Doctoral Dissertation

Motivated Forgetting: Selectivity and Control

(Olvido Motivado: Selectividad y Control)

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El doctorando Carmen Aguirre Rodríguez y los directores de la tesis María Teresa Bajo Molina y Carlos J. Gómez-Ariza. Garantizamos, al firmar esta tesis doctoral, que el trabajo ha sido realizado por el doctorando bajo la dirección de los directores de la tesis y hasta donde nuestro conocimiento alcanza, en la realización del trabajo, se han respetado los derechos de otros autores a ser citados, cuando se han utilizado sus resultados o publicaciones.

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Director/es de la Tesis   Doctorando

Fdo.:   Fdo.:

A mis padres.

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Introductory note

The content of this doctoral dissertation has been drawn up according to the regulations of the University of Granada to obtain the International Doctorate Mention in the Official Experimental Psychology and Behavioral Neurosciences Doctoral Program. According to this, the majority of the thesis has been written in English. Specifically, in Chapter I a theoretical introduction to the subject of investigation is presented in Spanish. Next, Chapter II contains a summary of the theoretical background written in English. The empirical chapter (Chapter III) is also written in English. Finally, the general discussion is written both in Spanish (Chapter IV) and English (Chapter V).

Índice

Prefacio

Querido lector:

Imagine que se encuentra en su primer día en un nuevo trabajo. Su supervisor le está dando información muy concreta, instrucciones y claves sobre cómo realizar sus nuevas funciones y responsabilidades. Es fácil pensar que se encuentre haciendo su mayor esfuerzo para tratar de memorizar todo lo que le está contando. No obstante, pasados unos minutos, y de forma repentina, el supervisor para de hablar, se disculpa, y le dice que hay *parte* de toda esa información que le acaba de transmitir que es errónea. Le pide que se olvide de *esa* parte, porque probablemente hará que se confunda con la información que sí era correcta. Esta equivocación puede ser un poco molesta al principio, sin embargo es muy probable que usted decidiera, de hecho, seguir el consejo del supervisor e intentara olvidar *esa* información. Resultaría la decisión más adaptativa, puesto que mantener información errónea sólo provocaría futuras confusiones y errores. Esta situación específica que se muestra en el ejemplo requiere actualizar nuestro conocimiento ejerciendo control sobre nuestra memoria. Más concretamente, para que sea llevado a cabo de manera satisfactoria, dicha actualización debe ser específica y estar dirigida de forma selectiva *sólo* a la información que ya no es relevante, puesto que el resto de las instrucciones que sí eran correctas debería recordarlas para poder realizar su trabajo.

Si, por ejemplo, su primer día hubiera sido horrible, quizás desearía olvidar el evento *por completo*. De esta forma no sería necesario que el control a ejercer sobre su memoria fuera tan específico y selectivo; bastaría con olvidar el episodio completo. Una buena cantidad de investigación avala, desde hace varias décadas, que se puede ejercer este tipo de control no selectivo sobre nuestra memoria y nuestros recuerdos. Se sabe que somos capaces de disminuir la interferencia de recuerdos desagradables o no deseados, o de información que ya no resulta útil para nuestros objetivos. Puesto que todo se encuentra en continuo cambio en la vida, esta capacidad de actualizar la información que ya no es relevante resulta crucial para un buen funcionamiento de nuestra memoria y para, en esencia, desenvolvernos a diario.

No ha sido hasta hace pocos años cuando se ha comenzado a observar la importancia de poder ejercer control sobre la memoria y los recuerdos de manera más específica y selectiva. Así, recientemente ha comenzado a dibujarse una nueva línea de investigación que centra su foco de atención en la capacidad de, tras aprender cierto volumen de información, olvidar *sólo una parte* de ésta. El presente trabajo se enmarca dentro de este nuevo panorama de investigación sobre el control intencional y selectivo de la memoria.

En el primer y segundo capítulo se pretende remarcar la importancia de investigar los fenómenos de olvido. Tras revisar las principales teorías clásicas del olvido y los hitos más importantes en la investigación del fenómeno, se describen, en función de la intencionalidad, dos tipos de olvido (incidental y motivado), para pasar a describir más detalladamente la investigación sobre este último. En el tercer capítulo se describen las tres series experimentales que conforman este trabajo. Éstas tendrán como objetivo replicar el recientemente observado fenómeno de olvido motivado selectivo, estudiar posibles factores que constriñen o modulan su aparición, así como la naturaleza controlada o no de los procesos subyacentes, para terminar estudiando la relación de este fenómeno con el envejecimiento y proponer los posibles mecanismos responsables del efecto. Por último, en el cuarto capítulo se resumirán las principales aportaciones de nuestro trabajo y se discutirá su relevancia dentro del marco teórico actual sobre el control de la memoria.

Preface

Dear reader:

Please imagine you are in your first day at your new job. Your supervisor is giving you very concrete information, instructions and keys about how to accomplish your new duties. It is easy to think that you are doing your best to try to memorize all that information. After some minutes and suddenly, however, he stops talking, apologizes to you, and tells you that *part* of the information he just told you is wrong. He asks you to forget *that* part because it will probably make you get confused with the information that was correct. This error might be a little annoying at first, although you likely decide, in deed, follow his recommendation and get rid of *that* information. It would turned out to be the more adaptive decision, as keeping in mind mistaken information would only cause confusions and mistakes in the future. This specific situation illustrated here requires updating knowledge through by exerting control over our memory. In particular, in order to be accomplished satisfactorily, such updating must be specific and be targeted in a selective way *only* to the information that is no longer relevant, as you must keep in mind the rest of the instructions that were correct in order to successfully perform your job.

If, for example, your first day would have been horrible, you might want to forget *the whole event*. In this way it would not be necessary that the control exerted over your memory was specific and selective, it would be enough to forget the whole episode. A big body of research supports that this type of non-selective control can be exerted over our memory system and our memories. Thus, it is well known that we are able to diminish the interference of bad or unwanted memories, or information that is no longer relevant for our current aims. Given that, in daily life, everything is always moving or changing, this capacity of updating no longer relevant information is crucial to a good and adaptive functioning of our memory and, in essence, to get along in our daily life.

It was not until few years ago when researchers started to observe the importance of exerting control over memory in a more specific and selective way. Thus, recently a new line of research has emerged. This new approach focuses in the capacity of, having learned a certain amount of information, forgetting *just a part of it*. The present work is framed in this new line of research about the selective control of memory.

The first chapter[1] is aimed to highlight the importance of researching forgetting phenomena. After going through the main classic theories of forgetting and the principal findings, two types of forgetting (depending on the intentionality) are described: incidental and motivated forgetting. Then this last type of forgetting is described in more detail[2]. In the third chapter the three experimental series that are included in the present work are reported. These series are aimed to replicate the recently found selective motivated forgetting effect, to

[1] For an English version, please see Chapter II.
[2] Chapter II will begin straightaway by describing directed forgetting phenomena.

study possible modulating factors that constrain it and to explore the nature of the processes underlying the effect as well as the relationship between this phenomenon and the aging process. Finally, in chapter four[3] the main contributions of this work will be summarized and its relevance for a contemporary framework on memory control will be discussed.

[3] For an English version, please see Chapter V.

Capítulo I

Introducción y objetivos

Me dijo: "Más recuerdos tengo yo solo que los que habrán tenido todos los hombres desde que el mundo es mundo". Y también: "Mis sueños son como la vigilia de ustedes". Y también, hacia el alba: "Mi memoria, señor, es como vaciadero de basuras".

Funes el memorioso. Borges, 1942.

1. El estudio del olvido

Solemos ser especialmente conscientes de nuestra memoria cuando nos falla. La mayoría de las veces las consecuencias de estos olvidos suelen ser triviales o, al menos, no muy importantes, pero eso no evita que nos resulten irritantes. Nos quejamos de nuestra mala memoria porque olvidamos el cumpleaños de alguien, perdemos cosas en nuestra propia casa o tenemos problemas para recordar el nombre de un conocido. Se trata de ejemplos de olvidos que son, en cierta medida, inesperados e involuntarios y que han sido interpretados tradicionalmente como el resultado de un sistema de memoria que, a veces, produce errores de acceso a la información. Como se verá a continuación, sin embargo, hoy día los investigadores en este campo coinciden en señalar el valor adaptativo de los procesos de olvido.

En su cuento "Funes el memorioso" Jorge Luis Borges (1944) narra la desdicha que sufre su personaje por recordar cada día, cada evento, cada detalle (bueno o malo) de su vida. En este sentido, el olvido puede ser más deseable de lo que pensamos. En 2006, los investigadores Elizabeth Parker, Larry Cahill y James McGaugh informaron del asombroso caso de AJ, una mujer americana de 42 años de edad que es capaz de recordar con todo detalle cada día de su vida, desde su adolescencia. Cuando los investigadores le pedían que recordara un día determinado de su pasado, ella era capaz de recordar qué día de la semana era, qué estaba pasando, qué tiempo hacía y cómo se sentía. Esta información podía ser verificada consultando un diario que venía escribiendo desde hacía 30 años. Además, estos recuerdos eran vívidos y, según afirmaba AJ, pasaban por su cabeza sin parar, como una película, y surgían también sin esfuerzo o control consciente por su parte. Desde luego, podríamos pensar que una capacidad para recordar tan extraordinaria resultaría deseable y beneficiosa para cualquier persona. Sin embargo, esto no parece ser así. AJ paga un coste muy alto por tener esa memoria excepcional, pues tampoco puede olvidar los sucesos desagradables que le ocurren. Como la propia Parker señala, "AJ es guardiana y a la vez prisionera de sus recuerdos", que ella misma califica como una gran carga. De hecho, afirma que si pudiera elegir desearía no tener esa memoria tan extraordinaria. Parker, Cahill y McGaugh (2006) denominaron a esta peculiar capacidad "Hyperthymestic Syndrome" (del griego *thymesis* = recuerdo e *hyper* = superior). No hace mucho pudo leerse en la prensa una entrevista a un joven fotógrafo, ganador del Premio Nacional de Fotoperiodismo, que había vivido en los peores barrios de Haití, visto cómo gente moría de cólera, cómo se desarrollaba el conflicto de Ucrania o sido testigo de la violencia de las maras de El Salvador. El encabezado de la noticia rezaba así: "Lo que más temo de mi profesión son los recuerdos. Has visto demasiado y te quedas *tocado*".

En definitiva, por tanto, parece que el olvido podría mostrarnos también una cara amable si lo que necesitamos es, precisamente, no recordar. A veces deseamos evitar recordar sucesos indeseables, como la pérdida de un ser querido. En otras ocasiones ciertas claves desencadenan recuerdos que nos hacen enfadar, estar ansiosos o asustados; una cara puede recordarnos una fuerte discusión que queremos olvidar; un simple papel puede recordarnos una incómoda tarea que preferimos evitar; o una imagen de la puerta de Atocha, en Madrid, puede recordarnos los tristes sucesos del 11 de marzo de 2004.

Cientos de investigaciones llevadas a cabo durante los últimos 50 años son un ejemplo del interés que, desde la psicología, se ha dedicado al estudio del olvido. Así mismo, demuestran que disponemos de la capacidad para olvidar de manera intencionada cuando hay alguna motivación o necesidad para ello. Esto ha llevado a que algunos tipos de olvido se interpreten como resultado de un eficiente procesamiento de la información y se consideren, hasta cierto punto, adaptativos (Bjork, Bjork, y Anderson, 1998). A continuación se abordan y se describen brevemente algunas de las investigaciones e hitos más relevantes e influyentes en el estudio científico del olvido, que nos han llevado hasta las teorías más importantes de hoy día.

1.1. Perspectiva histórica en el estudio del olvido

Los investigadores de la memoria siempre han estado interesados en el fenómeno del olvido y en los mecanismos por los cuales los recuerdos quedan atenuados. Tradicionalmente, la investigación sobre los procesos de olvido se ha focalizado sobre formas pasivas de olvido, que surgen de forma incidental en respuesta a cambios en el entorno, o por la acumulación de trazos de memoria (para una revisión, véase Anderson y Neely, 1996; Postman, 1971).

Aunque el estudio experimental de las causas del olvido se remonta a comienzos del siglo XX, cuando los investigadores alemanes Müller y Pilzecker (1900) reportaron la primera evidencia de la interferencia retroactiva, no será hasta unos años más tarde, gracias a los trabajos de McGeoch (1932, 1936, 1942), cuando se propuso que el olvido es consecuencia de la interferencia y la competición, más que de la mera pérdida de trazos de memoria *per se* (Bjork, Bjork, y Anderson, 1998).

Unos años antes, Herman Ebbinghaus (1885) llevó a cabo un clásico estudio sobre el olvido en el que él mismo fue el único participante, y donde aprendía listas de sílabas sin sentido para reaprenderlas de nuevo al cabo de un intervalo temporal comprendido entre 21 minutos y 31 días. Observó, usando como medida de olvido la cantidad de tiempo que necesitaba para re-aprender cada lista, que en todos los casos se producía olvido. Encontró además una relación clara entre tiempo y retención, y fue el primero en plasmar la relación del olvido y el paso del tiempo trazando su famosa curva del olvido, que representa la relación cuantitativa entre el recuerdo y el paso del tiempo. La curva representa la tasa de olvido y tiene forma logarítmica: el olvido es extremadamente rápido al principio, para luego ralentizarse de forma gradual a lo largo del tiempo.

Años más tarde se reportó una de las primeras demostraciones empíricas de olvido debido a interferencia retroactiva. En el campo de la psicología de la memoria, la interferencia hace referencia a la dificultad a la hora de recordar un ítem cuando éste es similar a otros ítems almacenados en la memoria (Anderson y Neely, 1996). A mayor similitud entre los trazos competidores, más se dificulta la recuperación. Por su parte, el término interferencia retroactiva hace referencia al olvido que causa la codificación de nuevos trazos en la memoria. Los investigadores Müller y Pilzecker (1900) mostraron que el recuerdo para una serie de pares asociados que eran sílabas sin sentido (consonante-vocal-consonante) se veía perjudicado por el hecho de aprender nuevas series de sílabas sin sentido (comparado con una condición en la que los participantes solamente descansaban durante el mismo período de tiempo). Explicaron sus resultados bajo la hipótesis de *perseveración-consolidación*. Los investigadores propusieron que este peor recuerdo ocurriría porque el proceso de almacenamiento de nuevos recuerdos interrumpía el proceso de consolidación que, de otra forma, habría fortalecido los trazos que se habían adquirido previamente. Los cambios en el sistema nervioso como consecuencia del aprendizaje de las primeras sílabas sin sentido, continuaban, no estaban completos aún al final del ensayo, pues la actividad cerebral se mantenía aún después del aprendizaje y era con esta perseveración como los trazos de memoria se consolidaban. Así, una actividad posterior, si era demandante y cercana en el tiempo a la tarea original de aprendizaje (por ejemplo aprender nuevos ítems), podría producir interferencia retroactiva interrumpiendo el proceso de perseveración-consolidación. No obstante, esta idea demostró ser falsa más adelante por diferentes motivos (véase Bjork, 1992, para una revisión). En primer lugar, no podía explicar por qué, incluso tiempo después de que el proceso de perseveración-consolidación estuviera completo, un nuevo aprendizaje podía producir considerable interferencia retroactiva. Además, no podía explicar por qué incrementar la intensidad de una nueva actividad no relacionada no resulta en un mayor grado de olvido, mientras que incrementar la similitud entre las tareas sí genera un menor recuerdo. Por último, tampoco daba cuenta de los fenómenos de interferencia proactiva, es decir, de la tendencia que tienen los recuerdos más antiguos a interferir con la recuperación de experiencias y conocimientos más recientes (Bjork, 1992). A pesar de todo, la teoría del olvido de Müller y Pilzecker (1900) jugó un papel central modelando la posterior investigación sobre la memoria y los mecanismos de la interferencia.

Otra explicación sobre el olvido particularmente influyente en su momento fue propuesta por Edward Thorndike (1914) y bautizada como la *ley del desuso*. Esta teoría hace referencia al decaimiento de la huella y proponía que, a menos que tengamos acceso a, y uso de, las representaciones de memoria, éstas terminan por deteriorarse. Aunque la teoría del decaimiento de la huella parece estar de acuerdo con nuestra introspección sobre cómo se forman y cómo se pierden los recuerdos, se ha comprobado que no es adecuada como teoría explicativa del olvido.

McGeoch (1932) realizó una influyente y devastadora crítica a la ley del desuso de Thorndike (1914). Este autor criticó, en primer lugar, que ésta no propone ningún mecanismo por el que se produzca el olvido. En segundo lugar, argumentó que la información no se pierde de la memoria completamente, como asumiría la teoría del desuso, si no que se encuentra menos accesible y puede ser recuperada en determinadas circunstancias. Y por último, hizo referencia a que el olvido no se produce simplemente por el desuso de la información durante un determinado período de tiempo, sino que está determinado por la cantidad de eventos que ocurran en dicho período, siguiendo una relación lineal: a mayor número de eventos (y más similares con el trazo de memoria que se desea recuperar), mayor olvido. Así mismo, McGeoch (1932, 1942) planteó una alternativa a las dos teorías que hasta la fecha predominaban para explicar científicamente el olvido [la teoría de perserveración-consolidación de Müller y Pilzecker (1900) y la ley del desuso propuesta por Thorndike (1914)] , y propuso los cimientos de la versión inicial de lo que más tarde se conocería como la teoría de la interferencia. Básicamente, argumentó que el olvido es una consecuencia de la competición entre trazos de memoria, más que simplemente una pérdida de trazos *per se*. La teoría de McGeoch asume que la memoria es fundamentalmente asociativa, y que el recuerdo está guiado por claves a las que los ítems se encuentran asociados. Como consecuencia de otras experiencias, sin embargo, otras respuestas pueden quedar asociadas a la misma clave. El recuerdo de una determinada respuesta a una determinada clave puede entonces sufrir de la competición con otras respuestas asociadas a esa misma clave. Dicha competición, de acuerdo con McGeoch, produce olvido a través de lo que él llama inhibición reproductiva (precedente teórico de lo que hoy conocemos como inhibición de la recuperación). La recuperación de la respuesta sería bloqueada o inhibida por el recuerdo de otras respuestas asociadas con esa misma clave. Estas otras respuestas podrían haber sido aprendidas antes o después de la respuesta en cuestión (interferencia proactiva y retroactiva, respectivamente). Además, proponía que esta interferencia varía en función de la similitud entre los episodios de aprendizaje. El trabajo y la propuesta de McGeoch estuvieron sujetos a décadas de investigación empírica y análisis teóricos, dando como resultado una gran cantidad de hallazgos y el desarrollo de la teoría de la interferencia. Este marco teórico, modificado y pulido durante las siguientes décadas, es considerado por muchos autores la formulación teórica más significativa y sistemática en el campo del aprendizaje y la memoria humana (para un resumen, véase Bjork, 1992; Bjork, Bjork y Anderson, 1998).

En esta línea, el trabajo de Melton e Irwin (1940) sobre la hipótesis del desaprendizaje y la recuperación espontánea resultó de gran relevancia para explicar la interferencia retroactiva. Según su hipótesis, el olvido se produce debido a que la asociación entre un estímulo y un trazo de memoria se debilita cada vez que otro trazo erróneo pero relacionado (por ejemplo una antigua contraseña) se recupera. La propuesta del desaprendizaje, que era análoga a la planteada en la literatura sobre aprendizaje animal (las respuestas aprendidas que no se refuerzan, van quedado gradualmente extinguidas), llevaba de la mano un segundo efecto: la respuesta desaprendida, con el tiempo, mostraría recuperación espontánea (recordando, nuevamente, a las teorías sobre aprendizaje animal).

Una teoría sobre el olvido y la interferencia que ha sido a menudo pasada por alto es la teoría sobre la inhibición recíproca de Osgood (1996, 1948). Según esta teoría, el fortalecimiento de la asociación entre un estímulo y una respuesta también fortalece una asociación inhibitoria entre el estímulo y respuestas semánticas antagonistas. El interés de esta teoría reside en que fue, quizás, la primera teoría sobre la interferencia retroactiva que atribuyó el olvido a un mecanismo inhibitorio (Anderson, 2003). Desde este punto de vista, el peor recuerdo era una consecuencia directa de inhibir respuestas potencialmente intrusivas.

Más tarde, Postman, Stark, y Fraser (1968) plantearon la hipótesis de la *supresión del set de respuesta* para explicar los efectos de la interferencia retroactiva. Propusieron que ésta es causada por una supresión activa de ítems aprendidos previamente que ya no eran relevantes, y que esta supresión ocurriría durante la adquisición de nuevos ítems como un "mecanismo selector". Como indica Anderson (2003), esta propuesta puede contemplarse como un ejemplo de la teoría sobre el control inhibitorio vigente hoy día: esta hipótesis atribuye el olvido a un mecanismo que suprime directamente las representaciones que ya no son necesarias, ayudando al sistema a seleccionar respuestas más recientes y apropiadas al contexto.

En el siguiente apartado se describirá el giro que dio la investigación sobre la interferencia y el olvido, al proponerse que éste podría resultar como consecuencia de un mecanismo de control executivo (la inhibición) que se pone en marcha para resolver una situación de interferencia.

1.2. Olvido incidental: interferencia e inhibición

Entender las causas de la interferencia y el mecanismo o mecanismos por los que ésta causa olvido ha sido una meta central en la investigación en el estudio de la memoria (Anderson y Neely, 1996). Una buena parte del pensamiento moderno sobre las causas de la interferencia ha sido modelado por el abundante cuerpo de investigación llevado a cabo durante lo que se conoce como "la era clásica de la interferencia" (que aproximadamente comprende las décadas entre 1900 y 1970). De hecho, la idea básica de que el olvido surge de la competición de los ítems de memoria por una clave de recuerdo compartida se originó durante este período.

Desde el punto de vista del enfoque clásico de la interferencia comentado en el apartado anterior, la propuesta de Müller y Pilzecker (1900) ofrece una explicación satisfactoria sobre el fenómeno del olvido: no es el paso del tiempo lo que dificulta los recuerdos, como podría parecer de manera intuitiva, sino los cambios que correlacionan con el tiempo, como el almacenamiento de nuevas experiencias en la memoria; en particular, experiencias similares. Así, el olvido no sería consecuencia del decaimiento de los recuerdos, sino del constante almacenamiento de nuevos trazos de memoria, y de la dificultad a la hora de recuperar y diferenciar trazos similares. Hacia finales de 1960, el papel de la interferencia proactiva y retroactiva había quedado patente (Bjork, 1992), y existía una respuesta común al interrogante de por qué olvidamos: el acceso a la información en la memoria está sujeto a la interferencia de información que compite, es decir, está sujeto a procesos de interferencia. Hoy, tras cientos de artículos de investigación sobre este asunto, existe poca duda de que la interferencia es una poderosa causa de olvido.

Sin embargo, la forma en la que la interferencia causa el olvido sí ha sido cuestionada y revisada. El enfoque más reciente sobre el olvido (en el que se encuadra la presente investigación) se centra en explicar cómo situaciones de interferencia pueden dar lugar al olvido, y enfatiza el mecanismo cognitivo por el que ésta es resuelta. Desde este punto de vista, no todos los tipos de olvido pueden verse como un proceso pasivo resultado de la interferencia, ya que algunos pueden reflejar el resultado de procesos activos de resolución de la interferencia (Anderson, 2003). La idea central de esta teoría propone que la competición que se crea entre representaciones de memoria en situaciones de interferencia también sería resuelta gracias a mecanismos de control inhibitorio que, en este caso, debilitan las representaciones de los competidores, reduciendo su interferencia y permitiendo así ejercer control sobre la recuperación (para revisiones, véase Anderson, 2003; Levy y Anderson, 2002). Desde esta perspectiva, la recuperación de recuerdos supone una situación especial que requiere procesos de control ejecutivo: por ello, sería el mecanismo de control que resuelve la interferencia y no la competición por sí misma, el que puede causar algunos tipos de olvido.

Anderson y Neely (1996) han destacado cómo la investigación sobre ciertos fenómenos relacionados con la interferencia ha influido en los estudios y las interpretaciones más recientes del olvido. En concreto, el desarrollo de esta nueva perspectiva sobre el olvido se originó con los estudios sobre la interferencia de salida[1] y otros fenómenos de olvido en presencia de interferencia, que resaltaron que el acto en sí de recordar podría ser una fuente de olvido en la memoria episódica. Uno de estos efectos se produce por la presentación de un conjunto parcial de claves. Por ejemplo, Slamecka (1968) hizo un estudio en que los participantes debían estudiar varias listas compuestas por palabras de varias categorías semánticas (por ejemplo, árboles y pájaros). En la prueba de memoria final, a un grupo de participantes se les proporcionaron algunos de los ítems de cada categoría como claves para recordar el resto de los ítems; a otro grupo no se le proporcionó ninguna clave. Los resultados mostraron que el grupo de participantes que había recibido las claves recordó menos información que el grupo que no había recibido ninguna clave. Es decir, el recuerdo de los participantes a los que se les presentó parte de la lista de palabras como pista para recuperar el resto fue inferior al recuerdo de los participantes a los que no se proporcionó ninguna clave. A este efecto de olvido se le conoce como olvido inducido por la presentación de parte de las claves del conjunto, y las primeras

[1] La interferencia de salida se refiere a un tipo de olvido que se produce al generar elementos de una lista, debido a la interferencia que la recuperación de los elementos que se verbalizan en primer lugar produce sobre el recuerdo de los elementos que les suceden (para una revisión, véase Tulvin y Arbuckle, 1963; Anderson y Neely, 1996).

teorías explicativas estaban basadas en procesos de bloqueo (interferencia provocada por las claves proporcionadas).

El papel de la recuperación en la generación del olvido inició una nueva forma de entender cómo la interferencia puede estar relacionada con el olvido, lo que llevó a idear un nuevo procedimiento experimental para probar la idea de que otro mecanismo distinto de la propia interferencia, podría ser el responsable del olvido inducido por la recuperación: el paradigma de práctica en la recuperación (Anderson, Bjork, y Bjork, 1994). En un experimento típico con este procedimiento, los participantes estudian algunos ejemplares de varias categorías (animales y frutas, por ejemplo). En una segunda fase (la fase de práctica en la recuperación) deben practicar el recuerdo de algunas de las palabras aprendidas y llevan a cabo una serie de ensayos de recuperación de la mitad de los ejemplares de la mitad de las categorías. En la tercera fase se lleva a cabo una prueba de memoria de todos los ítems estudiados. Los resultados generalmente encontrados con este tipo de procedimiento son dos: primero, y como es esperable, los ejemplares practicados tienden a recordarse especialmente bien en comparación con los no practicados de categorías no practicadas (condición control). Sin embargo, el hallazgo más interesante tiene que ver con los ítems no practicados pertenecientes a categorías practicadas (ítems irrelevantes en el momento de la práctica en la recuperación): su recuerdo tiende a ser significativamente peor que el de los ítems de control. Este efecto es conocido como "olvido inducido por la recuperación" (OIR) y puede explicarse desde una perspectiva inhibitoria. La idea es que la competición que se crea en la fase de práctica en la recuperación (cuando se activan los ítems irrelevantes pero asociados a la misma clave) se resuelve mediante un mecanismo que actúa inhibiéndolos para ayudar en el acceso a los ítems objetivo que requiere la tarea (Anderson, Bjork, y Bjork, 1994). Así, como consecuencia del despliegue de los procesos inhibitorios en la fase de práctica, los elementos en la memoria que se ven inhibidos se recuerdan peor que los de la condición control en una prueba de memoria posterior, lo que lleva al efecto de OIR.

