativa o disabler.

Por último, es importante destacar que la identificación de las limitaciones y dificultades que los escolares encuentran en el razonamiento deductivo podría ayudar al diseño de tareas y materiales didácticos más adecuados para favorecer un aprendizaje

efectivo para todo el alumnado y, en especial, para aquel que presenta dificultades de aprendizaje.

A modo de resumen, podríamos decir que los resultados de esta tesis doctoral presentan diferentes conclusiones principales. Por un lado, (1) demuestran el efecto de supresión de tres factores: el contenido del propio condicional, la información adicional a este y la búsqueda activa de contraejemplos. Además, (2) muestran que estos factores se relacionan en una función aditiva para causar supresión inferencial. Por otro lado, nuestra investigación (3) sugiere la importancia de un factor que podría ser clave en la dificultad que los niños y niñas encuentran en el razonamiento contrafáctico: el mantenimiento del estatus epistémico, diferenciando lo que es hipotético de lo que es real. Asimismo, (4) muestra el carácter evolutivo de este factor y confirma el desarrollo progresivo en la habilidad para razonar con contrafácticos. Por último, los resultados indican que (5) la posibilidad contrafáctica, que permite diferenciar lo hipotético de lo real, podría construirse a través del uso de alternativas explícitas al uso de la negación sintáctica haciendo uso del "no". Asimismo, (6) parece confirmar la relación entre el desarrollo evolutivo que muestra la negación en base a su concreción y la construcción de la posibilidad contrafáctica. No obstante, futuras investigaciones deberían replicar los nuevos hallazgos y permitir valorar la generalización de los resultados.

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