Aunque la explicación más extendida del efecto de OIR es que éste es producido por un mecanismo inhibitorio (para una revisión véase Storm y Levy, 2012), también se han propuesto otro tipo de explicaciones basadas en procesos asociativos propios de las teorías clásicas de la interferencia (e.g., Raaijmakers y Jakab, 2013). Según la hipótesis asociativa (de bloqueo) más conocida, los recuerdos compiten para el acceso a la consciencia cuando se proporciona una clave que comparten, de manera que se produciría la oclusión de la vía de recuperación de un elemento con su clave asociada (e.g., Raaijmakers y Jakab, 2013; Verde, 2012). Así, al presentar la clave compartida, los elementos más activos tendrían más facilidad de recuperación, mientras que el resto permanecerían inaccesibles. El nivel de interferencia aumentaría a medida que lo hace la fuerza asociativa entre la clave y el competidor, mostrando lo que Anderson y colaboradores (1994) denominan *competición dependiente de la fuerza*. La idea de que este tipo de proceso podría explicar la interferencia fue propuesta por McGeoch (1942). Según la hipótesis del bloqueo el olvido de los ejemplares no practicados de las categorías practicadas se produciría porque las asociaciones con los recuerdos practicados dominan la recuperación.

Aunque en principio las explicaciones asociativas clásicas podrían dar cuenta del efecto de OIR, la evidencia experimental demuestra que este efecto presenta unas propiedades que son difíciles de explicar desde el punto de estas teorías (Anderson, 2003). La investigación sobre el efecto de OIR ha revelado que algunas de sus propiedades apoyan la hipótesis del control inhibitorio y hacen poco plausibles las explicaciones desde las teorías clásicas de la interferencia (para una revisión, véase Anderson, 2003; Murayama, Buchli, Miyatsu, y Storm, 2014).

En primer lugar existen varios trabajos de investigación que han demostrado que el efecto de olvido de los ítems que compiten durante la práctica se observa utilizando en la fase del test claves de recuperación que no habían sido previamente presentadas antes en el experimento (Anderson y Bell, 2001; Anderson, Green, y McCulloch, 2000; Anderson y Spellman, 1995; MacLeod y Saunders, 2005; Radvansky, 1999). Esta propiedad se conoce con el nombre de *independencia de la clave*. Desde el punto de vista de la hipótesis del bloqueo se asume que el fortalecimiento de los ejemplares practicados bloquearía el acceso a los otros ejemplares de la misma categoría. Sin embargo, la evidencia experimental sobre la independencia de la clave apoya la explicación basada en la inhibición y descarta la hipótesis del bloqueo asociativo. En segundo lugar, se sabe que el efecto de OIR está sujeto a la recuperación de los trazos de memoria. Esta segunda cualidad se conoce como *especificidad de la recuperación*, y hace referencia a que, para que se produzca la inhibición y el olvido, es necesario que haya habido intentos de recuperación. Anderson, Bjork y Bjork (2000) llevaron a cabo un relevante estudio en el que manipularon la fase de práctica: la mitad de los participantes realizaba práctica en la recuperación de manera estándar (con la clave de la categoría junto con las dos primeras letras del ejemplar), mientras que la otra recibía re-exposición de claves y ejemplares. Los investigadores hallaron efecto de OIR solamente en el grupo que realizó la práctica en la recuperación con los intentos de recuperar los ejemplares. Desde el punto de vista de la hipótesis del bloqueo, tanto la práctica en la recuperación como la re-exposición o el estudio extra de los ítems debería producir efecto de OIR ya que se fortalecerían los ítems practicados/re-expuestos y producirían bloqueo de los ítems competidores. Sin embargo, desde la hipótesis inhibitoria el efecto sólo debería ocurrir cuando hay intentos de recuperar información, ya que es durante la recuperación cuando se produce competición y la necesidad de activar procesos inhibitorios para reducirla. Otra propiedad del efecto de OIR es la que se conoce como *dependencia de la interferencia*. Mientras que los intentos por recuperar (o la recuperación en sí misma) son necesarias para que se produzca la inhibición, ésta no es suficiente. Así, el efecto de OIR sólo surgirá cuando un trazo de memoria relacionado interfiera con el recuerdo del target y desencadene el control inhibitorio. La cuarta cualidad del efecto de OIR que apoya la explicación inhibitoria es la *independencia de la fuerza*, que hace referencia a que el grado fortalecimiento de los ítems que son practicados no predice la cantidad de efecto de olvido observado. Puesto que se ha demostrado que el olvido se produce incluso en ausencia del fortalecimiento de los ítems practicados (Storm, Bjork, Bjork, y Nestojko, 2006), que según la teoría del bloqueo sería lo que daría lugar al bloqueo de los ítems competidores, una explicación asociativa de esta naturaleza parece explicar poco del efecto. La demostración de estas propiedades en su conjunto hace que la hipótesis inhibitoria sea la que más apoyo ha recibido hasta el momento (véase Murayama et al., 2014, para un reciente meta-análisis que favorece una explicación inhibitoria del efecto).

En resumen, desde una perspectiva inhibitoria el olvido inducido por la recuperación o los efectos de la presentación parcial de claves reflejarían la consecuencia de un mecanismo de resolución de la interferencia durante la recuperación. Este mecanismo se pondría en marcha de forma incidental cuando se pretende recuperar algún recuerdo de manera selectiva de entre alternativas que compiten con él. Sin embargo, el control inhibitorio de la memoria también se ha propuesto en situaciones donde existe la intención explícita de prevenir que un recuerdo específico se recupere y acceda a la consciencia, y en situaciones en las que se requiere deshacerse de recuerdos no deseados o no apropiados. Estas situaciones han sido estudiadas en el laboratorio con el paradigma de Think-no think (e.g., Anderson y Green, 2001; Anderson y Huddleston, 2011; Anderson y Levy, 2009; Gagnepain, Henson, y Anderson, 2014; Hanslmayr, Leipold, Pastötter, y Bäuml, 2009**;** Joormann, Hertel, LeMoult, y Gotlib, 2009; Küpper, Benoit, Dalgleish, y Anderson, 2014) y el paradigma de Olvido Dirigido (e.g., Basden y Basden, 1998; Bäuml, Pastötter, y Hanslmayr, 2010; Bjork, 1970; Bjork, LaBerge, y LeGrand, 1968; Fawcett y Taylor, 2008; Hanslmayr et al., 2012;

Sahakyan y Goodmon, 2007), respectivamente, que revisaremos en las siguientes secciones.

1.3. Olvido motivado

Los ejemplos descritos al comienzo de este trabajo ilustran la importancia de poder ejercer algún control sobre nuestra memoria en situaciones en las que sería preferible no recordar. Parece, por tanto, que en ocasiones el olvido no es accidental sino que es el efecto deseado, producido por la necesidad de olvidar eventos desagradables o información no deseada o desactualizada. De acuerdo con Sahakyan y Goodmon (2010), cualquier sistema eficiente de memoria debe ser capaz de identificar algunos recuerdos como más relevantes que otros, y debe ser capaz de reducir la accesibilidad de la información no deseada. Resulta pertinente, por tanto, preguntarse cómo las personas consiguen olvidar cuando eso es precisamente lo que desean.

En principio, podría conseguirse reducir el recuerdo de información no deseada manipulando cualquier fase del procesamiento de la información. La manera más simple de evitar llegar a recordar algo más tarde es limitar su codificación. Podríamos mirar para otro lado o centrar nuestra atención sólo en los aspectos que nos interesan de la situación y, en definitiva, no codificar de manera adecuada la información. También podríamos cambiar de contexto para que se produzca un cambio en él entre la codificación y la recuperación. Es decir, si el evento ya ha sido codificado, podríamos evitar un encuentro con los estímulos asociados a él (por ejemplo, mudarnos de apartamento o de ciudad puede ayudarnos a no recordar eventos no deseados). Por último, y más importante para el objetivo del presente trabajo, podríamos tratar de hacer menos accesible en el futuro la información que deseamos olvidar. Incluso aunque esa información no tenga una valencia emocional negativa, olvidarla podría ayudar a recordar mejor otras cosas. Consideremos el ejemplo de Bjork (1970) sobre el trabajo habitual de un camarero. Durante una mañana normal, un camarero cualquiera de una cafetería cualquiera puede recibir decenas de pedidos de desayunos. Pero una vez terminado de servir uno, debe olvidarse de él y pasar al siguiente pedido. De no ser así el pedido anterior sólo molestaría y crearía interferencia en la preparación del siguiente. De igual forma, casi siempre quedo fascinada con la eficacia de la dependienta de la copistería de la facultad donde trabajo. Es capaz de memorizar varios pedidos de varias personas, siendo cada pedido un código de una, dos, tres y hasta cuatro cifras. Lo que más me asombra es cómo no confunde un pedido con el siguiente. Claramente, cuando ya ha atendido a una persona, se deshace de sus códigos, para que éstos no le impidan o le interfieran en la memorización del siguiente. Algo así como si presionara un botón de *reset* cada vez que termina un pedido para comenzar el siguiente. Muchos estudiantes parecen hacer algo similar cuando intentan "vaciar" su cabeza al acabar de hacer un examen, para así *deshacerse* de lo que han estudiado y "tener sitio" para la nueva información. Aparentemente, estos ejemplos sugieren que somos capaces de olvidar cierta información. Conocer cómo esto es posible ha sido (y continúa siendo) un asunto de gran relevancia para los investigadores de la memoria y será tratado con detenimiento en el presente trabajo. Durante las últimas décadas, una gran parte del estudio científico sobre el olvido ha dedicado sus recursos a estudiar cómo se puede olvidar intencionalmente información que ya ha sido codificada y está en la memoria a largo plazo.

Bjork (1989) describe el olvido motivado como un proceso funcional que permite al sistema de memoria actualizarse a sí mismo. En el laboratorio el olvido motivado ha sido estudiado con distintos procedimientos experimentales. En este apartado y en el siguiente se resumen algunos de los paradigmas experimentales más importantes en este sentido: el paradigma Think-No think (TNT, Anderson y Green, 2001; Anderson y Huddleston, 2011; Anderson y Levy, 2009; Gagnepain, Henson, y Anderson, 2014; Hanslmayr, Leipold, Pastötter, y Bäuml, 2009**;** Joormann, Hertel, LeMoult, y Gotlib, 2009; Küpper, Benoit, Dalgleish, y Anderson, 2014) y, más relevante para el presente trabajo, el paradigma de Olvido Dirigido (OD, Basden y Basden, 1998; Bäuml et al., 2010; Bjork, 1970; Bjork et al., 1968; Fawcett y Taylor, 2008; Hanslmayr et al., 2012; Sahakyan y Goodmon, 2007), que será ampliamente descrito en el siguiente apartado.

Para estudiar la capacidad de suprimir la recuperación de recuerdos, Anderson y Green (2001) diseñaron la tarea Think/No think (TNT), que sigue un procedimiento similar a la tarea Go/no-go utilizada para investigar la supresión de respuestas motoras. En esta tarea se presenta a los participantes un estímulo al que deben dar una respuesta motora lo más rápido posible. En una minoría de los ensayos se presenta un estímulo ‘no-go’, para el que los sujetos deben no dar la respuesta. Por ejemplo, se presentan una serie de letras, para las que los participantes deben responder pulsando una tecla, excepto para la letra ‘X’, en respuesta a la cual deben suprimir su respuesta. El porcentaje de ensayos no-go superados correctamente se toma como medida de la habilidad de control inhibitorio. Para comprobar si detener el acceso a los recuerdos también conlleva control inhibitorio, Anderson y Green (2001) adaptaron este procedimiento para crear el paradigma TNT, en el que los participantes deben detener el acto cognitivo de recuperar información de la memoria a largo plazo. En una tarea TNT típica los participantes estudian pares de palabras durante una primera fase. Durante la segunda fase deben recuperar la palabra asociada a algunos de ítems que estudiaron al ver el primer miembro del par (ensayos *think*), así como evitar recuperar la palabra asociada a otros ítems y que también estudiaron (ensayos *no-think*). Un tercer tipo de ítems sirve como condición control y nunca se presentan como clave durante la segunda fase. La idea que subyace a la tarea es que la inhibición actuará para detener la recuperación haciendo las representaciones de memoria implicadas cada vez menos accesibles. Para estimar el grado de inhibición de la memoria, en una tercera fase se mide el recuerdo de todos los ítems estudiados en el experimento. Los resultados normalmente encontrados con esta tarea muestran cómo el control sobre la memoria modula el posterior recuerdo (Anderson y Green, 2001; Anderson y Huddleston, 2011; Anderson y Levy, 2009; Anderson et al., 2004; Bergström, de Fockert, y Richardson-Klavehn, 2009). Así, se observan dos efectos en función de las condiciones: 1) Un efecto de facilitación de los ítems de los ensayos *think* y que puede explicarse por el incremento en activación de sus representaciones a lo largo de los ensayos de entrenamiento y, lo que es más importante aquí, 2) una clara tendencia a olvidar los ítems de los ensayos *no-think* en comparación con los de la condición control; un efecto que se interpreta en términos inhibitorios. Anderson y colaboradores (2004, véase Anderson y Hanslmayr, 2014 para una revisión) observaron, mediante el uso de técnicas de neuroimagen, que ciertas regiones cerebrales relacionadas con una red de control ejecutivo (fundamentalmente en el córtex prefrontal lateral), ejercen su acción sobre el hipocampo para prevenir el recuerdo.

Por otro lado, Bjork y colaboradores (1968) plantearon un procedimiento experimental para comprobar si los participantes podían, de manera intencional, deshacerse de la influencia de la interferencia proactiva, olvidando información episódica ya almacenada en la memoria. Sentaron así las bases de lo que se conoce como el procedimiento de olvido dirigido, con sus variantes del método del ítem y de la lista, ampliamente utilizados en las décadas siguientes. Dado que el olvido dirigido será el fenómeno objeto de estudio en la fase empírica de este trabajo, estos procedimientos serán descritos detalladamente en el siguiente apartado.

2. Olvido dirigido

Los distintos procedimientos de OD incluyen instrucciones a los participantes para que olviden cierto material estudiado recientemente, si bien pueden distinguirse dos paradigmas experimentales diferentes cuyos efectos de olvido se han interpretado tradicionalmente de formas distintas (para revisiones, véase Bjork, 1998 ó MacLeod, 1998).

En una tarea de OD con el *método del ítem*, los participantes estudian una serie de ítems. Tras la presentación de cada ítem, reciben la instrucción o bien de recordarlo, o bien de olvidarlo. Al final de la fase de estudio, los participantes realizan una prueba de memoria de todos los ítems presentados (los que tenían que ser recordados y los que tenían que ser olvidados). Los resultados de estos estudios muestran un menor recuerdo de los ítems asociados a la orden "olvidar". Este efecto de olvido se ha encontrado tanto en test de memoria explícita como implícita (Basden y Basden, 1998; MacLeod y Daniels, 2000), y tanto en pruebas de recuerdo libre como de reconocimiento (e.g., Basden y Basden, 1996; Basden, Basden, y Gargano, 1993). El hecho de que se haya encontrado el efecto de OD con el método del ítem en test de reconocimiento propició en un primer momento que los investigadores abogasen por explicaciones relacionadas con la codificación, ya que si estuviese asociado a procesos ligados a la recuperación tal como la inhibición, debería reducir sólo temporalmente la accesibilidad a los ítems afectados, de manera que debería ser posible liberar estos ítems de la inhibición mediante su presentación en pruebas de reconocimiento (Bjork, 1989). Tradicionalmente este efecto ha sido atribuido al repaso selectivo, por el cual los ítems a recordar serían repasados activamente, de manera que los ítems a olvidar ya no se seguirían procesando y serían objeto de un olvido pasivo.

La explicación del repaso selectivo sobre efecto de OD con el método del ítem ha sido la más común entre los investigadores hasta hace relativamente poco tiempo (Bjork, 1989). No obstante hoy día existen nuevas evidencias tanto comportamentales como neurales que indican que posiblemente se esté ejerciendo un control inhibitorio sobre la codificación episódica. Fawcett y Taylor (2008) pusieron a prueba la hipótesis de que el efecto de OD usando el procedimiento del ítem podría deberse a un mecanismo inhibitorio (Hasher y Zacks, 1988; Zacks y Hasher, 1994; no obstante, véase MacLeod, Dodd, Sheard, Wilson, y Bibi, 2003). De acuerdo con la explicación del repaso selectivo de los ítems a recordar, se debería producir más carga cognitiva en los ensayos 'recordar', cuando los participantes estarían repasando la información, que en los ensayos 'olvidar'. En estos últimos, los participantes simplemente no tendrían que repasar los ítems a olvidar, y dejarlos pasivamente decaer de su memoria de trabajo. Estos investigadores pusieron a prueba esta hipótesis en dos experimentos usando el paradigma de OD con el método del ítem junto con una tarea secundaria que cursaba justo después de que la instrucción de 'recordar' o de 'olvidar' fuera dada, y en las que se medía el tiempo de reacción. Los investigadores mostraron en ambos experimentos que el tiempo de reacción en la tarea secundaria durante los ensayos 'olvidar' fue mayor que durante los ensayos 'recordar'. Estos resultados fueron replicados por los mismos investigadores (Fawcett y Taylor, 2010) en otros dos experimentos usando el procedimiento de OD con el método del ítem combinado junto con tareas secundarias que medían la inhibición llevada a cabo en tareas de stop-signal (Experimentos 1 y 2) y la inhibición de retorno (Experimento 2). Los autores mostraron que, tras los ensayos de 'olvidar' los participantes realizaban mejor la tarea de stop-signal, y además las respuestas eran más lentas. Por otro lado, también encontraron un efecto de inhibición de retorno significativo tras los ensayos de 'olvidar', pero no tras los ensayos de 'recordar'. Estos resultados comportamentales apuntan a que un proceso activo (probablemente de naturaleza inhibitoria) podría ser el responsable del efecto de OD con el método del ítem (Zacks, Radvansky, y Hasher, 1996). Por otro lado, en los últimos años también se han acumulado evidencias neuroanatómicas (usando fMRI) que apuntan a que el efecto de OD con el procedimiento del ítem conlleva un proceso activo que inhibe la codificación que está en marcha. Wylie, Foxe, y Taylor (2008) encontraron que, el olvido intencional (OD con método del ítem), comparado con el olvido incidental, estaba asociado con un incremento de la actividad en el hipocampo y en el giro superior frontal. Por otro lado, cuando se comparaba con el recuerdo intencional, el olvido intencional se asociaba con actividad en el giro medial frontal, el giro medial temporal, el giro parahipocampal, y el giro cingulado. Comprobaron así que el olvido intencional dependía de estructuras neurales diferentes de las que se encuentran involucradas tanto en el olvido incidental como en el recuerdo intencional. Rizzio y Dennis (2013) también encontraron una disociación entre zonas cerebrales involucradas en el olvido incidental y en el olvido intencional. El olvido intencional estaba asociado a activación en regiones cerebrales relacionadas con el control inhibitorio (lóbulo parietal superior derecho, que ha sido propuesto que es una zona que contribuye a procesos de control cognitivo y recursos de redirección intencional de la atención); mientras que el olvido incidental estaba asociado a regiones relacionadas con la codificación (giro frontal inferior izquierdo, giro frontal superior izquierdo, y lóbulo parietal superior izquierdo). También se han llevado a cabo estudios utilizando la metodología de los potenciales evocados que, junto con los datos de resonancia magnética funcional, apuntan a que el olvido dirigido que se produce en el método del ítem involucra una red que abarca desde zonas prefrontales a zonas del lóbulo temporal medial, con la función de interrumpir o suprimir los procesos de codificación episódica. Ludowig y colaboradores, (2010), usando potenciales evocados de forma intracraneal, encontraron que las instrucciones para olvidar (cuando realmente causaban olvido) provocaron un decremento en la negatividad en el hipocampo anterior, comparado con las instrucciones de recordar que también causaron olvido (olvido incidental). A destacar, una mayor negatividad en el hipocampo a los 500 milisegundos aproximadamente se relacionaba con una correcta codificación. Paz-Caballero (2004) también encontró una positividad prefrontal prolongada tras la instrucción de olvidar, y Hauswald, Schulz, Iordanov, y Kissler (2011) localizaron esta positividad en el córtex prefrontal dorsolateral. Todos estos estudios cuestionan la visión pasiva sobre el olvido dirigido con el método del ítem que ha imperado en las últimas décadas.

Por su parte, en un experimento estándar de OD con el *método de la lista* los participantes estudian dos listas de palabras en orden consecutivo. Tras estudiar la primera lista, a la mitad de los participantes se les pide que la olviden, con el pretexto de que esta lista era de prueba, o de que el experimentador se ha confundido de lista, y que no se les va a realizar una prueba de memoria sobre ella, mientras que a la otra mitad se les dice que traten mantenerla en su memoria. A continuación ambos grupos estudian una segunda lista. Por último, todos los participantes realizan una prueba de memoria sobre los ítems de ambas listas. Los resultados normalmente encontrados con este paradigma son, por un lado, un peor recuerdo de las palabras de la primera lista por parte del grupo que recibió la orden de olvidar, en comparación con el que no la recibió (efecto de coste). Por otro, es frecuente encontrar un mejor recuerdo de las palabras de la segunda en el grupo que olvidó la Lista 1 (efecto de facilitación).

De acuerdo con Bjork (1998), los diferentes procedimientos de olvido dirigido se deben considerar como un conjunto de herramientas sobre las que se puede escoger según el problema de investigación que se plantee. Así por ejemplo si el objetivo es comprender la regulación inhibitoria de la memoria de trabajo (Hasher y Zacks, 1988; Zacks y Hasher, 1994), y cómo estos procesos evolucionan y cambian con la edad, la mejor elección sería el procedimiento del ítem. Si, por otro lado, el objetivo es investigar sobre la interferencia y los procesos inhibitorios en el sistema de actualización de la memoria episódica, el procedimiento de la lista sería el adecuado. Los objetivos de investigación de este trabajo requieren el uso (y la modificación) del olvido dirigido con el método de la lista.

2.1. Teorías explicativas del OD con el método de la lista. Controversia sobre inhibición y contexto.

Cabe mencionar que las primeras explicaciones sobre los efectos observados en OD con el método de la lista no fueron en términos de inhibición o supresión. En sus inicios el modelo de Bjork (1970, 1972) explicaba los efectos de olvido dirigido en términos de dos acciones tomadas por los sujetos en respuesta a la instrucción de olvidar: focalizar la atención en los ítems relacionados con la clave de recordar y, de alguna forma, segregar y diferenciar entre los ítems a recordar y los ítems a olvidar. No obstante, muy pronto el propio autor de esta hipótesis, junto con otros colaboradores, pusieron en duda esta explicación sobre la base de un buen número de evidencias experimentales que parecían apuntar a que algún tipo de proceso activo de olvido debería desencadenarse ante la instrucción de olvidar (Bjork, 1989; Bjork, 1998; Bjork, Bjork y Glenberg, 1973, citado en Bjork, 1998; Weiner y Reed, 1969). De esta forma se propuso entonces que algún proceso activo, probablemente de tipo inhibitorio, podría dar cuenta de los resultados obtenidos hasta la fecha.

Así, más adelante, y gracias al trabajo de Geiselman, Bjork y Fishman, (1983) se propuso formalmente que la inhibición de la recuperación jugaría un papel fundamental en la producción del patrón de resultados del olvido dirigido, y se descartó la explicación de los dos procesos de segregación y repaso selectivo. En este estudio investigaron los efectos de la instrucción de olvidar sobre ítems aprendidos de manera incidental. En el experimento se presentó a los sujetos una lista con dos tipos diferentes de ítems: unos que debían aprender para realizar un test de memoria después, y otros ítems sobre los que debían juzgar su *agradabilidad*, y que los participantes aprenderían de manera incidental. Estos dos tipos de ítems se presentaban de forma auditiva y de manera alternada, precedidos por su correspondiente instrucción (‘aprender’ o ‘juzgar’). A mitad de la lista los participantes recibían una instrucción de que los ítems que habían aprendido hasta ese momento eran sólo para practicar, y que debían olvidarlos (la instrucción de olvidar), o que los ítems que habían aprendido hasta entonces formaban la primera parte de la lista, y que debían recordarlos (la instrucción de recordar). Tras la presentación de la segunda mitad de la lista todos los participantes se enfrentaban a un test de recuerdo libre, y se les pedía que recuperasen todas las palabras que habían aprendido a lo largo de todo el experimento: tanto las palabras marcadas con la instrucción de 'aprender', como por la instrucción de 'juzgar', y tanto las palabras de la primera mitad de la lista como las de la segunda mitad. Para los ítems marcados con la instrucción de 'aprender' los resultados mostraron efecto de olvido dirigido esperado. No obstante, lo más llamativo fue que para los ítems aprendidos de manera incidental (los marcados con la instrucción de 'juzgar') también se observó el efecto de olvido dirigido. De esta forma, aunque los resultados obtenidos con los ítems aprendidos de manera intencional se podían explicar en base a la hipótesis del repaso selectivo) de Bjork (1970, 1972), el efecto de olvido dirigido obtenido con los ítems aprendidos de manera incidental no se podía atribuir al repaso selectivo de éstos, ya que no se espera que los participantes repasen ítems aprendidos de forma incidental. Así, esta explicación resultó insuficiente para explicar la presencia del efecto de OD en aprendizaje incidental (Geiselman et al., 1983; Sahakyan y Delaney, 2005, 2010; Sahakyan, Delaney y Goodmon, 2008). De esta manera, los autores propusieron que ambos tipos de ítems (los aprendidos de manera intencional e incidental) habrían sufrido el mismo tipo de proceso, presumiblemente de tipo inhibitorio. Surgió así la propuesta inhibitoria para explicar los resultados obtenidos con el olvido dirigido: cuando los participantes recibían la instrucción de olvidar la información aprendida hasta el momento y se les presentaba información nueva que debían aprender, se iniciaría un proceso de inhibición de la posterior recuperación de los ítems a olvidar. Además, como la información a olvidar no se encontraría disponible para su recuperación, ésta no crearía interferencia para recuperar a información a recordar (y explicaría así el mejor recuerdo de la lista de en la condición de olvidar).

Así, desde este punto de vista, el efecto de olvido se debería a la inhibición temporal de la información de la Lista 1 en respuesta a la instrucción de olvidar ante una situación potencial de interferencia mutua entre las dos listas aprendidas. Un gran número de evidencia experimental tanto comportamental como neurológica puede ser interpretada desde la hipótesis inhibitoria (Bjork, 1989; Bjork, Bjork, y Anderson, 1998; Conway, Harries, Noyes, Ràcsmany, y Frankish, 2000; Hanslmayr et al., 2012; Soriano y Bajo, 2007). Por ejemplo, de manera importante, no se ha encontrado efecto de OD en pacientes con daño frontal, que se piensa que sufren de un déficit inhibitorio (Conway y Fthenaki, 2003; Harnishfeger y Pope, 1996), ni tampoco en participantes sanos mientras realizan tareas secundarias demandantes de recursos cognitivos durante el aprendizaje de la segunda lista (Conway et al., 2000; Soriano y Bajo, 2007). Por otro lado, la investigación sobre los correlatos neurofisiológicos y de neuroimagen usando el procedimiento de olvido dirigido con el método de la lista indica que las instrucciones de olvidar desencadenan un proceso activo que interrumpe la actividad de la memoria (para una revisión, véase Anderson y Hanslmayr, 2014). Por ejemplo, recientemente dos estudios han investigado los mecanismos neuropsicológicos del olvido dirigido mediante la exploración de las oscilaciones cerebrales. La lógica que subyace a este tipo de investigaciones es que la formación de recuerdos se encuentra típicamente acompañada por un incremento de la sincronía de larga escala, un marcador neural que se piensa que refleja una modulación positiva u optimización de la plasticidad sináptica (Fell y Axmacher, 2011; Fell et al., 2001; Weiss y Rappelsberger, 2000). Bäuml, Hanslmayr, Pastötter, y Klimesch, (2008) midieron las oscilaciones cerebrales de participantes en una tarea de olvido dirigido durante el aprendizaje de la Lista 2 y encontraron que el efecto de olvido de la Lista 1 coincidía con una reducción en el acoplamiento de fase en la banda de frecuencia alta de alfa, indicando que la instrucción de olvidar lleva a menor sincronía en las estructuras cerebrales relevantes. Además, encontraron que las diferencias individuales en esta activación predecían el olvido de los ítems marcados con la instrucción de olvidar. Este último resultado sugiere que un descenso de la sincronía entre redes neurales parece señalar la interrupción de procesos neurales que mejoran la retención. Hanslmayr y colaboradores (2012) replicaron estos resultados en un estudio multimodal empleando electroencefalografía (EEG) y resonancia magnética funcional (fMRI, por sus siglas en inglés). En un primer experimento encontraron que la instrucción de olvidar inducía una reducción en la sincronización de fase de larga escala, junto con un incremento de la señal BOLD en el córtex dorsolateral prefrontal izquierdo (DLPFC). El incremento de la señal BOLD en el DLPFC estaba correlacionado con un decremento en la sincronía neural, específicamente cuando se les pedía a los sujetos que olvidasen la

Lista 1. En un segundo experimento encontraron que la estimulación directa del DLPFC con estimulación magnética transcraneal repetitiva (rTMS, por sus siglas en inglés), apoya selectivamente el olvido voluntario y la desincronización de fase, dando evidencia del papel causal del DLPFC en olvido motivado y sincronía de fase. Es decir, encontraron que estimulando el DLPFC izquierdo con rTMS se reducía la sincronía neural, incrementando significativamente el efecto de olvido dirigido. Estos resultados sugieren que la sincronía neural regulada al nivel prefrontal refleja un proceso de control activo en memoria. Estos resultados de aumento de la activación del DLPFC junto con el decremento de la sincronía neural sugieren que un proceso de control activo contribuye al olvido dirigido.

Como mencionamos anteriormente, se ha propuesto que el efecto beneficioso de la instrucción sobre la Lista 2 en el grupo que recibe la instrucción de olvidar se debe a la reducción de la interferencia proactiva como consecuencia de la inhibición de la Lista 1. No obstante, aunque esta ha sido una explicación muy frecuente, estudios recientes muestran que el olvido de la Lista 1 y el beneficio de la Lista 2 no se deben a un solo mecanismo. En primer lugar, se ha observado que el olvido de la Lista 1 y el beneficio de la Lista 2 no siempre se encuentran correlacionados (Bäuml et al., 2008; Conway et al, 2000; Sahakyan y Goodmon, 2007). En segundo lugar, el olvido de la Lista 1 puede ser modulado independientemente del beneficio de la Lista 2 (Hanslmayer et al., 2012; Pastötter y Bäuml, 2010). Y en tercer lugar, mientras que todos los ítems de la Lista 1 sufren el olvido, independientemente de su posición serial, el beneficio de la Lista 2 parece estar relacionado solamente con los primeros ítems de la lista (Pastötter y Bäuml, 2010).

Más recientemente Sahakyan y Kelly (2002) plantearon una nueva teoría que proponía que el efecto de coste del olvido dirigido podía ser explicado en términos de cambio de contexto mental. Su teoría se encuentra influida por los modelos formales de memoria episódica que proponen que las personas, durante el aprendizaje, codifican tanto el contenido del ítem como varias características contextuales o atributos que se encuentran presentes en el contexto actual (e.g. Anderson y Bower, 1972; Estes, 1955; Gillund y Shiffrin, 1984; Hintzman, 1988; Howard y Kahana, 2002; Mensink y Raaijmakers, 1988; Tulving; 1983). Esta hipótesis propone que la instrucción para olvidar la Lista 1 genera un cambio en el contexto mental de los participantes. De esta forma, ante la instrucción de olvidar, los participantes llevarían a cabo un cambio de contexto mental, probablemente pensando en algo diferente y no relacionado con el experimento o la lista que acaban de aprender, codificando, de esta forma, la Lista 1 y la Lista 2 como eventos separados y diferentes. La segunda lista sería entonces codificada con nuevas claves contextuales, que quedarían activas durante la prueba de recuerdo. El coste del OD ocurriría porque el contexto durante el recuerdo es más similar al contexto en que la Lista 2 se codificó que el contexto de la Lista 1. En cuanto al efecto de beneficio de la Lista 2, originalmente estos autores lo atribuyeron a la reducción de la interferencia proactiva gracias a la diferenciación contextual. Sin embargo, en una reformulación de su teoría sobre los efectos del olvido dirigido, si bien continúan dando importancia al efecto de la reducción de la interferencia proactiva, proponen que este efecto de beneficio podría deberse a los cambios en la estrategia de codificación que llevan a cabo los participantes tras haber recibido la instrucción de olvidar la Lista 1 (Sahakyan, Delaney, Foster, y Abushanab, 2013). Sahakyan y Kelley (2002) mostraron, en dos experimentos, el mismo grado de coste y de beneficio que en una tarea típica de OD, tan sólo dando instrucciones a los participantes de modificar el contexto mental. Estos autores han propuesto un paradigma de cambio de contexto mental/distracción, en el que, después de que aprendan la Lista 1, se pide a los participantes que generen pensamientos diferentes a la tarea que están realizando, con el fin de examinar el efecto que ese cambio de contexto mental ejerce en el recuerdo. Tareas como imaginar ser invisible (Sahakyan y Kelley, 2002) pensar sobre la casa de la niñez (Delaney, Sahakyan, Kelley, y Zimmerman, 2010; Sahakyan y Delaney, 2003; Sahakyan y Kelley, 2002), o imaginar unas vacaciones (Delaney et al., 2010) han demostrado crear el mismo efecto de olvido que la tarea de olvido dirigido.

Tanto la hipótesis sobre inhibitoria como la hipótesis del cambio de contexto mental atribuyen los dos efectos de dar instrucciones de olvido (el peor recuerdo de la Lista 1 y el beneficio de la Lista 2) a un solo mecanismo. Sin embargo, también se han tenido en cuenta explicaciones que atribuyen ambos efectos a dos mecanismos diferentes: el olvido de la Lista 1 estaría causado bien por mecanismos inhibitorios o por un cambio de contexto mental, mientras que el beneficio de la Lista 2 reflejaría, en parte, una mejora en la codificación de la información (Pastötter, Kliegl, y Bäuml, 2012; Sahakyan y Delaney, 2003).

Algunos autores también han esbozado la posibilidad de tomar una postura conciliadora que defendería el hecho de que el efecto de olvido observado con el método de la lista pueda estar mediado por diferentes mecanismos en diferentes situaciones, o que incluso diferentes individuos empleen distintas estrategias para enfrentarse de manera exitosa a la tarea (e.g., Kliegl et al., 2013; para un argumento similar con el procedimiento de Think/no-think, véase Anderson y Levy, 2008).

Finalmente, cabría destacar el hecho de que la explicación del efecto de olvido que propone la hipótesis del cambio de contexto mental (Sahakyan y Kelley, 2002; Sahakyan et al., 2013) no contradice a una posible explicación inhibitoria. El hecho de que una instrucción de cambio de contexto mental produzca el mismo efecto de coste que una instrucción de olvidar (Delaney et al., 2010; Pastötter y Bäuml, 2007; Pastötter, Bäuml, y Hanslmayr, 2008; Sahakyan y Delaney, 2003; Sahakyan y Kelley, 2002), demuestra que el cambio de contexto es una poderosa herramienta para olvidar información, pero no elimina la posibilidad de que procesos inhibitorios se desencadenen en respuesta a la instrucción de olvidar.

Como muestran los estudios sobre correlatos cerebrales, aunque las instrucciones de olvido dirigido y las instrucciones de cambio de contexto lleven a un efecto de olvido, éstas desencadenan respuestas neurales diferentes. La investigación sobre oscilaciones cerebrales ha encontrado que en condiciones donde el contexto permanece constante durante el estudio de las listas 1 y 2, el poder de theta y alfa muestran un incremento. Sin embargo, cuando se produce un cambio de contexto mental entre el estudio de ambas listas, se observa un decremento en las sincronías de alfa y theta (Pastötter, Bäuml, y Hanslmayr, 2008; Staudig y Hanslmayr, 2013). Este dato parece indicar la importancia de los procesos de codificación, y no sólo los procesos de recuperación, en el efecto de olvido producido por el cambio de contexto mental (Pastötter et al., 2008). Estos resultados también se han interpretado a favor de la idea de que el cambio de contexto mental podría indicar un reseteo de los procesos de codificación que induciría al efecto de coste observado con estos procedimientos. Por otro lado, sin embargo, recientes estudios han encontrado que las instrucciones de olvido dirigido desencadenan una respuesta cerebral diferente a las instrucciones de cambio de contexto mental (Baüml et al., 2008; Hanslmayr et al, 2012). Como se ha descrito más arriba, usando el procedimiento de olvido dirigido con el método de la lista, se observa una reducción en el acoplamiento de fase en la banda de frecuencia alta de alfa, un efecto diferente al que provocan las instrucciones de cambio de contexto, y que parece estar asociado a actividad cerebral inhibitoria (Hanslmayr et al., 2007; Kelly, Lalor, Reilly, & Foxe, 2006; Bäuml, Hanslmayr, Pastötter, y Klimesch, 2008; Hanslmayr et al., 2012).

No obstante, estos resultados proceden de estudios diferentes, y los efectos del cambio de contexto y de la instrucción de olvidar no han sido comparados en el mismo estudio. Aun así, en conjunto, se podría afirmar que aunque es cierto que las instrucciones de cambio de contexto mental provocan un efecto de coste en la información previa a la instrucción, también las instrucciones directas de olvidar desencadenan un proceso activo, y probablemente inhibitorio, que interrumpe la actividad de la memoria.

En el siguiente apartado discutiremos las condiciones necesarias para que aparezca el efecto OD y su relación con las distintas teorías propuestas.

2.2. Condiciones necesarias para el efecto de OD

Desde que en 1983 Geiselman y colaboradores rechazasen la explicación de los dos procesos de Bjork (1970, 1972) sobre el olvido dirigido y propusieran la explicación inhibitoria, un buen número de trabajos se ha dedicado a indagar sobre las condiciones necesarias para que se produzca el efecto de olvido dirigido (condiciones que, en numerosas investigaciones, van de la mano con las condiciones necesarias para que se desencadene un proceso inhibitorio).

2.2.1. Necesidad de interferencia de nueva información (Lista 2)

Gelfand y Bjork (1985, citado en Bjork, 1989) fueron los primeros autores en preguntarse por las condiciones necesarias para que apareciera el efecto de coste de OD usando el método de la lista. Su investigación estaba dirigida a conocer si tan sólo era necesaria una instrucción clara y no ambigua de que la información aprendida hasta el momento ya no era importante y debía ser olvidada. O si también sería necesaria la aparición de un nuevo material para aprender, para *reemplazar*, de alguna forma, a la información a olvidar. En su experimento estos investigadores manipularon lo que sucedía justo después de la instrucción de recordar/olvidar y antes del test de memoria: un grupo de participantes no hacía nada, mientras el experimentador pasaba el tiempo fingiendo hacer algo entre papeles y carpetas; otro grupo realizaba una tarea de aprendizaje incidental que consistía en juzgar si una lista de adjetivos describían o no a alguna figura pública; y otro grupo aprendía una nueva lista de palabras. Los resultados mostraron que cuando el estudio de la segunda lista era sustituido por una tarea no susceptible de generar interferencia con la Lista 1 (e.g., no hacer nada o juzgar una lista de adjetivos), el efecto de OD no aparecía (Gelfand y Bjork, 1985). Pastötter y Bäuml (2007) replicaron estos resultados, mostrando que en ausencia de aprendizaje de la Lista 2, el efecto de OD no aparece. Estas investigaciones ponen de manifiesto una característica importante que Bjork (1989; 1998) señala como fundamental o necesaria para que se produzca el efecto de olvido dirigido: la presencia de nuevos ítems que interfieran con la información a olvidar, que creen competición y, así, la necesidad de suprimir la Lista 1. En la línea de estos resultados, Pastötter y Bäuml (2010) encontraron que la cantidad de ítems codificados durante la Lista 2 (después de la instrucción de olvidar) influye en el efecto de olvido de la Lista 1: a mayor cantidad de ítems en la Lista 2, mayor era el efecto de olvido de la Lista 1.

2.2.2. Necesidad de recursos atencionales y de Memoria de Trabajo

Otro aspecto que ha sido investigado relacionado con el olvido dirigido ha sido el hecho de que cualquiera que sea el mecanismo que se desencadene en respuesta a la instrucción de olvidar, este mecanismo requiere recursos cognitivos. La lógica usada en estas investigaciones es introducir de manera concurrente a la tarea principal de olvido dirigido una tarea secundaria que demande recursos ejecutivos. En el caso de que la tarea principal de OD requiera también de recursos de control cognitivo, el efecto de olvido se verá disminuido o eliminado. Conway y colaboradores (2000) demostraron que la realización de una tarea concurrente durante el aprendizaje de la Lista 2 comprometía los recursos cognitivos de tal manera que eliminaba el efecto de OD. Justo antes de presentar a los participantes la segunda lista, se les daban 6 dígitos para que los mantuvieran en su memoria hasta después de haberse aprendido la Lista 2. Al terminar el estudio de la Lista 2 debían apuntar los dígitos. Los investigadores observaron que, bajo estas condiciones de tarea concurrente, el efecto de OD desaparecía (véase también Soriano y Bajo, 2007 para una réplica de estos resultados y su extensión a la Memoria de Trabajo). Macrae, Bodenhausen, Milne, y Ford (1997), en una tarea de olvido dirigido de recuerdo de estereotipos también encontraron que la instrucción de olvidar requería recursos atencionales de los participantes.

En cuanto a la capacidad de Memoria de Trabajo, Soriano y Bajo (2007) investigaron la influencia de tener alta o baja memoria de trabajo en los procesos inhibitorios en una tarea de OD. Investigaron diferencias individuales en la magnitud de efecto de OD y la relación entre estas diferencias y la capacidad de memoria de trabajo. En su primer experimento, de manera contraria a sus predicciones, el efecto de OD fue encontrado sólo para los participantes con baja capacidad de MT, mientras que los participantes con alta capacidad de MT no mostraron ese efecto. Las autoras atribuyeron este resultado inesperado a la diferente susceptibilidad a la interferencia de los participantes con alta y baja capacidad de MT. De esta manera, los participantes con alta capacidad de MT experimentarían menos interferencia que los participantes con baja capacidad de MT. Esta menor interferencia sería la razón principal por la que los participantes de alta MT no mostraron efecto de OD. En su segundo experimento comprobaron esta idea introduciendo una tarea concurrente que consistía en retener una carga de memoria durante el estudio de la Lista 2. En este caso encontraron el efecto de OD en el grupo de alta capacidad de MT y no en el de baja capacidad. En un tercer experimento incrementaron la interferencia aumentando el número de ítems de la primera lista, y de nuevo encontraron el efecto de OD en el grupo de alta capacidad de MT, y no en el de baja capacidad. Delaney y Sahakyan (2007) también mostraron un mayor efecto de OD en los participantes con mayor capacidad de MT. Aslan, Zellner, y Bäuml (2010) también investigaron la relación entre la capacidad de MT y el efecto de OD. Estos experimentadores encontraron que la capacidad de MT predecía el efecto de OD en participantes jóvenes, demostrando una relación positiva entre la capacidad de MT y ambos efectos (de coste y de beneficio) en la tarea de OD, y replicaron también estos resultados con niños. Esta evidencia experimental apoya tanto a la explicación inhibitoria como a la explicación basada en un cambio de contexto mental. No obstante los argumentos y los resultados descritos hasta ahora parecen apuntar a que el mecanismo responsable del efecto de olvido dirigido es un mecanismo costoso en términos de control cognitivo.

3. Olvido dirigido selectivo

Hasta hace poco tiempo la investigación sobre olvido motivado se ha centrado en proporcionar instrucciones de olvidar toda la información estudiada previamente. No obstante, algunos investigadores se propusieron el objetivo de investigar el olvido motivado cuando sólo parte de la información aprendida se convertía en información a olvidar. Delaney, Nghiem, y Waldum (2009) modificaron ligeramente el paradigma estándar de OD con el método de la lista para estudiar la capacidad de olvidar selectivamente. Dividieron la Lista 1 en dos subconjuntos de información: la mitad eran frases que hacían referencia a un personaje llamado Tom, y la otra mitad, frases sobre otro personaje llamado Alex. Además, la mitad de los participantes estudiaban una lista de frases sobre Tom y Alex temáticamente relacionada y la otra mitad, frases no relacionadas sobre los personajes. Los participantes estudiaban la primera lista de frases sobre los dos personajes y una segunda lista sobre un tercero (Joe). Tras estudiar la Lista 1, se pedía a los participantes de uno de los grupos que olvidaran la información aprendida sobre Tom, pero no la de Alex. A los de otro grupo se les decía que debían recordar toda esa información para la prueba posterior. Los autores encontraron, en la condición con frases relacionadas, que ambos grupos de participantes (los que habían recibido la instrucción de olvidar y los que no) tenían el mismo nivel de recuerdo sobre ambos personajes de la Lista 1. Estos datos son consistentes con la hipótesis de que el recuerdo para textos e información integrada temáticamente es mejor que para información no relacionada (e.g., Gómez-Ariza, y Bajo, 2003; Radvansky, 1999). Sin embargo, y más importante para nuestro trabajo, en la condición de frases no relacionadas encontraron un claro efecto de olvido selectivo: las frases de Tom se recordaron en menor medida que las de Alex en el grupo con la instrucción de olvido, pero no en el grupo con instrucciones de recuerdo. De este modo, Delaney y colaboradores (2009) hicieron un descubrimiento importante que incrementa nuestro conocimiento sobre el olvido motivado. Demostraron la posibilidad de ejercer control intencional sobre la memoria de manera selectiva, y abrieron una puerta hacia una mejor comprensión de los fenómenos de olvido. Las consecuencias teóricas del efecto de olvido dirigido selectivo para las hipótesis actuales sobre el olvido motivado serán descritas y discutidas en el siguiente sub-apartado.

El hallazgo de Delaney y colaboradores (2009) ha generado una incipiente línea de investigación sobre la selectividad en el olvido motivado. Kliegl, Pastötter, y Bäuml (2013) también encontraron evidencias que apoyan la idea de que el olvido dirigido puede ser selectivo. En un primer experimento aportan evidencia de que el efecto de OD con el método de la lista puede ser selectivo. Modifican el paradigma original de OD e introducen una tercera lista [usan un procedimiento muy similar al usado por Sahakyan (2004)]. De manera similar a como transcurre un experimento de olvido dirigido con el método de la lista, los participantes estudian las tres listas de palabras. Después del estudio de la segunda lista, a la mitad de los participantes se les dijo que olvidasen esa lista (pero no la primera), pues ya no era relevante para la tarea de memoria (la condición 'RFR') y que estudiasen la siguiente lista; a la otra mitad de los participantes se les pidió que estudiaran las tres listas (la condición 'RRR'). Los resultados muestran los efectos de beneficio y coste típicos de la tarea de OD: los participantes en la condición de 'RFR' recuerdan mejor la Lista 3 que los participantes del grupo de 'RRR', y además, recuerdan peor la Lista 2. Lo que resulta relevante es que estos autores encontraron un efecto de olvido dirigido selectivo: los participantes en la condición 'RFR' mostraron un recuerdo similar en la Lista 1 a los de la condición 'RRR'. Es decir, fueron capaces de olvidar, de manera selectiva, sólo la segunda lista, y no la primera (a pesar de que, en el momento de recibir las instrucciones de olvidar, habían aprendido las listas 1 y 2). En su segundo experimento usaron las mismas condiciones que en el Experimento 1 ('RRR' y 'RFR'), y añadieron una condición más: un grupo que, después de haber aprendido las listas 1 y 2, se les pedía que olvidasen ambas listas (condición 'FFR'). En este experimento replicaron los resultados del experimento anterior para las condiciones 'RRR' y 'RFR' y, para la nueva condición de 'FFR', encontraron un efecto de olvido dirigido para las listas 1 y 2. En el Experimento 3 su objetivo fue comparar los resultados con el procedimiento de tres listas usado en el Experimento 2 [similar al usado por Sahakyan (2004) con resultados que mostraban un olvido no selectivo] y un procedimiento de olvido dirigido con dos listas, en el que la información relevante e irrelevante forma parte de la misma lista [un procedimiento similar al ideado por Delaney y colaboradores (2009)]. Los resultados en la condición del procedimiento con tres listas replicaron los resultados obtenidos en los experimentos 1 y 2, mostrando un efecto de olvido dirigido selectivo, en el que los participantes fueron capaces de olvidar tan solo la información irrelevante y mantener la información importante. En la condición del procedimiento con las dos listas los resultados también mostraron un efecto de olvido selectivo dirigido, similar al que mostraban los resultados de Delaney y colaboradores (2009).

Este efecto de olvido dirigido selectivo (ODS) fue obtenido también por Gómez-Ariza y colaboradores (2013), con el mismo procedimiento introducido por Delaney y colaboradores (2009). Este estudio estaba basado en el hecho de que las personas que sufren ansiedad tienen la capacidad de control ejecutivo reducida (Airaksinen, Larsson, y Forsell, 2005; Bishop, 2009; Pacheco-Unguetti, Acosta, Callejas, y Lupiáñez, 2010). Los investigadores trataron de investigar si este déficit también se encontraba no sólo con información distractora perceptual no afectiva, sino también con información almacenada en la memoria a largo plazo. Así, en un grupo de adolescentes, encontraron que los participantes con trastorno de ansiedad social tenían un buen recuerdo de la información a olvidar, en comparación con otro grupo de adolescentes sin trastorno de ansiedad. De hecho, encontraron el efecto significativo de ODS en el grupo de adolescentes sin trastorno de ansiedad, pero no en el de adolescentes diagnosticados.

No obstante, no todos los datos apoyan la idea de que el OD puede ser selectivo. Sahakyan (2004), usando una tarea de OD con tres listas, no encontró efecto de ODS. En su experimento los participantes estudiaban tres listas de palabras (no relacionadas, Experimento 1; y relacionadas, Experimento 2). Después de cada lista pedía a los participantes o bien que recordasen esa lista para una tarea de memoria posterior, o que la olvidasen. Así, las tres condiciones de su experimento fueron un grupo al que se le pedía que recordasen las tres listas (‘RRR), otro grupo al que se le pedía que olvidase la primera lista pero recordase las listas 2 y 3 (‘FRR’) y otro grupo al que se le pedía que olvidase la Lista 2, pero que recordasen las listas 1 y 3 (‘RFR’). En ambos experimentos los resultados muestran efecto de olvido dirigido para las listas a olvidar. No obstante, y de manera importante, los grupos ‘RFR’ mostraron un recuerdo de la Lista 1 (señalada como lista a recordar) similar al recuerdo de la Lista 2 (información a olvidar). Los investigadores Storm, Koppel, y Wilson (2013), usando un procedimiento similar al usado por Delaney y colaboradores (2009), alcanzaron la misma conclusión sobre la selectividad en el efecto de olvido dirigido, y no encontraron efecto de ODS. Las razones por las que algunos investigadores no encuentran el efecto no están todavía claras, y por ello es necesaria más investigación que especifique la naturaleza del efecto y las condiciones que lo constriñen.

3.1. Consecuencias e interpretaciones teóricas sobre los resultados del efecto de ODS.

Como hemos mencionado, hasta la fecha se han encontrado varias evidencias de la existencia del efecto de olvido dirigido Selectivo. Sin embargo, la naturaleza del mecanismo o mecanismos que se desencadenan aún está por analizar. Los resultados obtenidos hasta ahora sobre el ODS tienen algunas implicaciones teóricas. En primer lugar, la mayoría de los resultados obtenidos hasta el momento sugieren que la hipótesis del cambio de contexto (Sahakyan y Kelley, 2002; Sahakyan, et al., 2013) para explicar los resultados obtenidos usando el paradigma de OD, no resulta adecuada para explicar el efecto de ODS. Tanto la información no deseada (Tom) como la información importante (Alex) es codificada en el mismo contexto (la Lista 1). La hipótesis del cambio de contexto predice el mismo porcentaje de recuerdo para los dos tipos de ítems. No obstante, en las investigaciones que muestran el efecto de ODS (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), se puede, en efecto, observar un porcentaje de recuerdo diferente para los ítems a olvidar y para los ítems a recordar. Teniendo en cuenta la definición de contexto mental que los investigadores Sahakyan y Kelley (2002) adoptan, esta hipótesis quedaría descartada para explicar los datos obtenidos con el procedimiento de ODS. En segundo lugar, desde que Delaney y colaboradores (2009) reportaran sus resultados sobre el ODS por primera vez, la hipótesis del repaso selectivo (Bjork, 1970, 1972) se ha vuelto a tomar en consideración (Delaney et al., 2009; Storm et al., 2013), ya que es posible que cuando a los participantes se les da la instrucción de olvidar parte de la Lista 1, éstos utilicen la estrategia de repasar selectivamente los ítems de la Lista 1 que sí son importantes. Así, desde esta explicación se propondría que el efecto de ODS sería un tipo de olvido pasivo provocado por la estrategia de repasar de manera selectiva el material a recordar, y de un menor procesamiento de los ítems a olvidar.

Por último, si bien Delaney y colaboradores (2009) evitaron discutir en profundidad la relevancia teórica de sus resultados, posteriores investigaciones usando el procedimiento de ODS han apuntado hacia una posible explicación inhibitoria (Gómez-Ariza et al., 2013; Kliegl et al., 2013). Desde el punto de vista que defienden estos estudios, los resultados de ODS son compatibles con la propuesta de que un mecanismo de control actúa sobre la primera lista. Más específicamente, desde un punto de vista inhibitorio, el ODS puede explicarse si se asume que la inhibición se despliega de forma selectiva sobre la Lista 1 más que sobre el conjunto íntegro de elementos que lo componen.

4. Organización y objetivos de la serie experimental

La motivación de la presente tesis es profundizar en el conocimiento de los fenómenos de olvido motivado selectivo. Aunque cierta evidencia experimental apoya el efecto de olvido dirigido selectivo (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), otros autores han reportado no obtener el efecto de ODS (Sahakyan, 2004; Storm et al., 2013). El objetivo principal del presente trabajo es examinar la posibilidad de olvidar selectivamente de manera motivada, conocer los procesos cognitivos que acompañan a este fenómeno de olvido e indagar sobre la naturaleza (controlada o no) de éstos.

En todas las series experimentales que conforman el presente trabajo, con especial énfasis en la primera, se intenta replicar el efecto de olvido dirigido selectivo, tanto con procedimiento ya utilizados previamente (Delaney et al., 2009; Gómez-Ariza et al., 2013; Storm et al., 2013) como con modificaciones notables en esos procedimientos. Así, el primer objetivo específico de este trabajo fue conocer si es posible observar el efecto experimental observado en el trabajo original de Delaney y colaboradores (2009) (Experimento 1). En el siguiente estudio de la primera serie (Experiment 2) se modifica el procedimiento para explorar posibles variables moduladoras de la capacidad para olvidar de forma intencional y selectiva. A este fin, se manipulará la dificultad en la selección de la información a olvidar modificando la proporción de información a olvidar y a recordar. Observar el recuerdo de los participantes a través de las diferentes condiciones de dificultad de la selección nos permitirá conocer un posible factor que favorece o dificulta la selectividad en el olvido dirigido, así como conocer si el proceso subyacente es un proceso costoso en términos de recursos cognitivos.

En la segunda serie experimental (Experimentos 3 y 4) nos centraremos en investigar si la capacidad de olvidar de manera selectiva está determinada por procesos de control ejecutivo y es de naturaleza controlada. Por otro lado, también indagaremos sobre el mecanismo que subyace al efecto de ODS. Mediante el uso de tareas concurrentes que requieren diferente demanda cognitiva (una tarea de actualización en Memoria de Trabajo y una tarea de supresión articulatoria) durante la realización de la tarea de ODS, se tratará de determinar si la naturaleza del proceso que subyace al efecto de ODS es controlada o automática. Si el ODS depende de recursos cognitivos, deberíamos observar un efecto diferente en función de la dificultad de la tarea concurrente utilizada. Además, observar la ejecución de los participantes en la tarea de ODS junto con la tarea secundaria de supresión articulatoria nos permitirá discernir entre los dos mecanismos propuestos para explicar el efecto de ODS: la inhibición y el repaso. Si el efecto de ODS depende de una estrategia de repaso selectivo de la información a recordar, no se debería observar efecto de ODS en este experimento. También podremos disgregar los procesos que dan lugar al efecto de ODS, y disociar entre un primer proceso de selección de la información a olvidar y un segundo proceso de inhibición o repaso.

Finalmente, en la tercera serie (Experimentos 5, 6 y 7) acotaremos las posibilidades sobre el mecanismo subyacente del ODS, y trataremos de probar si éste es de carácter inhibitorio. Compararemos la ejecución en la tarea de ODS de participantes mayores de 60 años a los que se les supone un déficit inhibitorio (Hasher, Lustig, y Zacks, 2007; Hasher y Zacks, 1988; Hasher, Zacks, y May, 1999) con participantes jóvenes. Esta comparación nos permitirá conocer si los procesos inhibitorios se encuentran implicados en la capacidad de olvidar de forma selectiva (Experimentos 5 y 6). Si el ODS depende de procesos inhibitorios, entonces los participantes mayores deberían mostrar un efecto de ODS nulo o menor que los participantes jóvenes. Siguiendo esta misma línea, el Experimento 7 nos permitirá completar y matizar las conclusiones extraídas de los Experimentos 5 y 6. En este experimento se pondrá a prueba la capacidad de olvidar de manera no selectiva (olvido dirigido estándar) de un grupo de participantes mayores de 60 años y un grupo de participantes jóvenes. Si se observa un efecto de OD tanto en los participantes jóvenes como en los participantes mayores, se podría concluir, en primer lugar, que el déficit inhibitorio que presentan los participantes mayores de 60 años aparece de manera gradual, permitiendo inhibir información cuando la tarea presenta menos demanda cognitiva (Experimento 7), y fallando cuando ésta es más demandante de recursos y requiere el proceso adicional de seleccionar la información (Experimentos 5 y 6). En segundo lugar, también se podría concluir que la tarea de olvido dirigido selectivo, comparada con la tarea estándar de olvido dirigido, requiere más recursos de control cognitivo.

En conjunto, nuestros experimentos van dirigidos a comprender los procesos cognitivos necesarios para olvidar intencionadamente y de manera selectiva.

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Chapter II

Summary introduction and aims

1. Theoretical background about directed forgetting

It is well known that already learned information can be forgotten when people are cued to do so (e.g., Anderson & Hanslmayr, 2014; Anderson & Huddleston, 2011; Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008; Bjork, 1989; Bjork & Bjork, 1996; Geiselman, Bjork, & Fishman, 1983; for reviews, see also Bjork, 1998; MacLeod, 1998). Motivated forgetting has been widely investigated by using the directed forgetting paradigm. Two general procedures have been used to investigate directed forgetting phenomena: the item method (IM-DF) and the list method (LM-DF). In the IM-DF procedure [first used by Muther (1965) and then labeled 'item-by-item' procedure by Bjork (1972)] participants study items one by one, and each item is followed by a forget or remember instruction. Later, memory for all items is tested. The typical pattern of results shows less recall for the to-be-forgotten items (TBF) compared to the to-be-remembered items (TBR) in both recall and recognition tests. The original LM-DF procedure, however, was introduced by Bjork, LaBerge, and LeGrand (1968) to study the ability to reduce proactive interference from previously learned items by asking participants to forget them just before being cued to study a second set of items. In a typical between-subjects LM-DF procedure, participants study a first list of items. Then, half of the participants (the *forget group*) are cued to forget that list because it is no longer relevant for the task, and told to study a second list instead. The other half of the participants (the *remember group*) is just told to study the second list of items. Finally, both groups' memory for List 1 and List 2 is tested through a free recall test. Typically, the forget group shows lower percentage of List 1 recall than the remember group (a cost effect) and also greater recall of List 2 items than the remember group (a benefit effect). Although both IM-DF and LM-DF procedures usually result in poor recall of the to-be-forgotten information, traditionally it has been thought that different mechanisms lead to forgetting in each case. Thus, IM-DF is frequently explained in terms of selective rehearsal of the TBR information (e.g., Bjork, 1970, 1972), though recent behavioral (Fawcett & Taylor, 2008, 2010) and neural evidence (Hauswald, Schulz, Iordanov, & Kissler, 2011; Ludowig et al., 2010; Nowicka, Marchewka, Jednoróg, Tacikowski, & Brechmann, 2011; Paz-Caballero, 2004; Rizio & Dennis, 2013; Wylie, Foxe, & Taylor, 2008) suggests that inhibitory control may play a role during encoding in the IM-DF procedure. LM-DF, however, has been traditionally understood in terms of retrieval inhibition (see below). According to Bjork (1998), IM-DF and LM-DF procedures can be useful as research tools depending on the peculiarities of the issue under study. Thus, IM-DF seems to be more suitable to address research questions on control during encoding, whilst LM-DF is more useful to study the role of interference and inhibition processes in the updating of well-learned information (Bjork, 1998). The present series of studies will focus on LM-DF.

1.1 Theoretical explanations of List-Method Directed Forgetting: Controversy about inhibition and context.

As aforementioned, different theoretical explanations have been proposed to account for the cost effect that usually come with the instruction to forget previously learned information. The very first account was proposed by Robert Bjork (1970, 1972), who posited selective rehearsal as the responsible mechanism for the poorer recall of the to-be-forgotten items. According to this account, participants accomplish two actions in response to a cue to forget: 1) they focus all of their postcue rehearsal and other mnemonic activities on the TBR items, and 2) they segregate or differentiate in memory the TBR items from the earlier TBF items. Thus, whereas the remember group would rehearse List 1 items during List 2 study, the forget group would only rehearse List 2 items. Importantly, this rehearsal-based account showed to be insufficient to explain the presence of the DF effect in incidental learning (Geiselman et al., 1983; Sahakyan & Delaney, 2005, 2010; Sahakyan, Delaney, & Goodmon, 2008), and was later replaced by the inhibitory account (Bjork, 1989; Geiselman et al., 1983) in response to the critical findings by Geiselman et al. (1983). In their study, Geiselman et al. (1983) had participants see a list of two different types of items: words that participants were asked to learn (intentional learning) and words that participants were asked to judge in a pleasantness scale (incidental learning). Then, they received the instruction either to forget all presented items because they were just for practice or to simply keep working with a new list of items to learn or judge. Finally, participants were asked to free recall all items (both intentionally and incidentally-encoded items from the two lists). The results showed a directed forgetting effect of both types of encoded words. Since their participants were not supposed to have been rehearsing the to-be-judged items (they were not to be studied), Geiselman et al. proposed that a process other than rehearsal, likely inhibitory in nature, could have played a role in forgetting List 1 items after the cue to forget.

The inhibitory account of LM-DF posits that the cue to forget triggers an inhibitory mechanism that makes List 1 items less accessible and harder to retrieve in an upcoming memory test. Specifically, it is thought that when subjects are told to forget previously encoded information and then presented with new information to learn, a process is initiated that inhibits the subsequent retrieval of the TBF information to prevent proactive interference. Behavioral and neural evidence seem to support the inhibitory account of DF (Bjork, 1989; Bjork, Bjork, & Anderson, 1998; Conway, Harries, Noyes, Ràcsmany, & Frankish, 2000; Hanslmayr et al., 2012; Soriano & Bajo, 2007). Thus, for example, the memory cost that follows the cue to forget vanishes when there is no List 2 to be studied (e.g., Gelfand & Bjork, 1985; Pastötter & Bäuml, 2007) and increases when the number of items of List 2 is larger (Pastötter & Bäuml, 2010). In addition, the forgetting of List 1 items usually leads List 2 items to be better recalled (presumably because of a lesser degree of proactive interference, Bjork & Bjork, 1996; Bjork, Bjork, & Glenberg, 1973). Importantly, patients with frontal damage who are thought to suffer inhibitory control deficit and healthy participants performing a secondary task while studying List 2 fail to show directed forgetting (Conway & Fthenaki, 2003; Conway et al., 2000; Harnishfeger & Pope, 1996; Soriano & Bajo, 2007). In addition, by using electroencephalography (EGG) and oscillation analyses Bäuml et al., (2008) observed that reductions in upper alpha phase coupling [which are thought to be associated with active inhibitory filtering in the brain (Hanslmayr et al., 2007; Kelly, Lalor, Reilly, & Foxe, 2006)] correlated with List 1 forgetting. More recently, Hanslmayr and colleagues (2012), by using EEG recordings along with functional magnetic resonance imaging (Experiment 1) and transcranial magnetic stimulation and EEG recordings (Experiment 2) found that directed forgetting is associated with specific activity in the dorsolateral prefrontral cortex, a brain area closely bound to cognitive control (MacDonald, Cohen, Stenger, & Carter, 2000). Thus, a variety of findings have been taken as evidence of the inhibitory nature of the mechanism underlying DF effects.

Inhibition is not the only mechanism thought to be responsible for DF effects. Sahakyan and Kelley (2002) put forward that the memory cost that usually follows a cue to forget could be understood in terms of a context change account. On the basis of formal models of episodic memory proposing that during study people encode the items themselves but also a large number of contextual features (Anderson & Bower, 1972; Estes, 1955; Gillund & Shiffrin, 1984; Hintzman, 1988; Howard & Kahana, 2002; Mensink & Raaijmakers, 1988; Tulving; 1983), Sahakyan and Kelley argued that after receiving the cue to forget participants attempt to establish a new mental context, presumably thinking of something unrelated to the experiment. That is, the cue “List 1 was just for practice, forget it” would lead participants to change their mental set, thereby encoding List 1 and List 2 as separated events. The second list is then encoded with new contextual cues, which remain active during recall. From this proposal the memory cost for List 1 occurs because the context during recall matches the List 2 encoding better than it matches the context for List

1. In order to find support for the context-change account of LM-DF, Sahakyan and Kelley introduced the so-called *mental-context change/diversion paradigm*. In this paradigm participants are asked to engage in diversionary thoughts after List 1 learning with the purpose of examining the impact of such activity on memory. Sahakyan and Kelley (2002) demonstrated in two experiments the same grade of forgetting and enhancement than in a standard DF experiment by directly manipulating the cognitive context. Since then, tasks such as imagining being invisible (Sahakyan & Kelley, 2002), thinking about the childhood home (Delaney, Sahakyan, Kelley, & Zimmerman, 2010; Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002), or daydreaming about vacations (Delaney et al., 2010) have shown to lead to List 1 forgetting, which supports that context change may play a role in LM-DF procedures.

Some authors have also suggested that the forgetting effect observed with the LM-DF procedure might be mediated by different mechanisms that may work in different conditions, and that different individuals may employ different strategies to successfully accomplish the task (Kliegl et al., 2013; for a similar argument with the Think/no-think procedure, see Anderson & Levy, 2008).

On the other hand, it is worth mentioning that the explanation that the context change account offers about the forgetting effect (Sahakyan & Kelley, 2002; Sahakyan et al., 2013) does not rule out a possible inhibitory mechanism responsible for the effect. The fact that a mental context change instruction produces a forgetting effect that is comparable to that produced by the direct instruction to forget tells us that context change is a powerful forgetting tool (Delaney et al., 2010; Pastötter y Bäuml, 2007; Pastötter, Bäuml, & Hanslmayr, 2008; Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002). However, it does not eliminate the possibility that active inhibitory processes are triggered in response to the forget cue.

As showed by studies on brain correlates of forgetting, although both forget and context change instructions led to a memory cost, these cues trigger different neural responses. Research about brain oscillations have found that when context is left unchanged between the study of lists 1 and 2, an increase of theta and alpha power was found. However, when context between the two lists changes, a theta and alpha power decrease was found (Pastötter, Bäuml, & Hanslmayr, 2008; Staudig & Hanslmayr, 2013). This information seems to highlight the importance of the encoding processes, and not only the retrieval processes, in the forgetting effect produced by a mental context change (Pastötter et al., 2008). These results have been also interpreted in favor of the idea that the mental context change could induce a reset of the encoding processes that would produce the observed cost effect with this procedure. On the other hand, however, recent studies have also found that forget instructions trigger a different brain response than context change instructions (Baüml et al., 2008; Hanslmayr et al., 2012). As described above, by using the LM-DF procedure, a reduction in upper alpha phase coupling has been found to correlate with List 1 forgetting (Baüml et al., 2008). This is a different effect that the one found in context change procedures, and it is thought to be associated with inhibitory brain activity (Hanslmayr et al., 2007; Kelly, Lalor, Reilly, & Foxe, 2006)].

However, these results are from different studies, and brain data about the context change and the forget instruction have not been compared within the same study. Even so, it could be argued that, although is true that context change instructions led to a forgetting of the information encoded before the instructions, showing that a context change can produce influence under the encoding processes, the forget instructions also trigger an active process, likely inhibitory in nature, that hampers the mnemonic activity.

2. Directed forgetting and selectivity of the instruction to forget

Typically, in the LM-DF procedure the cue to forget refers to the whole set of previously studied items (List 1), which is constrained to a certain temporal context (in contrast with IM-DF, in which the forget cue is given after one item at a time). Over the last decades, a good deal of research has used the standard paradigm to investigate the ability to intentionally forget. Very recently, however, interest has emerged in the field of motivated forgetting to investigate the extent to which intentional forgetting may be selective. Because it is usually the case in everyday situations that not all previously learned information in a given context is to be updated, Delaney, Nghiem, and Waldum (2009) modified the LM-DF procedure to study the ability to voluntarily forget in a selective way. To do so, they had participants study a List 1 consisting of either thematically unrelated or related sentences. Then they asked half of participants to forget just half of

List 1 items, which comprised 8 sentences about a character named Tom and 8 sentences about a character named Alex. Specifically, they were told to forget the facts learned about Tom and keep remembering the facts learned about Alex. The other half of participants, however, was told to keep remembering all the sentences about the two characters. Then both groups were presented a List 2 to study, which was composed of 12 sentences about a third character named Joe. Finally, participants' memory for both lists was tested. The authors failed to find memory impairment in the related sentences condition (which is consistent with the hypothesis that memory for texts and thematically integrated information is better than for unrelated information; e.g., Gómez-Ariza & Bajo, 2003; Radvansky, 1999). More interestingly, however, Delaney et al. (2009) observed a selective directed forgetting (SDF) effect in the thematically unrelated condition; whereas participants cued to forget recalled fewer TBF items (Tom) than participants cued to remember did, both groups recalled TBR items (Alex) to a similar extent. In this way, Delaney et al. (2009) provided new insights about motivated forgetting. The theoretical implications that selective intentional forgetting have for the current theories of motivated forgetting will be described and discussed in the next sub-section.

The original study by Delaney et al. (2009) has also fostered new experiments on selectivity in directed forgetting. Kliegl, Pastötter, and Bäuml (2013) also found evidence supporting the idea that LM-DF can be selective. In their Experiment 1 they examined if LM-DF could be selective in a 3-list task. Participants studied three lists of unrelated items. After the study of List 2, participants were either asked to keep remembering List 1 and List 2 (RRR condition) or to forget List 2 but keep remembering List 1 (RFR condition). Their results showed both the usual benefits and costs of providing a cue to forget: participants in the RFR condition showed enhanced recall of the post-cue information (List 3) and less recall of the to-be-forgotten pre-cue information (List 2) than participants in the RRR condition. More important, the forget group did not show poorer recall of the to-be-remembered pre-cue information (List 1), which suggests that these participants were able to forget in a selective way. In Experiment 2 they used the same cuing condition as in Experiment 1 (RRR and RFR) but added a third experimental condition in which study of List 2 was followed by a cue to forget both List 1 and List 2 (FFR). The results replicated the main finding of Experiment 1 concerning RRR and RFR conditions, but also showed that the group cued to forget two lists (FFR) had poorer recall of these lists than the other groups. Again, therefore, Kliegl et al. showed that motivated forgetting may be selective. Finally, in a third experiment the authors compared two procedures to selectively cue to forget; namely, the 3-list procedure previously used in Experiment 2 and a procedure similar to that used by Delaney and colleagues (2009) in which the TBR and TBF items were included in the same list (List 1). The results of Experiment 3 showed that both procedures led to comparable SDF.

A SDF effect was also found by Gómez-Ariza et al. (2013) in adolescents by using the Delaney et al.’s (2009) procedure. Based on previous research indicating that people with anxiety have reduced executive-control capacities (Airaksinen, Larsson, & Forsell,, 2005;

Bishop, 2009; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010), Gómez-Ariza et al. aimed to test if this deficit extends to the ability to forget no longer relevant memories. Their results showed that whereas the healthy control group exhibited a SDF effect, a group diagnosed with social anxiety disorder failed to forget.

However, not all studies looking at selective intentional forgetting have observed the expected effect. Thus, by using a 3-list task Sahakyan (2004) failed to find selective directed forgetting. She had participants learn three lists of 12 words either unrelated (Experiment 1) or related (Experiment 2). After each list, participants received the cue either to remember or forget the just learned list. They were instructed to remember all lists (RRR condition), to forget List 1 and remember the other two (FRR condition) or to forget only List 2 (RFR condition). The results showed a reliable effect of forgetting of the forget-cued lists in the FRR condition and in the RFR condition. However, and more importantly, in both experiments participants in the RFR condition showed a forgetting effect not only for the list cued to forget (List 2) but also for List 1, which was relevant information to keep. Similarly, and using a procedure similar to that originally used by Delaney et al. (2009), Storm, Koppel, and Wilson (2013) failed to replicate the SDF effect in three experiments. Hence, whereas some studies have reported reliable effects (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), others have failed to do so (Sahakyan, 2004; Storm et al., 2013).

2.1. Theoretical implications and accounts about SDF

The SDF effect has important theoretical implications. First, it challenges a general context-change account of directed forgetting (Sahakyan & Kelley, 2002; Sahakyan, Delaney, Foster, & Abushanab, 2013, 2013). As previously noted, according with this hypothesis the LM-DF cost arises because of a mismatch between the study and the retrieval mental context of List 1. This account, however, does not fit well with the SDF effect because the to-be-forgotten and to-be remembered items are encoded in the same mental context. Hence, it seems odd that only some items from List 1 become forgotten after providing the cue. Second, since Delaney and colleagues (2009) reported the SDF effect for the first time, the selective rehearsal account of list-method directed forgetting (Bjork, 1970, 1972) has been taken into account again (Delaney et al., 2009; Storm et al., 2013). Applied to the SDF procedure, this account would posit that after receiving the cue to forget participants would only rehearse the TBR information. Hence, the forgetting of the TBF items would result from a lesser degree of processing of these items relative to TBR items. In other words, from the selective rehearsal account the SDF would be a kind of "side effect" of rehearsing the TBR items.

In addition to the selective rehearsal account, the inhibitory view of DF could also account for SDF (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). As previously described, according to this view (Bäuml et al., 2008; Bjork, 1989, 1998; Conway et al., 2000; Geiselman et al., 1983; Hanslmayr et al., 2012) an inhibitory mechanism would make the to-be-forgotten information

(List 1) less available during retrieval. Hence, if one assumes that participants in a SDF experiment can encode and segregate the information about the two characters into two different subsets of information, it would be possible that, in the presence of a cue to forget, one of the subsets (the to-be-forgotten information) could uniquely be the target of inhibition in favor of the other subset (the to-be-remembered information).

Whereas selective rehearsal and inhibition could in principle be the mechanisms underlying SDF, no previous study has directly addressed this issue. Besides, the question of how selectivity is implemented by the cue to forget remains unknown. Hence, further research on SDF and its potential modulating factors is necessary. Some pieces of evidence suggest that successfully forget in the standard non-selective LM-DF procedure requires effortful control and draws on executive control (Bäuml et al., 2008; Conway & Fthenaki, 2003; Conway et al., 2000; Hanslmayr et al., 2012; Harnishfeger & Pope, 1996; Soriano & Bajo, 2007). Similarly, it has been suggested that the ability to selectively intentionally forget taps on executive-control capacities (Gómez-Ariza et al., 2013), although this issue has not been directly investigated so far.

3. Organization and goals of the experimental series

The general aim of the present thesis was to better understand selective motivated forgetting by looking at some boundary conditions that could shed light onto the nature of the mechanisms underlying this ability.

In the first experimental series we aimed to replicate the basic effect with the SDF procedure introduced by Delaney et al. (2009) (Experiment 1). In Experiment 2 we explored possible modulating factors that might constrain this effect. To this end we manipulated the level of difficulty of the selection process and focus on how successful selective intentional forgetting can be depending on the proportion of to-be-forgotten and to-be-remembered information. The selection process of intentional forgetting could vary in difficulty depending on how many items, out of the total previously encoded, are to be updated. Thus, we aimed to explore the involvement of executive control by increasing the demands for selectivity and observing the consequences on forgetting.

In the second experimental series (Experiments 3 and 4) we studied the possible controlled nature of the effect. By using a dual tasking approach and manipulating the concurrent-task demands across experiments, we try to determine if executive-control processes underlie the capacity to selectively forget. To the extent that SDF depends on attentional control, highly demanding concurrent tasks, but no barely demanding tasks, should prevent SDF. In addition, we also look at the possible role of rehearsal processes in SDF in Experiment 4 by using an articulatory suppression task along with the SDF task. If SDF effect relies on selective rehearsal of the TBR information, then we should not observe the effect in this experiment.

Finally in the experimental series 3 (Experiments 5-7) we take an individual-differences approach to study if SDF draws more on executive-control capacities than non-selective directed forgetting.

Since executive-control abilities are thought to decline with aging, older adults should exhibit less SDF than young adults if the ability to selectively intentionally forget taps on these executive capacities.

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Chapter III

Experimental section

Experimental series I

Intentional forgetting and selectivity

Experiment 1

As previously noted, whereas the SDF effect has been reported in some studies (Delaney, Nghiem, & Waldum, 2009; Gómez-Ariza et al., 2013; Kliegl, Pastötter, & Bäuml, 2013), others have failed to show reliable SDF effects (Sahakyan, 2004; Storm, Koppel, & Wilson, 2013). Thus, the aim of the present experiment was to replicate the SDF effect by using the procedure introduced by Delaney et al. (2009). Replicating the effect would allow us to use the paradigm across experiments to shed some light on the mechanism or mechanisms underlying the ability to selectively and intentionally forget.

Method

Participants

Fifty-six participants (mean age = 20.85 years; *SD* = 3.03; 34 women) were randomly assigned to the experimental conditions. All of them were undergraduate students from the University of Granada who received either course credit or money for their participation.

Materials and procedure

Participants studied two lists of sentences presented on a 19-inch computer screen. Stimuli were printed in black on white background and appeared in 18-point Courier New font. The first list consisted of 18 unrelated sentences regarding two characters: Tom and Alex (e.g., “Tom took his medicine”, “Alex flew a kite”), and the second list consisted of 14 unrelated sentences about a character named Joe (e.g., “Joe played video games”, “Joe woke up late”). These sentences were taken from the unrelated list of sentences used by Delaney et al. (2009), (two extra sentences were added to List 1; see Appendix I). The characters of List 1 were presented in alternating order with the character to be presented first and the relation “character-action” being counterbalanced across participants. Thus, the predicates associated with Tom for half the participants in each group were associated with Alex in the other half. Each sentence was presented on the middle of the screen during 8 seconds, with an inter-item interval of 1 second. Upon their arrival, all participants were randomly assigned to one of the two instruction conditions (remember vs. forget) and informed that they were participating in a memory experiment and that their memory would be tested after studying a set of sentences about different characters. Following List 1 presentation, participants in the group cued to remember were told the following: “Please, do your best to remember the just-studied sentences.” After this, they were asked to solve simple arithmetic operations for 90 seconds in order to discourage them from rehearsing the material. Finally, participants were told to study List 2. Participants cued to forget were told the following after studying List 1: “At this point you should know that Tom sentences are no longer relevant, they were just fillers. To do best on the memory test you should forget all you learned about Tom, because ignoring information about Tom will definitively help you to better recall information about Alex." The instructions for the forget group after studying List 1 emphasized the need to forgetting part of the just studied items because their memory about these "irrelevant" items was not going to be tested later and it might hinder the recall of target memories. Several times during the experimental session, participants were told to do their best to strictly follow the instructions provided by the experimenter. Then the forget group was also asked to solve simple arithmetic operations for 90 seconds. Following List 2 study, all participants again solved a series of math exercises for 90 seconds and then were provided with a blank sheet of paper and asked to recall and write down as many sentences as possible from List 1, including both Tom (TBF) and Alex (TBR) sentences. A second blank sheet was handed out to write down sentences from List 2. Four minutes were given to recall each list. The presentation of items and instructions was controlled by E-prime software (Schneider, Eschman, & Zuccolotto, 2002).

Once participants finished the memory test, they were asked to fill out a questionnaire concerning the use of strategies during the study phase. In addition, the group cued to forget was asked to report: a) whether they really tried to forget the "irrelevant" items when they were cued to do so as well as the reasons behind their behavior; and b) whether they really believed that their memory for the to-be-forgotten List 1 character would not be tested later. Four participants from the group cued to forget were replaced because they reported they did not believe that the irrelevant information would not be tested later. The session lasted about 40-45 minutes.

Results and discussion

In this and the following experiments recalled items were marked as correct if they kept the gist of the original sentences and contained the studied character-action association. Two independent coders scored the recall performance of each participant. The interrater agreement was greater than 95%. When agreement was not reached, additional coders were considered to solve the differences through discussion. Although our hypothesis focused on List 1, for completeness we also performed analyses on List 2 recall. We first report results from List 1 and then describe analyses for List 2 recall.

List 1 recall: Selective Directed Forgetting

We conducted a mixed factorial analysis of variance (ANOVA) on the recall percentages of List 1 with instruction (remember and forget) as the between-participants factors, and character (Tom and Alex) as the within-participants factor. The ANOVA revealed a main effect of cue, $F(1,54) = 4.14$, $MSE = 613$, $p < .05$, $\eta_p^2 = .07$ (remember group $M = 39.28$, $SD = 18.94$; forget group $M = 29.76$, $SD = 22.23$), and a significant interaction between instruction and character, $F(1,54) = 4.29$, $MSE = 231.1$, $p < .05$, $\eta_p^2 = .07$. The main effect of character was not significant, $F(1,54) = 1.54$, $MSE = 231.1$, $p = .21$, $\eta_p^2 = .02$. Planned comparisons revealed a reliable SDF effect: the forget group recalled fewer Tom items than the remember group, $F(1,54) = 7.89$, $MSE = 3353.17$, $p < .01$, $\eta_p^2 =$

.12, whereas both groups recalled Alex items to the same extent, $F(1,54) < 1$, $\eta_p^2 < .01$. Means and standard errors can be seen in Figure 1.

The ANOVA on List 2 recall percentages revealed the same level of performance in both groups, with no significant effect of the instruction $F(1,54) < 1$, $\eta_p^2 = 0.01$.

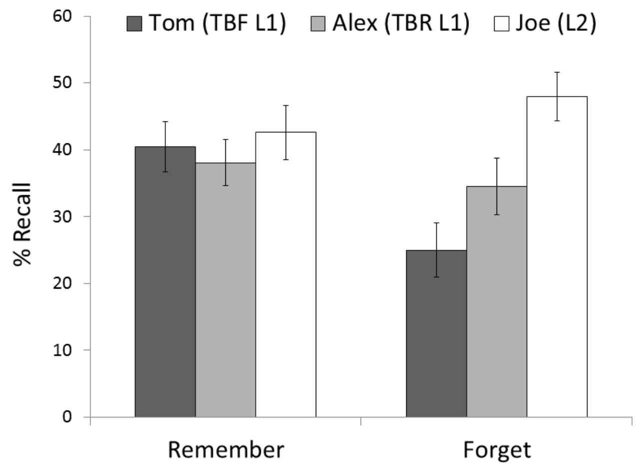

Figure 1. Mean percentages of correct recall as a function of instruction and character. Error bars represent standard errors of mean.

Previous research has shown conflicting results regarding whether LM-DF can be selective, with some studies observing SDF effects (Delaney et al., 2009, Gómez-Ariza et al., 2013, and Kliegl et al., 2013) and with others not showing it (Sahakyan, 2004; Storm et al., 2013). Hence, and before conducting new experiments to test more specific hypothesis, we started the experimental series replicating the basic effect found by Delaney et al. (2009). The results of the present experiment are clear and reveal that the SDF effect is a robust phenomenon. In agreement with some previous studies (Delaney et al., 2009, Gómez-Ariza et al., 2013, and Kliegl et al., 2013), Experiment 1 shows that people may successfully engage in selective forgetting when instructed to do so.

However, the mechanism or mechanisms whereby selective intentional forgetting is achieved, as well as the circumstances modulating this ability, remains unknown. Whereas it seems that a general context change account cannot explain SDF, at least two accounts arise as *a priori* candidates to understand this phenomenon: the inhibitory and the selective rehearsal accounts. Despite their differences, at this point both views could, at least partially, account for the memory impairment found with the SDF procedure. In the following experiments we attempt to better understand the process underpinning the ability to intentionally forget in a selective way.

Experiment 2

The aim of Experiment 2 was to shed some light onto potential factors modulating the SDF effect in order to learn how selectivity in intentional forgetting is implemented. As Kliegl et al. (2013) pointed it out, the issue is not whether directed forgetting may or may not be selective, but under which conditions is, or not, selective. In other words, SDF could be present under some conditions and absent under others. Based on research regarding visual search (Reijnen, Wolfe, & Krummenacher, 2013), we assumed that the proportion of the TBF information (which is supposed to be information to select in order to forget it) relative to the TBR information would play a role in the capacity to selectively forget. Thus, in the present experiment we attempt to elucidate if the degree of selectivity demanded by the cue to forget modulates the SDF effect. By doing so, we also expect to learn about the mechanism underlying the effect.

The specific aim of this experiment was twofold. First, we aimed to explore if the degree of selectivity imposed by the task is a factor that determines the presence of the SDF effect. We intended to assess to what extent the memory cost associated with the cue to selectively forget depends upon the amount of to-be-forgotten items relative to the amount of to-be-remembered items. Thus, we test here whether SDF can be observed in a 3-subset task by varying the proportion of TBF/TBR items. Second, we aimed to explore if in the ability to selectively forget demands executive control.

So far the studies on SDF have used variations of the LM-DF procedure in which people were cued to forget either half of the items of a list (Delaney, et al., 2009; Gómez-Ariza, et al., 2012; Kliegl et al., 2013; Storm et al., 2013), one out of three lists (Kliegl et al., 2013; Sahakyan, 2004), or two out of three lists (Kliegl et al., 2013; Sahakyan, 2004). However, as far as we know, the proportion of TBF relative to TBR information in the list has never been manipulated. This manipulation would help us to better understand the mechanisms that underlie SDF. In order to correctly accomplish the SDF task, participants need to select the to-be-forgotten items. Therefore, regardless the mechanism acting after selection, successful intentional forgetting could be dependent on the relative proportion of information to forget. Because intentional forgetting is thought to require executive control (Conway & Fthenaki, 2000; Conway, Harries, Noyes, Racsmány, & Frankish, 2000; Gómez-Ariza et al., 2013), we argue that the SDF effect could be modulated by the demands of control imposed by the selection process.

In order to address this issue we modified the standard SDF procedure used by Delaney et al. (2009) by including two conditions where an additional character was added to List 1. These conditions were thus composed of 3 characters so that we were able to manipulate the proportion of List 1 information to be forgotten. Thus, whereas one group was asked to forget 1 out of 3 characters, other group was asked to forget 2 out of 3 characters. There was also a control group that was asked to remember three characters. Based on previous research on selective attention using visual search tasks, we expected the to-be-forgotten/to-be-remembered ratio to modulate the

SDF effect. Reijnen, et al. (2013) found that search efficiency is determined by the target-to-distractor ratio rather than by the absolute difference between the number of distractor and target stimuli. Of relevance for our study, they found an asymmetry effect whereby searching for a smaller number of items among a large set was harder than searching for a larger number among a smaller set of items. Hence, we expected the forget-1/3 condition to involve more difficult selection processes (since participants were to select 33% of the encoded information to forget it), than the forget-2/3 condition (in which participants have to select the 66% of the information). We hypothesized that making SDF more selective could also provide us with some indication regarding whether SDF draws on executive control.

Method

Participants

Seventy-one students from the University of Granada (Spain) participated in the study for either course credits or the amount of 6 Euros (mean age = 22.36 years, *SD* = 4.35; women = 41).

Materials and procedure

Participants studied two lists of sentences that were created from the lists used in Experiment 1, but modified to include a third character named Martin (see Appendix II). Thus, the original List 1 used in Experiment 1 containing 9 sentences regarding Tom and 9 sentences regarding Alex was modified so that it now consisted of 6 sentences about Tom, 6 sentences about Alex, and 6 sentences about Martin.

List 2 consisted of the same 14 sentences about the character named Joe. The first character of List 1 to be presented and the action-character assignation were both counterbalanced across participants, resulting in 9 versions of the task. The order of presentation of characters was rotated so that each character appeared every three trials. The sentences were presented in the middle of screen for 8 seconds with 1-second inter-item interval.

The procedure was similar to that used in Experiment 1, except for the cues to forget. Thus, in this experiment one group was cued to forget Tom (forget-1/3 group), other group was told to forget Tom and Martin (forget-2/3 group), and other group was instructed to remember all characters (remember group). As in the previous experiment, after either the cue to remember or forget, and also after studying List 2, all groups were asked to solve simple arithmetic operations for 90 seconds in order to discourage them from rehearsing the sentences. Then, a free recall test took place and participants were given 4 minutes to recall everything they could from the entire List 1 (Tom, Martin and Alex). Finally, they were given 4 minutes to recall List 2 sentences. Participants completed the same questionnaire as in the previous experiments. We replaced 4 participants in the forget-2/3 group because they reported not to believe the instructions to forget.

Results

List 1 recall: Selective Directed Forgetting

We first conducted a mixed factorial ANOVA on the recall percentages of List 1 with instruction (remember, forget-1/3, and forget-2/3) as the between-participants factor and character (Tom, Martin, and Alex) as the within-participant factor. The main effect of instruction did not reach statistical significance $F(2,68) = 1.23$, $MSE = 1278.1$, $p = .29$, $\eta_p^2 = .03$. However, the main effect of character, $F(2,136) = 5.08$, $MSE = 216.5$, $p < .01$, $\eta_p^2 = 0.06$, and, importantly, the interaction instruction x character was significant $F(4,136) = 4.55$, $MSE = 216.5$, $p < .01$, $\eta_p^2 = 0.11$. To qualify this interaction we conducted separate factorial ANOVAS for each forget condition. Means and standard errors can be seen in Figure 2.

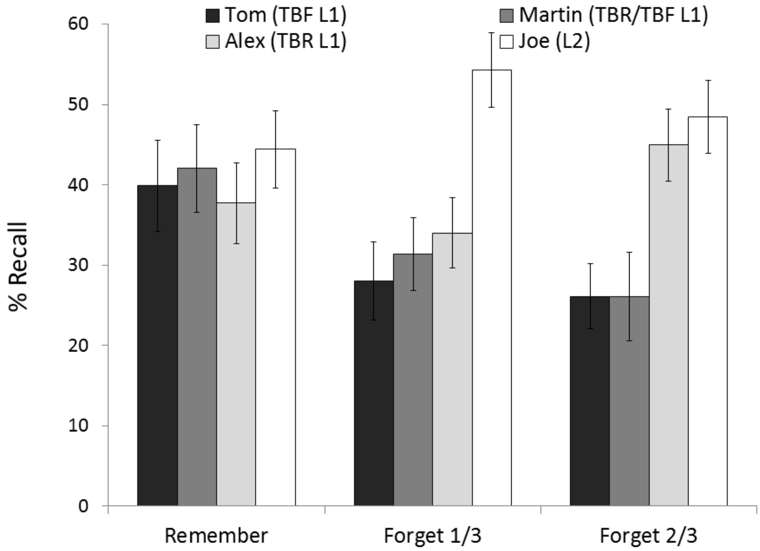

Figure 2. Mean percentages of correct recall as a function of instruction and character. Error bars represent standard errors of mean.

Remember and forget-1/3. The ANOVA 2 (instruction: remember vs. forget-1/3) x 2 (character: Tom, Martin and Alex) revealed that the interaction was not statistically significant $F(2,92) < 1$, $p = .38$, $\eta_p^2 = .02$. Neither the main effect of instruction, $F(1,46) = 2.10$, $MSE = 1302.9$, $p = .15$, $\eta_p^2 = .04$, nor the main effect of character reached statistical significance, $F(2,92) < 1$, $p = 0.67$, $\eta_p^2 < .01$.

Remember and forget-2/3. This ANOVA also showed a non-significant effect of instruction, $F(1,44) = 1.51$, $MSE = 1276.5$, $p = .22$, $\eta_p^2 = .03$. However, the main effect of character, $F(2,88) = 3.75$, $MSE = 251.3$, $p < .05$, $\eta_p^2 = .07$, (Tom, $M = 32.97$, $SD = 24.46$, Martin, $M = 34.05$, $SD = 27.20$, Alex, $M = 41.30$, $SD = 22.97$), and, more importantly, the interaction instruction x character did reach statistical significance, $F(2,88) = 7.50$, $MSE = 251.3$, $p < .001$, $\eta_p^2 = .14$. Further analyses revealed a reliable SDF effect: whereas the forget-2/3 group recalled fewer sentences about Tom [$F(1,44) = 3.87$, $MSE = 562.69$, $p = .055$, $\eta_p^2 = .08$] and Martin [$F(1,44) = 4.23$, $MSE = 690.60$, $p < .05$, $\eta_p^2 = .08$] than the remember group did, both groups recalled Alex items to the same degree, $F(1,44) = 1.14$, $MSE = 525.91$, $p = .28$, $\eta_p^2 = .02$.

List 2 recall

For completeness we also carried out a one-way ANOVA on recall percentages of List 2. The results revealed a non-significant main effect of group, $F(2,68) = 1.15$, $MSE = 513.1$, $p = .32$, $\eta_p^2 = .03$.

Discussion

Whereas some findings suggest that intentional forgetting, as measured with LM-DF procedures, may recruit executive control (e.g., Conway et al., 2000; Hanslmayr et al., 2012), it remains unknown if it also applies to selective directed forgetting. Thus, in this experiment we approached this issue by manipulating the selectivity component in the SDF procedure. Our aim was to explore possible modulating factors of the SDF effect and we expected the selection demands to be one of these factors. We thought that manipulating the proportion of information to be forgotten could also provide us with insights regarding the involvement of executive control in SDF and the nature of the mechanism underlying the effect.

Given that selective intentional forgetting might involve higher demands of memory control than forgetting a whole set of items, we created conditions of high and low selectivity. If selectivity in the SDF procedure is driven by executive control, one would expect successful performance to depend on the level of selectivity required by the instruction to forget. Thus, we modified the original procedure introduced by Delaney et al. (2009) to add one more character to List 1 and manipulated the amount of information to be forgotten (TBF) and remembered (TBR).

The present experiment replicated the SDF effect found in Experiment 1 and also in some previous studies (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). This is an important finding because some studies have failed to show the effect (Sahakayan, 2004; Storm et al., 2013). Specifically, we observed a clear SDF effect in the low selectivity group (forget 2/3). However, and of relevance for our main purpose, we did not find any evidence of selective forgetting in the condition with the highest demand of selectivity (forget 1/3). Moreover, although this group showed a slight trend towards forgetting the entire List 1, this effect was not reliable indicating that under this more difficult condition, participants were not able to use the mechanism that entitle them to forget. This suggests that increments in the difficulty of selection impair the capacity of the participants to select the proper items and to forget.

Based on previous findings in the realm of visual selective attention (Reijnen et al., 2013), we assumed that correctly performing the SDF task (that is, selecting the forget items and forgetting them) might be harder with low proportion of TBF items. The results of the present experiment support this assumption and indicate that the TBF/TBR items ratio modulates the ability to intentionally forget in a selective way. Specifically, it seems that making intentional forgetting more demanding (because of a lower amount of to-be-forgotten information relative to the TBR information) compromises the selection and downregulation of to-be-forgotten memories. If so, our finding of no forgetting effect in the forget-1/3 condition might indirectly be suggesting that SDF depends on executive control capacities that may be overstressed when the demands for selectivity are high.

Our results seem to indicate that SDF is mediated by some control mechanism that might be inhibitory in nature and that would act on the selected TBF items (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). However, successful SDF could also be achieved through non-inhibitory processes. Thus, for example, after receiving the cue to forget people could engage in selectively rehearsing TBR items from List 1. From this view, selective forgetting could result from differential encoding for TBR and TBF items. Whereas further research is needed to make clear this point, some aspects of our experiment do not fit well with the selective rehearsal hypothesis. First, after being told to either forget or remember, participants solved a set of math operations that presumably discouraged them from rehearsing. Second, if selective rehearsal were the mechanism responsible for the SDF effect, one would expect TBR items to be better recalled in the forget groups than in the remember group. This, however, was not the case in this study nor was in previous experiments observing SDF (including our Experiment 1).

The main finding of the present experiment agrees with those reported by Gómez-Ariza et al. (2013). In their study a group of healthy adolescents exhibited a SDF effect while an age-matched group diagnosed with social anxiety disorder failed to show SDF. Interestingly, and in line with results from the forget-1/3 group of the current experiment, the clinical group did not exhibit forgetting at all of List 1. Gómez-Ariza et al. (2013) attributed this absence of forgetting to the executive control deficits associated with high anxiety, so suggesting that SDF involves executive control. In this line, it might be argued that when executive control is overtaxed (either because of the demands of the task or because of a neurocognitive impairment), participants are not able to select the target information and no forgetting at all is observed.

In summary, in the present experiment our results suggest that SDF is modulated by the selectivity demands imposed by the task, which might be indicative of the role that executive control might play in SDF. In the next two experiments we attempted to directly test this idea by taking a dual-task approach. According to this methodology, if two tasks rely on the same process, then concurrently performing them will cause a detrimental effect in performance of, at least, one of the tasks. Thus, in the next two experiments we use two different concurrent tasks to be performed during List 2 study. In Experiment 3 participants studied List 2 while performing an updating task that is well known to rely on executive control (Román, Soriano, Gómez-Ariza, & Bajo, 2009). In Experiment 4, however, participants studied List 2 while concurrently performing an articulatory suppression task, which is thought to tap much less on executive control (Baddeley, 1986; Baddeley & Larsen, 2007; Murray, 1968). To the extent that SDF depends on attentional control after the cue to forget, the effect should be reduced or eliminated with a highly demanding concurrent task.

Experimental series II

Selective directed forgetting and attentional resources

Experiment 3

Dual-task procedures have previously been used to study the nature of the mechanisms thought to underlie incidental and intentional types of forgetting. Thus, for example, Román et al. (2009) found that performing a concurrent updating task during retrieval practice led participants to show less retrieval-induced forgetting (an incidental type of forgetting that is thought to be an aftereffect of an inhibitory mechanism that suppress competing memories during selective retrieval), which suggests that the updating task hindered the executive processes in charge of suppressing competing memories (see also Ortega, Gómez-Ariza, Román, & Bajo, 2012). As for intentional forgetting, the studies by Conway et al. (2000) and Soriano and Bajo (2007) provide evidence that LM-DF is driven by executive control. In their experiments (Conway et al., 2000, Experiment 4; Soriano & Bajo, 2007, Experiment 2), participants were instructed to learn a sequence of six digits just after receiving the instructions to forget or to remember List 1, and to keep the sequence in mind while learning List 2 since their memory for the digits was going to be tested later. In Conway et al.'s study (Experiment 4) the memory cost of the instruction to forget was absent in the dual-tasking condition. By using a similar dual-task procedure Soriano and Bajo (2007; Experiment 2) also failed to observe directed forgetting in a group of participants with low working memory capacity (WMC). Interestingly, they also found that participants with high WMC did show the memory cost even when performing the concurrent task. According to the authors, whereas the concurrent memory task overloaded the cognitive resources of the low WMC participants so that they were not able to exert control over the TBF items in memory, their high WMC counterparts forgot successfully by virtue of a greater availability of executive control resources.

On the basis of the aforementioned results and those from studies on SDF suggesting that selective voluntary forgetting may depend on executive control (Gómez-Ariza et al., 2013), in Experiment 3 we aimed to learn the extent to which the SDF effect may be hindered by overloading attentional control. To do so, we borrowed the continuous updating task used as concurrent task by Román et al. (2009). In this task participants are to listen to a random digits sequence and to press a bottom whenever three odd numbers are presented in a row. Given that this task requires participants to continuously update working-memory contents, it becomes highly demanding and it is especially suited to tax executive control. Thus, and partially following the procedure used in previous dual-tasking studies on intentional forgetting (Conway et al., 2000; Soriano & Bajo, 2007), in the present experiment participants engaged in the updating task just after receiving the remember/forget instruction.

If executive control mediates the SDF effect, overloading control resources with the updating task should compromise the ability to selectively forget. Based on results by Conway et al. (2000)

with the standard LM-DF procedure, one could expect the concurrent task to diminish or eliminate the SDF effect, relative to the single condition.

Method

Participants

One hundred and twenty eight participants (mean age = 19.58 years; *SD* = 2.28; 81 women) were randomly assigned to the experimental conditions. All of them were undergraduate students from the University of Granada who received either course credit or money for their participation. We replaced participants who admitted they did not believe the forget cue and, accordingly, they did not try to forget (9 from in the single condition and 2 from the dual condition)

Materials and procedure

The details regarding the presentation and the character-action counterbalancing procedures of the experimental sentences were the same as used in Experiment 1 (see Appendix I). Half of the participants were randomly assigned to the standard “single” SDF condition as introduced by Delaney et al. (2009) and the other half was assigned to perform the “dual-tasking” SDF condition. The single condition closely followed the procedure of Experiment 1, although changes were made in the distracter task to better suit the purpose of the study. Thus, instead of arithmetic operations in this experiment we used an updating task consisting of the auditory presentation of pseudorandom sequences of single digits at a rate of 1 digit per second. The proportion of odd digits was twice as much the proportion of even digits. Participants were instructed to press a key whenever they heard three odd digits consecutively. We had two reasons to use the updating task as a distracter task. First, and as in our previous experiments, by using a distracter task we minimized the chances to rehearse during the interval between List 1 and List 2 presentation. Second, because participants also performed this task as a concurrent task in the dual-tasking condition, we provided them with practice before introducing the concurrent task during the List 2-study phase. The procedure in the dual-tasking condition was similar to that in the single condition with the only difference that participants were asked to study List 2 and perform the updating task at the same time. Thus, after going through List 1study and the updating distracter task, participants in the dual condition were instructed to learn List 2 sentences while performing the updating task (participants in the single condition were only instructed to study List 2). Once they finished List 2 learning, all participants performed the updating task as a new distracter task for 90 seconds and, finally, they were given the free recall test.

Participants filled out the same questionnaire as in Experiments 1 and 2. The experimental session lasted about 40-45 minutes.

Results

As in previous experiments we first report results for List 1 and then describe analyses for List 2. Means and standard errors can be seen in Figure 3.

List 1 recall: Selective Directed Forgetting

We conducted a mixed factorial analysis of variance (ANOVA) on the recall percentages with condition (single and dual) and instruction (remember and forget) as the between-participants factors, and character (Tom and Alex) as the within-participants factor.

The ANOVA revealed a main effect of instruction, $F(1,124) = 5.96$, $MSE = 670$, $p < .05$, $\eta_p^2 = .04$ (remember $M = 38.88$, $SD = 21.23$; forget $M = 30.98$, $SD = 18.79$), and a significant interaction between instruction and character, $F(1,124) = 1.55$, $MSE = 137.1$, $p < .05$, $\eta_p^2 = .03$. The main effect of condition [$F(1,124) < 1$, $p = .70$, $\eta_p^2 < .1$], the interaction condition x instruction [$F(1,124) < 1$, $p = .30$, $\eta_p^2 < .007$] and the main effect of character [$F(1,124) < 1$, $p = .5$, $\eta_p^2 < 1$] were not significant. The interaction character x condition was however marginally significant, $F(1,124) = 2.95$, $MSE = 137.1$, $p = .08$, $\eta_p^2 = .02$. Finally, although the highest order interaction did not reach statistical significance, $F(1,124) = 1.55$, $MSE = 137.1$, $p =.21$, $\eta_p^2 =.01$, because of its relevance for our hypothesis we conducted separated analysis for each condition.

Single condition. The mixed ANOVA with instruction and character as factors showed the usual SDF interaction to be statistically significant, $F(1,62) = 6.14$, $MSE = 132$, $p < .05$, $\eta_p^2 = .09$; the simple effects of instruction and character were not [instruction: $F(1,62) = 1.13$, $MSE = 622,2$, $p = .29$, $\eta_p^2 = .01$; character: $F(1,62) < 1$, $p = .4$, $\eta_p^2 < .01$]. Planned comparisons on the significant interaction revealed that the forget group tended to recall fewer Tom items (TBF items) than the remember group, $F(1,62) = 3.48$, $MSE = 433,46$, $p = .06$, $\eta_p^2 = .05$, while both groups recalled Alex items (TBR items) to the same extent, $F(1,62) < 1$, $\eta_p^2 < .01$.

Dual condition. In contrast to the single condition, the ANOVA (instruction x character) on the recall percentages indicated that the usual character x instruction interaction was not statistically significant, $F(1,62) < 1$, $\eta_p^2 < .01$. Similarly, the main effect of character [$F(1,62) = 2.7$, $MSE = 142.1$, $p = .10$, $\eta_p^2 = .04$] failed to reach statistical significance. Interestingly, there was a significant main effect of instruction, $F(1,62) = 5.5$, $MSE = 717.8$, $p < .05$, $\eta_p^2 = .08$ (remember group: $M = 40.97$, $SD = 23.41$; forget group: $M = 29.86$, $SD = 17.47$), thus revealing an overall forgetting effect in the group cued to forget, but no evidence of selectivity.

List 2 recall

An ANOVA on recall percentages with condition and instruction as the between-participants factors items showed that participants in the dual condition ($M = 14.84$; $SD = 13.12$) recalled fewer items than participants in the single condition ($M = 47.54$; $SD = 21.22$), $F(1,124) = 108.86$, $MSE = 314.3$, $p < .01$, $\eta_p^2 = .89$. No other source of variance reached statistical significance [instruction: $F(1,124) < 1$, $\eta_p^2 < .01$; interaction: $F(1,124) < 1$, $\eta_p^2 < .01$].

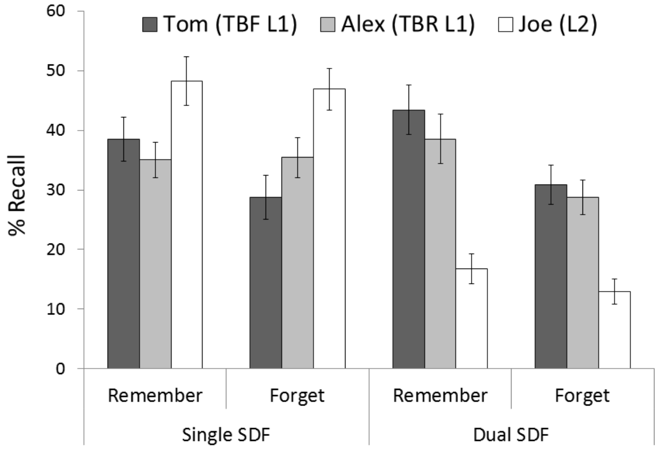

Figure 3. Mean percentages of correct recall as a function of condition, instruction and character. Error bars represent standard errors of mean

Updating task

Performance on this task was analyzed by looking at accuracy (errors) and reaction time measures (see Table 1).

In order to understand the impact of dual tasking on performance during the updating task, we carried out an instruction (remember and forget) x updating condition (1st single distracter, dual task, and 2nd single distracter) ANOVA on each dependent measure. The analysis on errors revealed that the only significant source of variance was updating condition, $F(2,122) = 6.50$, $MSE = .0009$, $p < .01$, $\eta_p^2 = .096$. Planned comparisons showed that participants made fewer errors in the 1st single distracter task than in the dual task condition $F(1,61) = 12.36$, $MSE = .0009$, $p < .01$, $\eta_p^2 = .16$., and in the 2nd single distracter task, although this latter effect was only marginal, $F(1,61) = 3.44$, $MSE = .0006$, $p = .06$, $\eta_p^2 = .05$. Similarly, the ANOVA on RT only showed updating condition to be significant, $F(2,122) = 6.36$, $MSE = 7912$, $p < .01$, $\eta_p^2 = .094$. Planned comparisons revealed that RTs in the dual task and in the 2nd single distracter task conditions were significantly longer than RT in the 1st distracter task condition; respectively, $F(1,61) = 17.06$, $MSE = 5299.94$, $p < .01$, $\eta_p^2 = .21$ and $F(1,61) = 6.46$, $MSE = 8740.50$, $p < .01$, $\eta_p^2 = .095$. The results of these analyses suggested, then, that updating was impaired by the simultaneous study of List 2, but it also showed that single updating after List 2 study was more difficult than single updating before List 2 study.

In addition, to better understand this last effect, we conducted a second set of analyses in which we considered performance on the updating tasks only when they were performed as distractor tasks in both the dual and single SDF conditions. We first analyzed updating performance before List 2 presentation (1st distractor task). The ANOVA with condition (single and dual) and instruction (remember and forget) as factors showed that for both percentage of errors and RTs there were no significant sources of variance (main effects and interactions with $F<1$ and $\eta_p^2 < .01$), indicating that the instructions to forget were not affecting updating performance before List 2 was presented.

In contrast, the ANOVA performed on updating errors after List 2 (2nd distractor task) revealed a significant interaction between condition (single and dual) and instruction (remember and forget), $F(1,115) = 4.09$, $MSE = .002$, $p < .05$, $\eta_p^2 = .03$. Planned comparisons revealed that participants in the forget group of the single SDF condition made significantly more errors than participants in the remember group of the same condition [$F(1,115) = 6.72$, $MSE = .002$, $p < .01$, $\eta_p^2 = .05$]; while the forget and remember groups in the dual SDF condition made the same level of errors [$F(1,115) = .03$, $MSE = .002$, $p = .84$, $\eta_p^2 = .0003$]. These differences were however no evident on RTs (main effects and interactions with $F<1$ and $\eta_p^2 < .01$). The condition x instruction interaction on errors is interesting because it suggests that the difficulty of updating after List 2 was more evident when participants were instructed to forget after List 2 in the single condition.

		Single SDF		Dual SDF	
		Remember	Forget	Remember	Forget
Errors (%)	First single distracter task	.015 (.040)	.018 (.038)	.022 (.059)	.010 (.020)
	Concurrent task	-	-	.041 (.052)	.036 (.047)
	Second single distracter task	.004 (.01)	.039 (.074)	.027 (.043)	.024 (.048)
RT (ms)	First single distracter task	681.94 (112.2)	701.68 (131.83)	710.30 (157.13)	705.46 (133.08)
	Concurrent task	-	-	784.42 (166.44)	741.46 (140.41)
	Second single distracter task	705.1 (141.77)	713.84 (118.45)	740.01 (206.79)	764.79 (170.56)

Table 1. Mean reaction time and percentage of errors (and standard deviations) in the updating task performance as a function of condition (single/dual), instruction (remember/forget) and its role as first or second distracter task and as a concurrent task during List 2 presentation.

Discussion

Recent studies suggest that LM-DF effects are driven by inhibitory control (e.g., Bäuml et al., 2008; Hanslmayr et al., 2012). However, the mechanism underlying the SDF effect has not been investigated. In this experiment we explored the controlled nature of the mechanism producing the SDF effect by comparing performance in a standard SDF condition (Delaney et al., 2009) with performance in dual-task condition where participants were asked to perform a concurrent task right after receiving the instruction to forget. Based on previous results showing that performing a secondary task during List 2 study reduces or eliminates forgetting in standard LM-DF procedures (Conway et al., 2000; Soriano & Bajo, 2007), we used the dual task methodology with the SDF procedure and added an updating concurrent task during List 2 study. If controlled processes are necessary for the SDF effect to occur, one could expect that the effect would diminish in the dual-tasking condition relative to the single condition.

By analyzing performance on the single and dual task conditions, we observed a clearly different pattern of results. Thus, the single SDF condition revealed a reliable SDF effect. However, when we modified the procedure and introduced a concurrent updating task during List 2 study to overload executive control, the pattern of forgetting changed: participants in the forget group recalled significantly fewer List 1 items (both TBF and TBR items) than participants in the remember group, suggesting that the concurrent task abolished the selectivity component of the ability to intentionally forget. This pattern suggests that when executive control is stressed during List 2 learning, it is selectivity, rather than the capacity to forget what is compromised. Hence, these findings point to an important role of attentional control during selective directed forgetting.

Surprisingly, dual tasking produced overall forgetting whereas no forgetting at all would be expected. However, it is possible that participants in the dual-tasking condition might still have some resources available to generally down regulate memories despite being unable to do it selectively. Together with those from Experiment 2, the present results suggest an important dissociation between the selection process and the forgetting process. In Experiment 2, increments on the difficulty of the selection process globally eliminated the forgetting effect. In the present experiment, however, stressing cognitive resources by means of a concurrent task made SDF disappear but led participants to forget TBF as well as TBR List 1 items. Thus, it is possible that different variables differentially affect the two possible processes involved in SDF (target selection and forgetting).

Our results are partially consistent with those reported by Conway et al. (2000) and Soriano and Bajo (2007). In these studies the presence of a concurrent task eliminated directed forgetting, whereas in the present study forgetting was still present. This apparent inconsistency might however be explained considering the nature of the concurrent tasks used as well as the demands of the forgetting tasks (selective vs. non-selective). Thus, in the studies by Conway et al. (2000) and Soriano and Bajo (2007) the secondary task was a memory span task wherein participants had to keep six numbers in mind while studying List 2. In contrast, we used a concurrent updating task that made participants to continuously update working memory contents. While it is not obvious to us how these two concurrent tasks might be influencing DF and SDF effects, interactions between updating and selectivity may be producing differential results. In addition, Soriano and Bajo (2007) had high and low WM participants in their study and the abolishment of the DF effect with the concurrent task was only observed for the low WM span group. Given that we did not measure WM span in our participants, we are blind regarding how this variable might have influenced our results. Most likely, however, our participants might have been medium-high WM span participants who, on average, might have enough resources available to globally forget. Further research regarding working memory capacity and SDF should be conducted to clarify this point.

Interestingly, the results of the updating task indicated that the group cued to forget in the single SDF condition made more errors than the remember group in the same condition. This difference might indicate that when participants are instructed to forget, an effortful executive control mechanism may be triggered during List 2 learning. It is interesting that both the remember and forget groups in the single SDF condition only differ in the instructions received previous to studying List 2 and therefore the increments in errors can only be attributed to the forgetting instructions. One possible reason for this increment in errors might be related to resource depletion caused by the attempts to forget. According to the resource depletion framework, higher cognitive processes are resource limited and can be temporarily exhausted (Anguera et al., 2012; Engle, Conway, Tuholski, & Shisler, 1995; Muraven & Baumeister, 2000; Parasuraman, 1998). Therefore, the increment in updating errors in the forget condition after List 2 learning might be due to resource depletion due to the executive control processes used during List 2 learning to make part of List 1 less accessible. Regardless the specific mechanism involved in this selective forgetting effect, here we argue that possibilities are that the mechanism recruited by the forget group is cognitive demanding. In addition, the difference in updating performance between the forget and remember condition was only evident after List 2 learning and it was not present during the updating task performed before presentation of List 2. This suggests that this executive control mechanism is not immediately triggered by the instructions to forget, but later on upon presentation of a new list.

In general terms, then, our results support that SDF depends upon effortful control. Altogether, the findings of Experiments 2 and 3 allow us to suggest that the ability to selectively intentionally forget relies on executive control capacities. However, one might still argue that the lack of selectivity of the forgetting effect in our Experiment 3 is a byproduct of just introducing a concurrent task during List 2 study, regardless its executive demands. Thus, before strongly claiming that SDF taps on cognitive control it becomes necessary to conduct a new dual-tasking experiment with a concurrent task involving executive control to a much lesser extent. In the next experiment we conduct such an experiment.

An additional reason to do the next experiment has to do with an attempt to rule out alternative accounts of the SDF effect. As previously noted, the effect could in principle be understood either from an inhibitory or a selective-rehearsal account. SDF could be thought of as a memory cost reflecting the aftereffect of having previously exerted inhibitory control over certain information (which would be an effortful process). Alternatively, SDF could be attributed to a less demanding process; namely, after being cued to forget participants could engage in selective rehearsing of the TBR items of List 1. If so, TBF items would become more poorly encoded than TBR items, which would make them less recallable. In Experiment 4 we also address this issue by using a concurrent task taxing rehearsal processes.

Experiment 4

The main purpose of this experiment was to further explore the involvement of executive control in the SDF effect. To do so, we again used a dual-task approach but with a lower demanding concurrent task. Experiment 3 showed that overloading attentional control hinders the ability to selectively forget suggesting that this ability relies on executive control. However it would still be possible to argue that the simple act of dual tasking, regardless the attentional demands of the secondary task, is what hampers SDF. Thus, to claim that SDF taxes executive control it is important to show that the experimental effect appears with a secondary task entailing relatively low demands of executive control.

In this experiment we used an articulatory suppression task during the study of List 2 as a concurrent task. In articulatory suppression studies participants are asked to say irrelevant sounds, numbers or syllables while they are memorizing a set of items. The subsequent recall of these items is significantly impaired because of the repetitions, which are thought to prevent items from being rehearsed. Indeed, it has been well established that this concurrent articulation disrupts the action of the phonological loop (Baddely, 1986; Baddeley & Larsen, 2007; Murray, 1968). Importantly, the effect of articulatory suppression does not seem to be due to overtaxing attentional resources. Also of relevance, because the articulatory suppression task prevents people from rehearsing (while imposing low attentional demands), it is particularly suitable to address the role of selective rehearsal in producing the basic experimental effect found with the SDF procedure.

As previously mentioned, the SDF effect apparently fits well into two different accounts of directed forgetting. From an inhibitory view (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), SDF could be thought as an aftereffect of an inhibitory-like mechanism in charge of suppressing irrelevant memories (Bjork, 1998; Anderson, 2005). If that is the case, the SDF effect could reflect the action of an intentionally driven control mechanism that is selectively targeted to the information cued to forget. On the contrary, from a selective rehearsal account, SDF could result from a better encoding of the TBR items, relative to the TBF ones, because of selective rehearsal of the TBR following instructions to selectively forget (Storm et al., 2013). If so, a straightforward prediction in the present experiment is that articulatory suppression should reduce the SDF effect. On the other hand, if SDF does not rely on selective rehearsal, the selective memory cost should even arise when articulatory suppression is performed concurrently. If the latter was the case, and taking our previous results into account, one could argue that the mechanism responsible for SDF is effortful and independent of rehearsal. In addition, finding SDF with articulatory suppression as a secondary task would also enable us to claim that SDF is not a byproduct of selective rehearsal.

Method

Participants

Fifty-six students from the University of Granada took part in the study for money. Their mean age was 20.03 (*SD* = 2.13; 34 women).

Materials

The same sentences as in Experiments 1 and 3 were used here (see Appendix I). In addition, we used a metronome to let participants know the right speed to repeat 'Bla'.

Procedure

The procedure was the same as used in the dual condition of the previous experiment, except for the secondary task, that in the present experiment was articulatory suppression. In this condition, participants were asked to repeatedly say the syllable 'Bla' at a rate of 80 beats per minute. Importantly, participants performed articulatory suppression during the intervals of time that were more likely for participants to rehearse the TBR items: namely, during List 2 study, just after receiving the forget/remember cue and, importantly, also while the instruction was being given. We decided to give participants the remember/forget instruction after they had started the articulatory suppression task because otherwise rehearsal of the to-be-remembered items (Alex) could take place meanwhile the specific instruction was provided. Thus, by giving the cue to forget while performing the articulatory suppression task we wanted to avoid any chance for the participants to verbally rehearse the TBR material. The procedure took place as follows: first, participants studied List 1 and right after they were asked to perform the articulatory suppression task. Participants started to pronounce 'Bla' before being given any instructions either to forget or remember. Specifically, they were given the forget/remember instruction only after having been saying 'Bla' for about 10 seconds, and continued with the articulatory suppression task for 90 more seconds. At that point, with participants still saying 'Bla', they were to study List 2 while still engaged in the articulatory suppression task. Once List 2 presentation ended, participants continued saying "Bla" for other 90 seconds. After that, the free recall test took place. Participants first recalled List 1 and then List 2. The same questionnaire as the previous experiments was administered. We replaced 9 participants in the forget group who reported not to believe the instructions.

Results

List 1 recall: Selective Directed Forgetting

To check for SDF we conducted a mixed ANOVA on the recall percentages with instruction (remember and forget) as the between-participants factors and character (Tom and Alex) as the within-participant factor. The analysis revealed that the main effect of character was statistically significant, $F(1,54) = 6.83$, $MSE = 117.5$, $p < .05$, $\eta_p^2 = .11$, (Tom: $M = 34.72$, $SD = 19.07$; Alex: $M = 40.07$, $SD = 20.50$). The effect of instruction did not reach significance, $F(1,54) = 1.05$, $MSE = 655.9$, $p = .31$, $\eta_p^2 = .01$, but the usual SDF interaction instruction x character was significant, $F(1,54) = 5.86$, $MSE = 117.5$, $p < .05$, $\eta_p^2 = .09$. Planned comparisons showed that the forget group recalled fewer items about Tom (*M* = 29.76, *SD* = 20.74) than the remember group (*M* = 39.68, *SD* = 16.12), [*F*(1,54) = 3.99, *MSE* = 345.14, *p* = .05, η_p^2 = .06]. Both groups, however, recalled Alex items to the same extent [forget: *M* = 40.07, *SD* = 22.29; remember: *M* = 40.07, *SD* = 18.96; *F*(1,54) < 1, η_p^2 < .001]. Results can be seen in Figure 4.

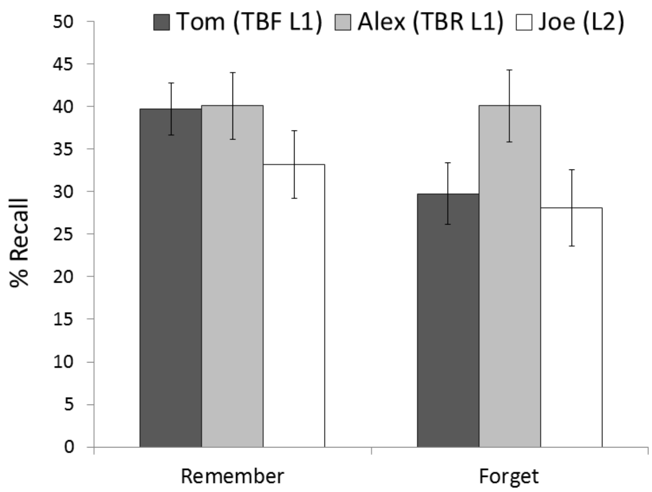

Figure 4. Mean percentages of correct recall as a function of instruction and character. Error bars represent standard errors of mean

List 2 recall

The one-way ANOVA on the recall percentages of List 2 showed that there was no statistical difference between the two instruction groups, *F*(1,54) = 1.21, *MSE* = 506.56, *p* = .27, η_p^2 = .02.

Discussion

The aim of the present experiment was twofold. First, we wanted to further explore the idea that executive control is involved in SDF by using a concurrent task that is not thought to rely on executive control (which contrasts with the one used in Experiment 3). If SDF recruits executive control, a secondary task demanding low attentional control should allow the SDF effect to appear. Secondly, we aimed to directly test the involvement of selective verbal rehearsal in SDF. Both aims were achieved by having participants perform articulatory suppression after studying List 1 and List 2 as well as during List 2 presentation. Articulatory suppression is a well-known experimental task thought to prevent rehearsal while scarcely drawing on executive control. Thus, if selective verbal rehearsal is the strategy used by participants to face the instruction to forget, one would expect the effect to be absent or diminished when participants perform articulatory suppression at the times when, otherwise, they would be engaged in rehearsing.

The results of the present experiment show a reliable SDF effect that is similar to those found in previous experiments of this series (Experiment 1; single condition of Experiment 3) and experiments by others (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013; but see Storm et al., 2013). Taken together, the findings of Experiments 3 and 4 strongly suggest that SDF relies on executive control by revealing dissociation between the effects of the two concurrent tasks used in both experiments. Thus, while the updating task seems to hamper the ability to selectively forget, the articulatory suppression task apparently has no effect at all on the mechanisms underpinning SDF.

Regarding our second aim, the present results seem to suggest that selective rehearsal strategy cannot easily account for SDF. Although cognitive load is not excessive under articulatory conditions, the memory traces cannot be verbally rehearsed in this situation and the recall is impaired (Baddeley, 1986; Baddeley & Larsen, 2007; Murray, 1968). If this is the case, the presence of SDF in this experiment cannot be attributed to rehearsal of the TBR items. Hence, this finding raises an important conclusion regarding the possible mechanism underlying SDF; whereas the present results do not fit well with a rehearsal-based account of SDF, they are compatible with an inhibitory account of the effect. From this view, an inhibition-like mechanism would be triggered in response to the forget cue to make the to-be-forgotten information less accessible.

In Experiments 5 to 7 we attempt to elucidate this question by using an individual differences approach. Based on the extended idea that aging involves a decline in executive-control capacities, we use both the standard and the selective LM-DF procedures to study the ability to intentionally forget of older and younger adults. Given that aging is also thought to bring a decline in inhibitory control, older adults would be expected to show less SDF than their younger counterparts. In addition, failing to observe SDF in older adults while observing standard (no selective) DF, relative to younger adults, would support the idea that executive control plays an important role in the capacity to selectively forget.

Experimental series III[1]

Selective directed forgetting and aging

An influential view on cognitive development suggests that aging brings a decline in inhibitory efficiency (Hasher & Zacks, 1988; Hasher, Zacks & May, 1999). Because of this inhibitory deficit, older adults are less able to control for interference from irrelevant (external or internal) stimuli. They also present with less efficient withdrawing from dominant but inappropriate responses. As a result, age-related differences may be observed in processing of task-relevant information. Evidence supporting this inhibitory account of cognitive aging comes from a variety of experimental tasks thought to draw on inhibitory control (for a review see Lustig, Hasher, & Zacks, 2007). Thus, for example, older adults have more difficulty than younger adults on the antisaccade task (Butler, Zacks, & Henderson, 1999; Olincy, Ross, Young, & Freedman, 1997), discarding misleading interpretations of text passages as confronted with conflicting evidence (Hamm & Hasher, 1992), and responding in the Stroop test (West & Alain, 2000), where the aging effect has been found despite controlling for speed of processing.

[1] This experimental is now published as Aguirre, C., Gómez-Ariza, C.J., Bajo, M.T., Andrés, P., & Mazzoni, G. (2014). Selective voluntary forgetting in younger and older adults. *Psychology and Aging, 29*, 128-139.

More relevant for the present work, the age-associated decline in inhibitory control has been also observed in the realm of episodic memory. Radvansky, Zacks, and Hasher (2005), for example, used a memory analog to the negative priming paradigm (e.g., Tipper, 1985) to test the inhibitory-deficit hypothesis. They predicted that if competing memories on trial *N* are inhibited, the aftereffect of this process should be observable whenever the inhibited memories turn out to be targets on trial $N + 1$. Interestingly, they found that older adults had smaller costs (actually null) than their younger counterparts when recognizing specific pieces of information that had been distracters in previous trials. As Radvansky et al. (2005) argued, the fact that the older adults did not show reduced accessibility to negatively primed targets fits well with the idea that aging entails a deficit to inhibit memories that compete for retrieval. More recently, Anderson, Reinholz, Kuhl, and Mayr (2011) used the Think/No think paradigm to compare the ability to intentionally inhibit retrieval in younger and older adults. In two experiments they demonstrated that their aged participants, relative to their younger counterparts, showed significantly less forgetting of the items of which retrieval had been suppressed (but see Murray, Anderson, and Kesinger (2015); Murray, Muscatell, & Kensinger, 2011). Because forgetting in this paradigm is thought to be the consequence of inhibitory control over retrieval, Anderson et al.'s (2011) results also support the hypothesis that aging brings a decline in inhibitory capacities.

From the hypothesis that aging brings a decline in inhibitory control, one would expect older adults to show reduced DF cost, relative to younger adults, in LM-DF experiments if one assumes that inhibition is involved in DF effects. Impoverished capacity to intentionally inhibit episodic memories should make older people recall the to-be-forgotten items to the same extent as the to-be-remembered items. Contrary to this expectation, a number of studies that examined adult-age differences in LM-DF by comparing older adults (typically ranging from 60 to 75 years) and young university students essentially failed to show less forgetting in the first cohort (Sahakyan et al., 2008; Sego, Golding, & Gottlob, 2006; Zellner & Bäuml, 2006; but see Zacks, Radvansky, & Hasher, 1996). For example, using the standard procedure Sego, et al., 2006; (Experiment 2A) and Zellner and Bäuml (2006) reported comparable forgetting effects in younger and older adults. More recently, Sahakyan et al. (2008; Exp. 1) observed reduced memory impairment in the older relative to the younger participants. However, the authors attributed this age difference to older participants being more reluctant to follow the instruction to forget because they usually believe that they do not need to do anything to forget. This suspicion was confirmed in a second experiment whereby instructions were modified to emphasize the importance of forgetting List 1 and where comparable memory impairments were found in older and younger participants. Hence, Sahakyan et al.'s results join other findings to show no adult-age differences in the LM-DF procedure.[2]

[2] Zacks, Radvansky, and Hasher (1996) reported adult-age differences in directed forgetting with lists of items using an unusual procedure that involved repeated testing of the to-be-remembered items. Participants studied a series of word lists varying in number of items, and after studying each list they were told either to forget or remember the items of each. In the latter case, participants performed an immediate recall test. Finally, participants'

Recently, Aslan and Bäuml (2013) have shown that whereas LM-DF is present in the so-called “young-old” adults (60–75 years), thus replicating previous findings, no DF cost is observed in “old-old” adults (above 75 years). Interestingly, this result agrees with findings from different cognitive domains suggesting that executive-control processes decline rather late in life (for a meta-analysis see Verhaeghen, 2011). Thus, it would seem that the ability to voluntarily forget irrelevant or unwanted memories (at least as measured with LM-DF procedures) entails control processes that generally operate efficiently in healthy adults under their seventies. Although such a conclusion is suggestive, alternative explanations may be considered. Recent work on the retrieval-induced forgetting (RIF) effect (an incidental type of forgetting that is thought to be an aftereffect of inhibiting competing memories during selective retrieval) suggests that age differences in memory inhibition may result from differences in the control demands imposed by the experimental task. Ortega et al. (2012) have for example shown that a critical factor in finding adult-age differences in memory control tasks is the overall challenge posed by the tasks. It could then be the case that young-old adults show reduced (if any) memory cost in those LM-DF procedures that tax

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memory for the to-be-remembered and to-be-forgotten items was tested. Relative to the younger participants, the older ones showed a lesser recall difference between both types of items that the authors interpreted in terms of a deficit in exerting inhibition over nonrelevant memories. A possible criticism of this study, however, is that the nonstandard testing procedure could have enhanced participants’ memory for the to-be-remembered items relative to the to-be-forgotten items. Hence, the lesser memory cost in the older adults could be attributed to enhanced benefits from repetitive testing for the younger participants rather than to older adults’ poorer ability to forget.

more executive control than the standard ones used in previous studies. Ortega et al. (2012) reported that the RIF effect was eliminated in older and younger adults under dual-tasking conditions that, thus, were thought to impose high executive-control demands. Interestingly, whereas performing a concurrent three-digit updating task during retrieval did not eliminate the memory impairment in the younger participants (only a five-digit-updating task abolished the effect in the group of university students), the three-digit concurrent updating task was enough to eliminate forgetting in the older group. Thus, Ortega et al.'s findings support the idea that the mechanism underlying RIF taxes inhibitory executive control of memory (see also Román et al., 2009) and, more important here, suggest that aging brings a progressive loss of this capacity. More recently, Murray et al. (2015) have shown that when older adults are provided with the proper strategy to successfully suppress information, they exhibit similar suppression effects than younger adults in a Think/No think procedure (Murray et al., 2015). Hence, their results suggest that, by reducing the cognitive demands of the task by providing a strategy to face it, older adults seem to be able to engage in inhibitory processes. Also supporting this idea, Aslan and Bäuml (2012) found deficient RIF in old-old adults but not in young-old adults. Therefore, it could also be the case that a majority of people under 75 years of age may successfully engage in forgetting in the standard LM-DF task because this task only requires moderate levels of memory control and, hence, the task is not sensitive enough to reveal adult-age differences in the ability to intentionally forget.

As previously mentioned, the SDF procedure might involve higher demands of executive control than the standard LM-DF procedure. On the basis of the results from our previous experiments one could assume that the selective nature of the SDF procedure requires more demanding cognitive control than the standard (nonselective) procedure. If so, the SDF paradigm might be especially suitable for exploring individual differences in intentional forgetting. The rationale behind this assumption relies also upon previous work with the stop-signal task, a well-established procedure to measure inhibitory control over motor responses. Studies using different versions of this task have shown that the age-related differences in inhibition are easier to observe through a selective version of the task (where the stop signal requires suppression of responses to some stimulus but not to others; e.g., Bedard et al., 2002) than when using the nonselective standard version of the stop-signal procedure (Williams, Ponesse, Schachar, Logan, & Tannock, 1999). Hence, one could suggest that the SDF procedure imposes higher demands of memory control because it would require to select and suppress specific memories rather than to proceed to the global forgetting of an entire list. From this view, the process of selecting which information is to be discarded might burden the process in charge of making the target memories less accessible. Thus, relative to the standard DF procedure, the SDF procedure would entail higher level of cognitive control that would surpass the capacity of older adults.

Of course, to what extent the SDF paradigm is a better procedure than the standard one to reveal adult-age differences in intentional forgetting is an empirical question. However, the SDF paradigm has now shown to be useful to investigate differences in memory control between healthy and clinical samples (Gómez-Ariza et al., 2013). Supporting the hypothesis that high anxiety entails impoverished executive control (Bishop, 2009; Pacheco-Unguetti et al., 2010), Gómez-Ariza et al. (2013) found reliable SDF in a group of nonclinical adolescents but failed to find the effect in a group of participants diagnosed with social anxiety disorder. Hence, there are reasons to expect older adults to show reduced or null SDF effect relative to younger adults.

The main motivation of the present work was to explore the capacity of older adults to engage in selective voluntary forgetting. If SDF taxes higher executive-control demands than standard directed forgetting and executive-control processes decline with age, one would expect SDF to be absent (or reduced) at an age where standard DF may be usually present. This absence of SDF in older adults may take two forms: first, it is possible that we do not observe forgetting of any of the characters from List1 (i.e., that the to-be-forgotten and to-be-remembered items from List 1 are equally recalled and to a similar extent as in the group cued to remember). If, as stated, the process that makes memories less accessible is hampered by having to select which specific memories are to be suppressed, one would not expect any forgetting to emerge in older adults. On the other hand, it is also possible that the lack of SDF in the older adults may take the form of reduced recall of the entire List1. This might happen because impoverished control capacities may result in difficulties in selecting the appropriate to-be-forgotten information but not in the forgetting process itself. In this case, and as the result of nonselectivity, older adults would end up suppressing all the information in List 1. Although we did not have a clear a priori prediction regarding which of these two outcomes would arise in older adults, our previous results as well as those from Gómez-Ariza et al. (2013) with a clinical sample made us expect that deficits in executive control would result in no forgetting at all of List 1 items.

In the present experimental series we report three experiments in which we tested older adults' ability to intentionally forget episodic memories. In Experiment 5 we compare young and older adults by using the procedure introduced by Delaney et al. (2009). Experiment 6 basically aimed to overcome some methodological shortcomings of Experiment 5 and was run only with older participants. Experiment 7 was essentially identical to Experiment 5 except for the instructions provided to participants in the forget condition; namely, participants were told to forget all sentences of List 1 rather than a subset of them.

Experiment 5

Method

Participants

Forty-eight young (*M* = 20.5 years, *SD* = 2.04) and 48 older adults (*M* = 68.31 years, *SD* = 6.66) participated in the experiment. The younger participants were undergraduates from the universities of Granada (Spain, *n* = 22) and Hull (England, *n* = 26) who received course credit. The older participants were recruited through participant pools at the University of Hull (*n* = 32) and a public health center in the province of Granada (n = 16). None of the older participants (in this and the next experiments) had a history of neurological disorders or psychiatric conditions. All participants reported being in good health and having normal or corrected vision and hearing. In addition, older participants had at least 11 years of formal education (M = 13.23, SD = 2.89). To control for global cognitive functioning we administered the short-term memory (STM) (WMS–III) and vocabulary scales from the WAIS (Wechsler, 1997). Older participants showed normal performance (WMS–III with M = 16.89, SD = 4.07; vocabulary with M = 44.87, SD = 11.86). The younger participants' mean was 17.23 (SD = 3.22) in the WMS–III and 41.67 (SD = 6.33) in the vocabulary test. There were no differences between young and older participants in memory span ($p > .50$), but older adults marginally outperformed younger adults in vocabulary ($p > .10$).

Materials and procedure

The sentences, the details regarding their presentation and the character-action counterbalancing procedures were the same as used in Experiment 1, 3 and 4 (see Appendix I). An English version of the material for the English participants can also be seen in Appendix I. The procedure was the same as that one in Experiment 1. Importantly, special care was taken to highlight the importance of forgetting in the case of the older participants (Sahakyan et al., 2008). The same questionnaire as the previous experiments was administered. At the end of the experimental session, participants performed the vocabulary and the memory span tasks. The session lasted about 40–45 minutes.

Results

The data from two older participants (one from each instruction condition) were excluded from the analyses because of extremely low performance in the recall test (one of them did not recall any sentence of any of the lists, and the other was the only participant in the remember group who did not recall any sentence of List 2).

We first conducted a mixed factorial analysis of variance (ANOVA) with age (younger and older) and instruction (remember vs. forget) as between-participants factors and character (Tom, Alex, and Joe) as the within-subject factor on the recall percentages. The younger participants (*M* = 36.34; *SD* = 23.35) significantly recalled more sentences than the older did (*M* = 17.97; *SD* = 18.18), $F(1, 91) = 48.67$, *MSE* = 727, $p < .001$, $\eta_p^2 = .348$ (see Figure 5). No other main effect reached statistical significance. The interaction age x instruction x character was statistically significant[3], $F(1, 182) = 7.54$, *MSE* = 208,

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[3]Before carrying out specific analyses for our hypothesis, we checked for performance differences as a function of the nationality of participants through a 2 (nationality: English and Spanish) x 2 (age: younger and older) x 2 (instruction: remember and forget) x 3 (character: Tom, Alex, and Joe) mixed analysis of variance (ANOVA) on recall percentages. The analyses showed all sources of variability involving nationality to be nonsignificant except the interaction age x nationality, F(1, 87) = 15.84, MSE = 602, p < .01. Further analyses revealed that the young Spanish participants (M = 50%) tended to better recall than their English counterparts (M = 33%, p < .01), whereas the opposite was true in the older participants (Spanish sample with M = 11% and English sample with M = 21%, p < .05). Importantly, the pattern of the interaction age x instruction x character did not change as a function of nationality (four-way interaction with F(1, 174) = 1.83, MSE = 206, p = .16).

$p < .001$, $\eta_p^2 = .076$, and we followed it up through separate ANOVAS for List 1 and List 2.

List 1 Recall: Selective Directed Forgetting

In order to check for SDF we first performed a 2 (age) x 2 (instruction) x 2 (List 1 character) mixed ANOVA on recall rates. Importantly, the higher order interaction was marginally significant, $F(1, 90) = 2.86$, $MSE = 182$, $p = .09$, $\eta_p^2 = .031$, and we carried out a 2 (instruction) x 2 (character) ANOVA in each age group.

The analysis on the younger participants' recall percentages of List 1 items showed a significant effect of the interaction character x instruction, $F(1, 46) = 6.46$, $MSE = 244$, $p < .05$, $\eta_p^2 = .123$. Further analyses revealed reliable SDF; the group cued to forget recalled fewer items about Tom (TBF items) than the remember-cued group did, $F(1, 46) = 10.49$, $MSE = 453$, $p < .01$, $\eta_p^2 =.186$, whereas no significant difference was found between groups in the recall of items about Alex (TBR items), $F(1, 46) < 1$, $\eta_p^2 = .008$. The same ANOVA on the older group's recall rates, however, failed to show reliable SDF. The interaction character x instruction was not significant, $F(1, 44) < 1$, $\eta_p^2 = .009$. The forget group recalled as many items about Tom as the remember group did, $F(1, 44) < 1$, $\eta_p^2 = .019$. No significant difference between groups was also found in the recall of items about Alex, $F(1, 44) < 1$, $\eta_p^2 = .003$.

As in previous studies focusing on individual differences in SDF (Gómez-Ariza et al., 2013), we further examined the older adults' performance to determine the extent to which their memory impairment could depend upon the participants' willingness to forget. Specifically, we conducted an additional ANOVA on recall percentages after removing from the analysis five participants in the forget condition who reported not having followed the instruction to forget. The results of this analysis indicated that the lack of SDF did not depend on the participants' willingness to follow the instructions, because the instruction x character interaction remained nonsignificant, $F(1,39) < 1$, $\eta_p^2 = .009$. The sentences linked to Tom (17.28%) were recalled by the group cued to forget to the same extent as those sentences linked to Alex (19.75%) and as well as the items about Tom in the remember-cued group (19.80%).

Finally, we performed analyses on between-character confusion rates within List 1 (sentences about Tom incorrectly assigned to Alex and vice versa). The mean percentage of source confusions by the younger participants was 2.76 (*SD* = 5.62) in the remember group and 11.67 (*SD* = 13.58) in the forget group. The older participants' means were 18.74 (*SD* = 26.80) and 21.35 (*SD* = 30.83), respectively. A 2 (age) x (instruction) ANOVA showed only the main effect of age to be significant (all other effects were $F < 1$), $F(1, 90) = 8.34$, $MSE = 463$, $p < .01$, $\eta_p^2 = .08$. On average, the older adults (*M* = 20.04, *SD* = 28.60) made more source confusions than the younger participants (*M* = 7.22, *SD* = 11.23).

Output order analysis

To assess whether output interference could account for the memory impairment of Tom sentences in the younger participants, we calculated output position percentiles for each participant according to the procedure introduced by Bjork and Whitten (1974). The rationale behind this analysis is that if participants in the forget group tended to recall Alex sentences before Tom sentences, this could have led to lower the recall of the Tom items because of output interference.

A 2 (character) x 2 (instruction) mixed ANOVA on younger participants' output position scores revealed that neither source of variance reached significance (all *p*s $< .21$). There were no differences in output order between the sentences associated to Tom ($M = .55$; $SD = .16$) and the sentences associated to Alex ($M = .60$; $SD = .17$) in the remember group ($F < 1$) nor were there differences between the output order for Tom and Alex sentences in the forget group ($M = .63$; $SD = .16$ and $M = .56$; $SD = .17$, respectively), $F(1, 35) = 1.04$, $MSE = .05$, $p = .31$, $\eta_p^2 = .029$. This pattern suggests that output interference did not play a relevant role in producing SDF in the younger participants.

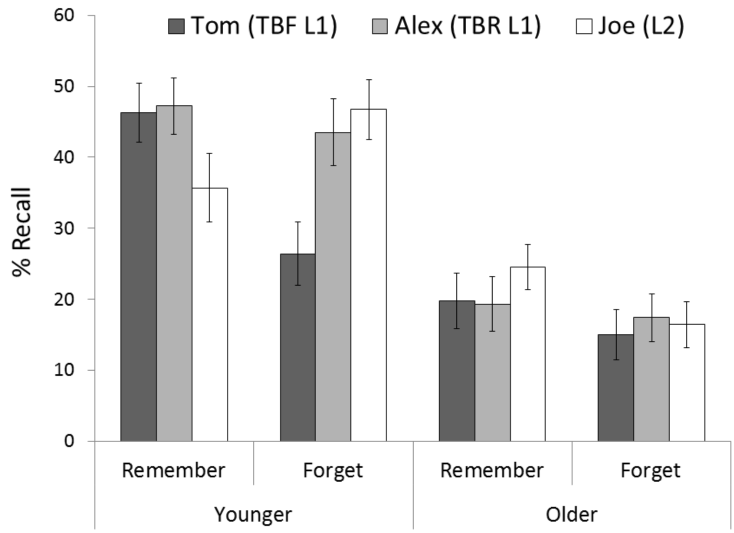

Figure 5. Mean percentages of correct recall as a function of age, instruction, and character. Error bars represent standard errors of mean.

List 2 recall

Although our hypothesis focused on List 1, for completeness we also performed analyses on List 2 recall. A 2 (age) x 2 (instruction) ANOVA on recall percentages showed the interaction to be significant, $F(1, 75) = 7.50$, $MSE = 352$, $p < .01$, $\eta_p^2 = .091$, and we followed it up by carrying out analyses for younger and older participants separately. The younger participants cued to forget recalled more sentences about the List 2 character that those cued to remember, $F(1, 75) = 6.28$, $MSE = 352$, $p < .05$, $\eta_p^2 = .077$. The same analysis on the older participants' recall rates, however, did not show significant effect of instruction on List 2 recall, $F(1, 75) = 1.77$, $MSE = 352$, $p = .19$, $\eta_p^2 = .023$.

Intrusions from List 1

Finally, we analyzed intrusions from List 1 during List 2 recall (attributing to Joe actions that were previously learned either related to Tom or to Alex) because they could be informative about List 1 items' accessibility. A 2 (young vs. old) x 2 (remember vs. forget) ANOVA on overall intrusion percentages showed that older participants (*M* = 22.7, *SD* = 30.6) made more intrusions than younger participants (*M* = 8.7, *SD* = 19.3) when recalling List 2 items, $F(1, 87) = 7.61$, $MSE = 620$, $p < .01$, $\eta_p^2 = .080$. Importantly, this age effect was qualified by an interaction with instruction, $F(1, 87) = 5.77$, $MSE = 620$, $p < .05$, $\eta_p^2 = .062$. Although there was no difference in intrusion percentages between younger and older adults in the remember condition (younger: *M* = 15.2; *SD* = 25; older: *M* = 17, *SD* = 24.2, $F < 1$), the difference was statistically significant in the forget condition (younger: *M* = 2, *SD* = 5.9; older: *M* = 29, *SD* = 40, respectively, $F(1, 87) = 12.88$, $MSE = 620$, $p < .01$, $\eta_p^2 = .129$). The frequency of intrusions related to Alex and Tom, however, was statistically similar in younger (Alex: *M* = 58%; Tom: *M* = 42%) and older participants (Alex: *M* = 52%; Tom: *M* = 48%) and did not depend on the instruction (all ps > .60).

Discussion

The present results reveal that younger and older participants showed a different pattern of performance as a function of instruction. Whereas the former showed selective memory impairment for the to-be-forgotten items of List 1, which replicates previous findings with the SDF procedure (Delaney et al., 2009; Gómez-Ariza et al., 2013;

Kliegl et al., 2013; Experiments 1 and 3 from the present series; but see Storm et al., 2013), no effect of the forget instruction was evident in the older participants, who recalled as many to-be-forgotten items as to-be- remembered items.

The absence of intentional forgetting in our older participants is important because previous studies have shown comparable DF effects in older adults (less than 75 years) and younger participants (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006; but see Zacks et al., 1996). However, because we used a modification of the DF procedure that requires participants to forget selectively, the demands for cognitive control may have also been increased. That is, the introduction of this selectivity component in the procedure might make older adults less capable of forgetting after being cued to do so. Thus, our findings could indicate that the SDF procedure is more demanding of memory control and, hence, more sensitive than the standard DF procedure to individual differences in the ability to intentionally forget.

However, before drawing strong conclusions from our findings in Experiment 5, we wanted to rule out the possibility that our results were because of the general low performance of the older participants in the memory task, which could have prevented forgetting from being easily observed. Because the task was difficult and the older participants showed low recall level, it might be argued that the absence of SDF in our older participants reflected a floor effect. Thus, we decided to run a new SDF experiment with older adults using the same procedure as in Experiment 5, but reducing the memory load of the task. The goal was to improve the overall memory performance of the older participants and to be able to discard potential floor effects.

Experiment 6

Method

Participants

Forty-four older adults (*M* = 65.32 years, *SD* = 4.78) participated in this experiment. They were recruited through participant pools at the University of the Balearic Islands (*n* = 10) and the University of Granada (*n* = 34). All participants reported having normal or corrected vision/hearing as well as having at least 11 years of formal education (*M* = 13.44, *SD* = 2.14). As in Experiment 5, participants showed a good performance on the STM subscale from the WMS–III (*M* = 14.95, *SD* = 2.98) and the vocabulary subscale (*M* = 47.53, *SD* = 6.43) from the WAIS test.

Materials and procedure

These were the same as those used in the Experiment 1, 3, 4 and 5 except for the number of sentences conforming List 1 and List 2 (see Appendix III). From the results of the previous experiment we selected the 12 List 1 sentences with the highest recall rates to be used in the present experiment. In addition, we randomly removed two sentences of the List 2 from Experiment 5. Thus, participants now studied a first list composed of 12 (instead of 18) sentences (6 about Tom and 6 about Alex) and then a new list with 12 sentences about a third character.

Results

List 1 recall

To check for SDF we performed an ANOVA with Instructions (remember vs. forget) x List 1 character (Tom vs. Alex) that failed to yield significant effects [main effects with $F < 1$ and interaction with $F(1, 42) = 1.26$, $MSE = 160$, $p = .27$, $\eta_p^2 = .029$]. The forget group recalled Tom items to the same extent as the remember group did, $F(1, 42) < 1$, $\eta_p^2 = .010$. The difference between both groups regarding Alex items was also not statistically significant, $F(1, 42) < 1$, $\eta_p^2 = .004$. In addition, this pattern remained the same after removing from analyses the data from 5 participants who reported not following the instruction to forget. Hence, no evidence of forgetting was found in the present experiment despite observing an overall enhancement in List 1 recall relative to Experiment 5 [*M*Exp1 = 17.87, *SD*Exp1 = 16.12; *M*Exp2 = 26.62, *SD*Exp2 = 16.12; $F(1, 86) = 3.94$, $MSE = 519$, $p < .05$, $\eta_p^2 = .044$ (See Figure 6).

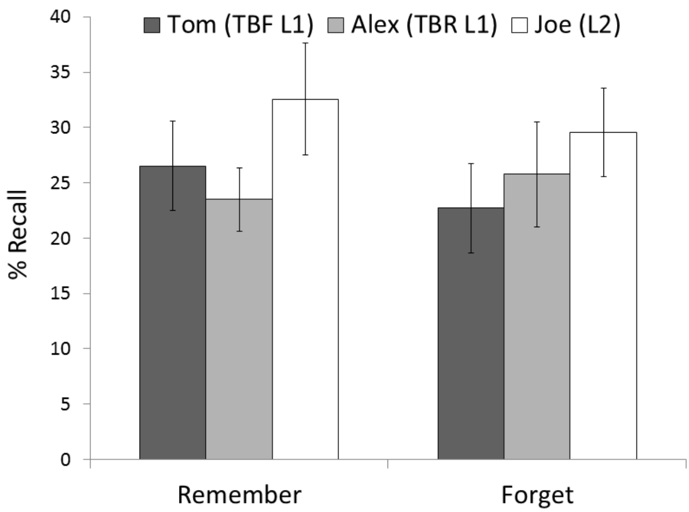

Figure 6. Mean percentages of correct recall as a function of instruction, and character. Error bars represent standard errors of mean.

We also looked at between-character confusions within List 1. The percentage of confusions was numerically lower in the remember group (*M* = 9.47, *SD* = 18.38) than in the forget group (*M* = 18.93, *SD* = 32.00), although the difference did not reach statistical significance, $F(1, 42) = 2.48$, $MSE = 398$, $p = .12$, $\eta_p^2 = .056$. The mean percentage of source confusions in Experiment 6 (*M* = 12.92, *SD* = 24.78) was marginally lower than that in Experiment 5 (*M* = 22.73, *SD* = 30.64), $F(1, 84) = 2.89$, $MSE = 772$, $p = .09$, $\eta_p^2 = .033$.

List 2 recall and intrusions from List 1

Analysis on List 2 revealed that the instruction did not have any effect on correct recall, F < 1 (see Figure 6). Likewise, the percentages of intrusions from List 1 did not vary as a function of the instruction provided before studying List 2 (remember group: M = 10.15, SD = 20.77; forget group: M = 15.68, SD = 28.46, $F < 1$) nor the List 1 character (intrusions from Tom: M = 12.5, SD = 32.57; intrusions from Alex: M = 14.77, SD = 35.07, $F < 1$). The interaction also failed to reach statistical significance ($F < 1$). Finally, the distribution of intrusions from Alex and Tom were statistically similar in both instruction groups (Alex: M = 53%; Tom: M = 47% $p > .70$).

Discussion

Results from Experiment 6 basically replicate those from Experiment 5 showing no selective forgetting in older adults. Even when only six different facts were studied about the two List 1 characters, participants over 60 years old failed to selectively forget. Importantly, the overall memory enhancement observed in the present experiment (more correct responses and fewer character misattributions) relative to Experiment 5, makes it difficult to attribute the lack of experimental effect to floor performance. In support of this conclusion, SDF was absent even when the data of Experiments 5 and 6 were combined and participants with the lowest performance were removed.

The finding that older adults do not show SDF when previous studies have shown similar DF effects for older and younger adults is suggestive of how different SDF and DF may be. One reason to expect age differences in the SDF procedure is that memory selection could impose high demands of cognitive control that would surpass the capacity of older adults. If so, then removing the selectivity component of the SDF procedure would turn the task into a standard DF procedure and comparable forgetting should be observed in younger and older adults. Thus, we conducted a new experiment with essentially the same material and procedure as Experiment 5 except for the nature of the instruction to forget; namely, in Experiment 7 the cue required participants to forget all the sentences in List 1 rather than only a subset of them. Hence, we predicted that to the extent that the failure to find any evidence of forgetting for older adults in Experiments 5 and 6 was because of the selective component of the task, in Experiment 7 we should find comparable forgetting in younger and older adults, thus replicating previous DF research.

Experiment 7

Method

Participants

Forty-eight young (M = 19.75 years, SD = 2.16) and 44 older adults (M = 64.2 years, SD = 3.19) participated in the present experiment. The younger participants were undergraduates from the Universities of Granada and Jaén who received course credit for participating. Most of the older participants were recruited from a pool of participants at the Universities of Granada and Jaén. All of them reported over 10 years of formal education. As in Experiment 5, STM and vocabulary tests from the WAIS were administered and the older participants showed normal performance on them (M = 14.9, SD = 3.2 and M = 44.3, SD = 16.2, respectively). The younger participants had mean scores of 15.6 (SD = 2.7) and 42.53 (SD = 5.14) on the WMS–III and vocabulary tests, respectively. There were no differences between older and younger adult participants in STM ($p > .50$) or vocabulary ($p > .21$).

Materials and procedure

The materials and procedure of the present experiment essentially matched those in Experiment 5 with the exception that the participants assigned to the forget condition were told to forget the whole set of List 1 sentences rather than just a subset of them (see Appendix IV). Specifically, they were told: “At this point you must know that the forthcoming recall task will not test your memory about the just-learned items. List 1 was given just as an example and the presented sentences are no longer relevant. Instead, you will be tested on the next list that I will present you now. Therefore, to do your best in the forthcoming memory test on the material that you are still to learn, you should forget all you have learned so far. Ignoring information about the previous list will definitively help you to better recall relevant information." Each of the 18 sentences included in List 1 started with the name of just one character (Tom). As in the previous experiment, at test participants were first required to recall List 1 and then List 2.

Results and Discussion

We followed the same criteria of all previous experiments to mark recalled items as correct. Figure 7 shows the correct recall for each group as a function of list and instruction. The data of two older participants in the remember condition were removed from the analyses because of an extremely low general performance in the memory tasks. First we performed a 2 (age: younger and older) x 2 (instruction: remember and forget) x 2 [character (List): Tom and Joe] mixed ANOVA on correct recall percentages. All main effects reached statistical significance: young adults (M = 42.27; SD = 20.52) recalled more sentences than older adults (M = 24.28; SD = 15.73), $F(1, 86) = 43.03$, $MSE = 421$, $p < .01$, $\eta_p^2 = .333$; more items were recalled in the remember condition (M = 38.64; SD = 20.58) than in the forget condition (M = 31.4; SD = 20.66), $F(1, 86) = 4.80$, $MSE = 421$, $p < .05$, $\eta_p^2 = .052$; and List 2 (M = 37.53; SD = 19.64) was better recalled than List 1 (*M* = 32.34; *SD* = 21.85), $F(1, 86) = 7.26$, *MSE* = 177, $p < .01$, $\eta_p^2 = .078$. Age did not interact with any factor (both first-order interactions with $p > .25$ and second-order interaction with $F < 1$).

List 1 recall: Directed Forgetting

A 2 (age) x 2 (instruction) between-participants ANOVA on List 1 recall confirmed a main effect of instruction, $F(1, 86) = 17.97$, *MSE* = 283, $p = .01$, $\eta_p^2 = .315$ and a nonsignificant effect of the interaction, $F(1, 86) = 1.36$, *MSE* = 283, $p = .25$, $\eta_p^2 = .016$. The cost of the instruction to forget was observed in the group of younger participants, $F(1, 86) = 15.66$, *MSE* = 283, $p < .01$, $\eta_p^2 = .154$, as well as in that of older participants, $F(1, 86) = 4.42$, *MSE* = 283, $p < .04$, $\eta_p^2 = .049$.

List 2 recall

The 2 (age) x 2 (instruction) ANOVA showed age to be the only significant effect, $F(1, 86) = 22.74$, *MSE* = 314, $p < .01$, $\eta_p^2 = .172$ (other effects with $F < 1$). Although the reason why the cue to forget did not lead to recall enhancement for List 2 in this experiment is not evident, it is now known that having participants recall List 2 after recalling List 1 (such as is done in our experiments) quite often reduces recall enhancement for List 2 (see Pastötter, Kliegl, & Bäuml, 2012). The group of older participants (*M* = 28.06; *SD* = 20.30) recalled fewer items than their younger counterparts (*M* = 45.83; *SD* = 13.87).

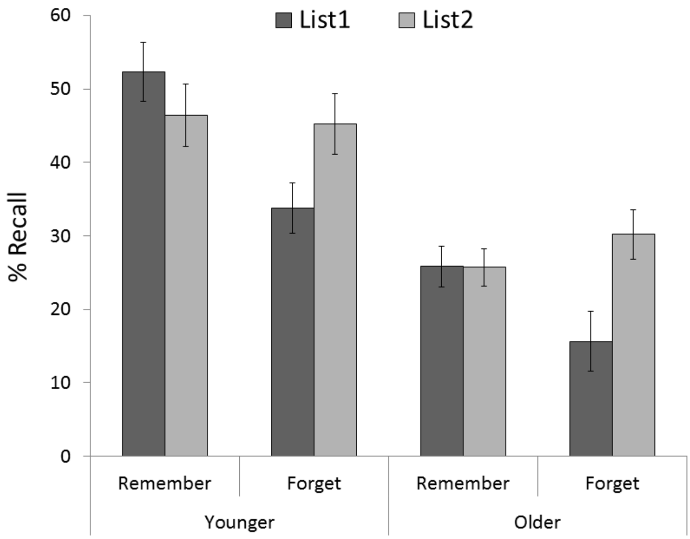

Figure 7. Mean percentages of correct recall as a function of age, instruction, and list. Error bars represent standard errors of mean.

Intrusions from List 1

As in the previous experiments, intrusions from List 1 during List 2 recall were computed and analyzed through a 2 (age) x 2 (instruction) ANOVA. The analysis only showed a main effect of age (other effects were $F < 1$), $F(1, 86) = 11.93$, $MSE = 345$, $p < .01$, $\eta_p^2 = .122$. The older participants ($M = 26.5\%$, $SD = 21.17$) made more intrusions than the younger ones ($M = 13\%$, $SD = 15.54$).

General discussion of the experimental series

Previous studies with LM-DF procedures in older adults under 75 years of age have mostly failed to show reduced forgetting effects relative to younger adults (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006; but see Zacks et al., 1996). In the present experiments we aimed to further study this issue by comparing young-old and young adults' performance with the selective directed forgetting procedure (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). Because in this task the instruction is to forget only a subset of List 1 items, we assumed that successfully achieving this goal would involve higher demands of memory control than following an instruction to forget in a nonselective way, such as is required in standard LM-DF procedures. Selecting and suppressing some memories could be more demanding than suppressing without need of selection. If so, and on the basis of previous research suggesting that aging entails a deficit in executive control (e.g., Andrés & Van der Linden, 2000; Braver & West, 2008; Gunning-Dixon, & Raz, 2003; Ortega et al., 2012; West, 1996), we predicted older people not to show selective directed forgetting. Supporting this hypothesis, in three experiments we show evidence of older adults' impoverished capacity to voluntarily forget episodic memories, though only when the task required selective forgetting. Using the procedure introduced by Delaney et al. (2009), in Experiment 5 we observed SDF only in young adults. The younger participants who were cued to forget the information associated to one of the List 1 characters showed selective memory impairment for the to-be-forgotten items relative to the participants who were instructed to keep remembering the two characters. Finding the SDF effect in young people is important: whereas it has been replicated elsewhere (Gómez-Ariza et al., 2013; Kliegl et al., 2013; Experiments 1 and 3 from the present series), failures to observe this phenomenon have also been reported (Storm et al., 2013).

Of relevance here, the pattern of results for the older participants was completely different from that for the younger ones because no differences in recall were observed between the groups cued to forget and remember. Thus, the older group failed to show any memory cost following the instruction to selectively forget. The absence of SDF in older participants does not seem to be due to their overall lower performance. Although it could be argued that this low memory performance (below 20%) could have made it difficult to detect an effect of the forget cue in Experiment 5, we run a new experiment (Experiment 6) with essentially the same task except for the smaller number of items per list presented to the participants. Replicating those from Experiment 5, results from Experiment 6 showed no evidence of forgetting in a new sample of participants over 60 years of age. In fact, we failed to observe forgetting even when combining data from the two experiments and considering in the analyses only participants with the highest level of performance.

Interestingly, the lack of directed forgetting found in older adults in Experiments 5 and 6 contrasts with the reliable effect found in Experiment 7 where DF effects were present in both older and younger participants and not significantly different in the two groups. In Experiment 7 we slightly modified the procedure of Experiment 5 so that participants were asked to forget the complete set of sentences comprising List 1 rather than asking them to only forget a subset of them. In this way, Experiment 7 essentially involved a standard LM-

DF procedure, whereas Experiment 5 (like Experiment 6) conformed to a selective LM-DF procedure. Hence, it seems that selective voluntary forgetting imposes high demands of memory control that surpass the capacity of older people. Specifically, we suggest that it is the concurrent operation of memory selection and downregulation that is affected with aging. On the basis of the data showing that the lack of SDF took the form of no forgetting at all, one could even argue that selectivity cannot be the only process playing a role in older adults' failure to selectively forget. Otherwise they would have shown general forgetting of List 1 items. Thus, with aging the process of making memories less accessible (i.e., inhibition) would be more easily hampered by having to select which specific memories are to be forgotten than having to forget the whole list. If so, and also from the proposal that the ability to update episodic memory depends on executive-control processes (Anderson, 2005; Conway, et al., 2000; Delaney & Sahakyan, 2007; Hanslmayr et al., 2012), our results agree with other data reporting adult-age differences in executive control of episodic memory (e.g., Anderson, et al., 2011; Aslan & Bäuml, 2013; Hasher et al., 1996; May & Hasher, 1998; Ortega et al., 2012). Aging brings a decline in executive-control capacities (e.g., Andrés & Van der Linden, 2000; Braver & West, 2008; Gunning-Dixon & Raz, 2003; Lustig et al., 2007), and exerting control over outdated memories to make them less accessible (in favor of more relevant ones) becomes more vulnerable with age.

In support of an impoverished ability to downregulate episodic memory with aging, across experiments we found older adults to be more prone to proactive interference than younger adults because they made more intrusions from List 1 when recalling List 2 items (for related results see Hasher, Chung, May, & Foong, 2002). Of special relevance, intrusion errors in the SDF procedure were especially sensitive to instructions provided after List 1 study. Although no age differences exist regarding the remember groups, those older participants cued to forget made more List 1 intrusions than their younger counterparts as recalling List 2 items. Hence, younger (but not older) adults seem to have been successful in forgetting irrelevant memories when cued to do so.

At first sight, our finding would seem in conflict with that of Aslan and Bäuml (2013) showing that voluntary forgetting is a “late-declining” capability only absent in old-old adults. However, this apparent discrepancy can be easily explained by considering that a) “executive control” is not an all-or-nothing capacity and b) age differences in the ability to intentionally forget may result both from variations in this capacity and also from differences in the executive-control demands imposed by the task (Ortega et al., 2012). Thus, because in Experiments 5 and 6 we used a (selective) directed forgetting task that putatively imposed more control demands than the standard (nonselective) one used in previous studies (Aslan & Bäuml, 2013; Sahakyan et al., 2008; Sego et al., 2006; Zellner & Bäuml, 2006), our task might be more sensitive to age differences in memory executive control. Hence, although only older adults over 75 years old would show a breakdown in nonselective voluntary forgetting, the deficit in selective intentional forgetting would become apparent much earlier.

The fact that older adults do not show SDF seems to fit with an inhibitory-deficit framework (Hasher & Zacks, 1988). If SDF is thought as an aftereffect of an inhibitory process recruited to cause loss of accessibility of outdated memory traces (e.g., Delaney et al., 2009; Gómez-Ariza et al., 2013), then our findings suggest that older (but not younger) adults would fail to downregulate accessibility of specific episodic memories after receiving the selective forget cue. As aforementioned, it has been suggested that inhibition may play a role in nonselective directed forgetting. Bäuml et al. (2008), by using electroencephalography (EGG) and observing oscillatory correlates of memory updating during a LM-DF task, found that reductions in upper alpha phase coupling correlated with List 1 forgetting. Importantly, these alpha oscillations are thought to be associated with active inhibitory filtering in the brain (Hanslmayr et al., 2007; Kelly, Lalor, Reilly, & Foxe, 2006). In addition, Hanslmayr et al. (2012) have suggested a causal role of the dorsolateral prefrontal cortex in driving forgetting by decreasing neural synchrony. Specifically, Hanslmayr et al. put forward that reduced phase synchronization might be related to the inhibition of the original encoding context of the to-be forgotten items, which would make these items harder to recall in a later test.

Whereas an inhibitory account of SDF emphasizes the role of executive control in retrieval, and as it has been discussed in previous experiments, memory control could also be exerted at encoding and SDF could arise from exerting selective rehearsal on the to-be-remembered items of List 1. If so, the different pattern of performance in young and older adults in the SDF procedure could be related to differential ability to encode information rather than differences in inhibiting nonrelevant memories (e.g., after they were cued to forget, younger participants could have managed to rehearse Alex items more times than older adults). Two aspects of this series of experiments, however, preclude interpretation of SDF in terms of selective rehearsal. First, as in previous experiments, in order to minimize List 1 rehearsal, participants were asked to perform a distracter task right after receiving the forget/remember cue. More importantly, the selective rehearsal hypothesis would lead to expect the forget-cued younger group to show lower recall of Tom items (because less encoding resources were devoted to them) but enhanced recall of Alex items (because full attention was paid to this character) relative to the remember group. Contrary to this, we found that both instruction groups recalled the to-be-remembered items of List 1 to the same extent (for similar results see Delaney et al., 2009; Gómez-Ariza et al., 2013, and Kliegl et al., 2013). This finding suggests that selective rehearsal does not underlie SDF in younger adults and that it is not related to the lack of memory cost in older adults. Importantly, the results of Experiment 4 support the idea that rehearsal is not involved in the memory cost observed with the SDF procedure.

The fact that younger (but no older) adults show SDF seems difficult to accommodate to a general context-change account of LM-DF forgetting. According to the context-change account of LM-DF (e.g., Sahakyan & Kelley, 2002), directed forgetting reflects a mismatch between the study and the test contexts for List 1 in response to the forget instruction. In the memory test, the retrieval context matches the encoding context for List 2 better than that of List

1, producing reduced recall of List 1 items. Importantly, the SDF effect does not fit well with a general context-change account of forgetting that follows the instruction to forget as sentences about the two List 1 characters were learned in the same context before receiving the cue to forget one of them. Hence, a general context-change theory of directed forgetting would predict that this cue would limit the accessibility of the whole set of List 1 rather than selectively impair a subset of it. In addition, the absence of SDF effect in the older group cannot be easily attributable to diminished vulnerability to context changes in older adults. In agreement with the idea that context-change does not underlie SDF, previous research has shown older adults to be as prone as younger adults to forgetting after inducing mental context changes (Sahakyan et al., 2008). Hence, if context change played a role in SDF memory cost should also have been evident in our older participants in Experiments 5 and 6.

Finally, a potential account of our main finding deserves commentary. Because aging has also been shown to bring an associative memory deficit (e.g., Naveh-Benjamin, Kilb, & Reedy, 2004), one could argue that it is this memory shortage, rather than a deficit in executive control, that underlies older adults' failure to show SDF. Put simply, the inability to forget in the SDF procedure could be a consequence of a failure to differentiate which actions belonged to each of the List 1 characters. After all, without accurate memories on the facts associated to each character, any of us would find puzzling the task of suppressing some of these memories. In opposition to this argument, we think that the rates of character-list confusions among older participants are not high enough (particularly in Experiment 6 with less than 10% in the remember group), to easily attribute the absence of SDF to a deficit in associative memory. More importantly, should an associative memory deficit play a role in preventing SDF from emerging in older adults who are able to forget in a selective way, one would expect SDF to show up when source confusions within List 1 are marked as correct responses. Under this scenario, those facts originally associated with the to-be-remembered character but incorrectly linked to the character to be forgotten during the recall test should be better recalled than the facts originally associated to the to-be-forgotten character that were successfully forgotten. To assess this possibility, we reanalyzed the older adults' data from Experiments 5 and 6 after including between-character confusions within List 1 as correct responses. Neither source of variability reached statistical significance when the data from the two experiments were analyzed separately and jointly (all Fs < 1), which parallels the results obtained when source confusions are marked as incorrect. Altogether, this suggests that the failure to find SDF in our experiments does not seem to relate to a deficit in retrieving detailed information.

To conclude, Experiment 5 to 7 showed adult-age differences in directed forgetting but only when participants were cued to selectively forget. We argue that engaging in selective intentional forgetting entails higher demands of executive control to downregulate irrelevant memories, which is what makes older adults less able to successfully accomplish this task. While in agreement with previous results showing reduced memory control capacities with aging, ours also join other findings to suggest that sensitiveness to detect adult-age differences in cognitive control may strongly depend on the control demands imposed by tasks.

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Capítulo IV

Discusión general

Aunque se ha generado mucha investigación en torno al olvido motivado, la idea de que este pueda ser selectivo resulta más novedosa. De este modo, el objetivo general de los experimentos incluidos en esta tesis era explorar la naturaleza del mecanismo que subyace a la capacidad de olvidar intencionalmente y de forma selectiva. Aunque existen propuestas para explicar efectos experimentales de olvido intencional de carácter no selectivo, muy poco se conoce aún sobre la naturaleza del efecto de ODS.

Ya que los resultados de algunos estudios previos han mostrado dificultades para replicar el efecto de ODS y han puesto en duda que el olvido motivado (medido mediante tareas de olvido dirigido) se pueda llevar a cabo de manera selectiva, el presente trabajo pretende aportar evidencia de que es posible olvidar intencionadamente de manera selectiva. Los siete experimentos descritos tienen como objetivo abordar cuatro cuestiones principales: 1) replicar resultados que muestren la posibilidad de olvidar de manera intencionada y selectiva; 2) explorar factores que pueden modular la capacidad para olvidar intencional y selectivamente; 3) investigar si el olvido intencional selectivo depende de mecanismos de control ejecutivo; y 4) identificar el mecanismo cognitivo que pudiera ser responsable del efecto experimental de olvido dirigido selectivo (ODS).

Tras la revisión de la literatura pertinente sobre olvido dirigido en el Capítulo I, la sección experimental plantea tres series de experimentos enmarcadas en tres aproximaciones diferentes. En primer lugar, tanto el Experimento 1 (como primera replicación del efecto experimental de ODS) como el resto de los estudios del Capítulo III, nos permiten concluir que el ODS es un fenómeno robusto que se puede estudiar experimentalmente. En el Experimento 2 se manipula la dificultad de la tarea de selección. Con esta estrategia se pretendía abordar el segundo de los objetivos planteados, es decir, conocer si el éxito en olvidar intencional y selectivamente se ve modulado por la proporción relativa de información a olvidar. Los resultados de ese experimento ponen de manifiesto que la selección de la información a olvidar depende de la cantidad de información a considerar. Por otro lado, con el objetivo de explorar factores que modulen el efecto ODS y la implicación de mecanismos de control ejecutivo, en los Experimentos 3 y 4 se manipuló la disponibilidad de recursos atencionales mediante tareas que diferían en el grado de control cognitivo. Los resultados sugieren que el control ejecutivo está implicado en el efecto de ODS. Por último, para abordar la cuestión del mecanismo concreto que puede ser responsable del ODS, se ha usado una perspectiva basada en la comparación entre grupos de edad que difieren en capacidades de control inhibitorio. Los Experimentos 5, 6 y 7 apoyan la dependencia de ODS del control ejecutivo, además de proporcionar resultados que sugieren que el mecanismo subyacente al ODS podría ser de tipo inhibitorio. Cada aproximación al problema aportará datos y arrojará luz a los problemas que motivan el presente trabajo.

A continuación se resumirán los principales resultados obtenidos en los experimentos del presente trabajo y se discutirán sus implicaciones teóricas. El capítulo se organizará alrededor de los apartados sobre la relación de los resultados con la investigación previa en ODS, la relevancia teórica de los resultados en relación con las teorías que explican el olvido dirigido (no selectivo) con el método de la lista, así como la naturaleza del mecanismo subyacente al ODS. Además, se discutirá la aportación de los resultados de la última serie con respecto a la comprensión del envejecimiento cognitivo, así como la repercusión que los resultados descritos en el conjunto de la tesis pueden tener en los modelos actuales sobre el control de la memoria.

1. El efecto de ODS: evidencia de olvido motivado y selectivo.

La evidencia experimental hasta la fecha sobre si el olvido dirigido puede ser selectivo es mixta, con algunas demostraciones claras de selectividad (Delaney, Nghiem, y Waldum, 2009; Gómez-Ariza et al., 2013; Kliegl, Pastötter, y Bäuml, 2013;) y algunos fallos a la hora de replicar el efecto ODS (Storm, Koppel, y Wilson, 2013; para un estudio con un método relacionado, véase Sahakyan, 2004). Como hemos mencionado con anterioridad, Delaney y colaboradores (2009) fueron los primeros en mostrar que los participantes pueden olvidar parte de la Lista 1 en el procedimiento de olvido dirigido si se les presentan dos subconjuntos diferenciados de información (p.e. dos personajes diferentes) y se le pide que olviden uno de los subconjuntos, aunque para ello es necesario que la información no esté relacionada entre sí.

Desde la publicación del trabajo de Delaney y colaboradores (2009), sin embargo, los intentos de replicar el efecto de ODS no siempre han dado resultados convergentes. Entre los estudios que replican los resultados del experimento original se encuentra el de

Gómez-Ariza y colaboradores (2013) con adolescentes con y sin trastorno de ansiedad social. Mientras el grupo de adolescentes con trastorno de ansiedad no mostró ninguna evidencia de poder olvidar tras recibir la instrucción de hacerlo de forma selectiva, el grupo control sin ansiedad mostró un efecto significativo de ODS (si bien proporcionalmente más pequeño que el mostrado por adultos en el experimento original de Delaney y colaboradores (2009). También Kliegl y colaboradores (2013) investigaron sobre la selectividad del OD, haciendo uso de dos tipos de procedimientos distintos: un paradigma de olvido dirigido con tres listas similar al usado previamente por Sahakyan (2004), y el procedimiento de ODS introducido por Delaney y colaboradores (2009). Tanto utilizando el procedimiento de tres listas (Experimentos 1, 2 y 3) como el original de ODS (Experimento 3), Kliegl y colaboradores encontraron evidencias de olvido dirigido selectivo.

Sin embargo, Sahakyan (2004), también con un procedimiento de olvido dirigido con tres listas, no encontró evidencia alguna de ODS. Así mismo, Storm y colaboradores (2013) tampoco encontraron el efecto experimental en una serie de tres experimentos que ligeras diferencias entre ellos. En el primero, utilizaron el mismo procedimiento usado por Delaney y colaboradores (2009), si bien eliminando el intervalo de tiempo que éstos autores introdujeron entre las listas. En el segundo experimento, replicaron exactamente el mismo procedimiento. En el tercero, pidieron a los participantes que repasasen de manera selectiva sólo los ítems a recordar.

Aunque la causa de las discrepancias entre estudios no es evidente, nuestro primer objetivo, con el Experimento 1, fue replicar el efecto de ODS con el mismo procedimiento creado por Delaney y colaboradores (2009). Los resultados de este primer experimento mostraron un claro efecto de olvido dirigido selectivo que, además de constituir una condición indispensable para abordar el resto de los objetivos de la investigación, tienen importancia en tanto en cuanto suponen una replicación del ODS con un paradigma con el que no siempre se ha obtenido.

Aunque los mecanismos por los que podría producirse este efecto experimental no están claros aún, y hay poca investigación sobre el olvido selectivo, la replicación sistemática del fenómeno a lo largo del presente trabajo va en la línea de lo encontrado en trabajos previos (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), y sugiere que el ODS es un efecto robusto. Así mismo, y en su conjunto, los resultados de todos estos estudios permiten establecer la capacidad de las personas para olvidar de manera intencional y selectiva, y por tanto la necesidad de que los modelos actuales sobre el control de la memoria y el olvido incorporen supuestos que identifiquen los procesos que están a su base.

2. Implicaciones del efecto de ODS para las teorías explicativas del Olvido Motivado

Los resultados del presente trabajo permiten matizar las propuestas teóricas existentes sobre los posibles mecanismos responsables del olvido intencional. Al menos, en lo que respecta al efecto de coste normalmente encontrado con procedimientos de olvido dirigido basados en el método de la lista.

Como se describió a lo largo del capítulo de introducción, el olvido dirigido no selectivo puede ser explicado desde dos marcos teóricos que proponen procesos diferentes. Desde una perspectiva inhibitoria, el efecto de olvido dirigido estándar se explicaría como resultado de ejercer algún tipo de control inhibitorio sobre los ítems estudiados tras recibir la instrucción de olvidar y el aprendizaje (necesario) de una segunda lista de ítems (Bäuml, Hanslmayr, Pastötter, y Klimesch, 2008; Bjork, 1998; Bjork, Bjork, y Anderson, 1998; Geiselman, Bjork, y Fishman, 1983; Hanslmayr et al., 2012; Pastötter y Bäuml, 2007; Soriano y Bajo, 2007). Según esta hipótesis, la inhibición de estos ítems tendría el coste de hacer más difícil su recuperación en un momento posterior. Sin embargo, el menor recuerdo de la Lista 1 en el paradigma estándar de olvido dirigido también se ha atribuido al efecto de cambio de contexto producido por la instrucción de olvidar (Sahakyan y Kelley, 2002; Sahakyan, Delaney, Foster, y Abushanab, 2013). El nuevo contexto estaría aún activo durante la prueba de recuerdo, de manera que favorecería la recuperación de los ítems de la Lista 2 pero dificultaría el recuerdo de la Lista 1.

Los resultados de los experimentos descritos en el presente trabajo, sin embargo, cuestionan una teoría general del cambio de contexto para explicar todos los efectos olvido dirigido (obtenidos con el método de la lista). El fenómeno de ODS resulta difícil de conjugar con la idea de que es la no coincidencia entre los contextos de estudio y recuperación, lo que lleva al olvido de parte de la Lista 1. Con los procedimientos de olvido selectivo utilizados hasta la fecha, tanto la información a olvidar como la señalada a recordar son codificadas en el mismo contexto de la Lista 1 (previo a proporcionar la instrucción). Así, según esta propuesta, el cambio de contexto que provocaría la instrucción de olvidar haría que todos los ítems de la lista estudiada (fuesen o no señalados como a olvidar), fueran más difíciles de recuperar en el contexto de la prueba posterior de memoria. Sin embargo, tanto en los estudios del presente trabajo como en los de otros (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013) la instrucción de olvidar da lugar al olvido selectivo de parte de la Lista 1.

Los resultados de olvido dirigido selectivo sí pueden interpretarse desde la propuesta de que es un mecanismo de tipo inhibitorio el que da lugar a una reducción de la accesibilidad de la información tras proporcionar la orden de olvidar. Si se asume que los participantes pueden codificar la información separando entre los dos subconjuntos de la Lista 1, la inhibición podría actuar de manera selectiva sólo sobre uno de los subconjuntos, dejando la información a recordar fuera del rango de influencia de cualquier mecanismo de regulación (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013). Por tanto, si se considera que el ODS es un efecto similar al olvido dirigido, la evidencia de ODS debería interpretarse en apoyo a las teorías inhibitorias.

Sin embargo, el efecto de ODS podría ser interpretado en términos de teorías basadas en procesos de repaso. Esta explicación, propuesta en su origen por R. Bjork (1970, 1972) para dar cuenta de los primeros resultados del olvido dirigido, proponía que el menor recuerdo que seguía a la instrucción de olvidar se debe a que los participantes segregan la información que debe ser olvidada y recordada, y entonces repasan esta última. Esta explicación, actualizada y adaptada al procedimiento de ODS sugiere que tras la instrucción de olvidar parte de la Lista 1, los participantes siguen la estrategia de repasar únicamente la información que ha sido señalada para recordar (Delaney et al., 2009; Gómez-Ariza et al., 2013; Storm et al., 2013). Ya que tanto la explicación inhibitoria como la basada en el repaso selectivo podrían, en principio, dar cuenta del efecto de olvido dirigido selectivo, un objetivo del presente trabajo era el de investigar hasta qué punto el ODS requiere esfuerzo cognitivo y puede depender de procesos de control ejecutivo. En el siguiente apartado se discutirán los hallazgos de las tres series experimentales en relación con esta cuestión.

3. Naturaleza controlada del ODS

Los resultados de nuestros experimentos 2 a 4 parecen indicar que el proceso que subyace al efecto de ODS requiere de recursos atencionales, ya que la observación del efecto depende de la dificultad que presente la propia tarea de olvido (Experimento 2) y de la disponibilidad de estos recursos (Experimentos 3 y 4). Esta conclusión encaja bien con la propuesta de que el olvido dirigido (no selectivo) recluta mecanismos neurocognitivos de control ejecutivo (Bäuml et al., 2008; Conway, Harries, Noyes, Pacsmány, y Frankish, 2000;

Conway y Fthenaki, 2003; Hanslmayr et al., 2012; Harnishfeger y Pope, 1996; Soriano y Bajo, 2007).

Aunque el objetivo principal del Experimento 2 consistía en investigar posibles factores moduladores del efecto de ODS, la manipulación realizada también permitía conocer si ese efecto experimental requiere de procesos costosos en términos de los recursos cognitivos que implica. De hecho, los resultados de ese experimento constituyen, dentro de la serie experimental que conforma la presente tesis doctoral, la primera prueba de que el efecto de ODS requiere esfuerzo cognitivo; la manipulación de la dificultad del proceso de selección de la información permitió observar que el ODS sólo aparecía en condiciones donde la dificultad era menor.

Estos resultados llevaron a plantear la siguiente serie experimental, utilizando procedimientos de tarea dual, para conocer si el ODS depende de la cantidad de recursos disponibles. Tal y como se propone en los estudios que usan esta metodología tanto en el ámbito del olvido intencional (Conway et al., 2000; Soriano y Bajo, 2007) como en el del olvido incidental (Román, Soriano, Gómez-Ariza, y Bajo, 2009; Ortega, Gómez-Ariza, Román, y Bajo, 2012), la idea es que si el mecanismo responsable del efecto de olvido depende de una capacidad general de control ejecutivo, el efecto debería reducirse en situaciones de tarea dual que también impliquen procesos ejecutivos. Con esta premisa, en los Experimentos 3 y 4 se introdujo una tarea secundaria durante la fase de aprendizaje de la Lista 2. En el Experimento 3 se usó una tarea concurrente altamente demandante que requería actualizar información de la memoria de trabajo (Miyake et al., 2000). Los resultados del Experimento 3 muestran que la introducción de esa tarea concurrente hace desaparecer el efecto de olvido dirigido selectivo, ya que se observó un olvido generalizado de toda la información estudiada antes de la instrucción de olvidar. En el Experimento 4, sin embargo, se utilizó una tarea concurrente de supresión articulatoria, considerada poco demandante de recursos atencionales (Baddeley, 1986; Baddeley y Larsen, 2007; Murray, 1968). Los resultados de este experimento mostraron que la supresión articulatoria no eliminaba el efecto de ODS. Así, tomados conjuntamente, los principales hallazgos de estos dos experimentos sugieren que, al igual que ocurre con los efectos de otros paradigmas relacionados con el control de la memoria (e.g., Anderson y Levy, 2009; Román et al., 2009), el olvido dirigido selectivo es el resultado de un mecanismo de control ejecutivo que depende de la disponibilidad de recursos atencionales.

Resulta interesante observar que es el componente de selección el que se ve afectado por la tarea concurrente en el Experimento 3, dando lugar a un efecto de olvido generalizado de la Lista 1. A la luz de los datos reportados en los estudios de Conway et al., (2000) y Soriano y Bajo (2007) en los que una tarea concurrente hacía desaparecer el efecto de olvido dirigido (no selectivo), nuestro hallazgo podría, en principio, resultar inesperado. No obstante, el hecho de que el procedimiento en nuestros experimentos implique la puesta en marcha de procesos de selección, abre la posibilidad de que sea precisamente este proceso el que se vea afectado por la disminución de recursos atencionales con el uso de una tarea concurrente (algo que no podría ocurrir con el paradigma estándar de olvido dirigido que no implica selección). Por otra parte, el estudio de Soriano y Bajo (2007) con el procedimiento de OD (no selectivo) mostró que la desaparición del efecto por la presentación de una tarea concurrente ocurría únicamente en participantes con baja amplitud de memoria de trabajo. Aslan, Zellner, y Bäuml (2010) también observaron una relación positiva entre la capacidad de memoria de trabajo y el efecto de OD, y encontraron que la capacidad de MT predecía el efecto de OD en participantes jóvenes y en niños. Dado que en nuestro estudio no se midió la amplitud de memoria de los participantes, hace posible que la presencia de olvido generalizado en el Experimento 3 se deba a que nuestros participantes tuviesen una amplitud de memoria promedio, suficiente para llevar a cabo un olvido generalizado de la Lista 1.

Los resultados obtenidos en los Experimentos 2, 3 y 4 resaltan la importancia del proceso de selección en el efecto ODS y que la dificultad de este proceso modula este efecto (Experimento 2) que parece requerir recursos cognitivos (Experimentos 3 y 4). Este aspecto es importante porque aporta evidencia de que los procesos responsables del olvido intencional selectivo son más complejos que los que permiten olvidar de forma no selectiva.

3.1. El Olvido Dirigido Selectivo: Disociación entre procesos de selección y olvido.

Aunque los resultados del Experimento 1 replicaron el efecto básico de ODS encontrado en trabajos previos (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013), no permitían extraer conclusiones sobre la naturaleza de los mecanismos implicados en la obtención del fenómeno.

Los resultados del Experimento 2 indican, como ya se ha comentado, la posibilidad de que procesos de control ejecutivo puedan ser responsables de la capacidad para olvidar intencional y selectivamente. Por otro lado, también indican que la cantidad de información señalada como irrelevante (a olvidar), en comparación con la cantidad de información relevante (a recordar), modula la efectividad de la instrucción de olvidar selectivamente,

Reijnen, Wolfe, y Krummenacher (2013) encontraron, en el ámbito de la búsqueda visual, que la eficiencia en la selección de información está determinada por la proporción objetivo/distractores. En concreto, encontraron que la búsqueda de un pequeño número de objetivos entre un número más grande de distractores resultaba más difícil que la búsqueda de un número más grade de objetivos que de distractores. Tomando como punto de partida las similitudes que pueden establecerse entre la búsqueda visual y la búsqueda en memoria, nuestros resultados apuntan a que la selección en la memoria episódica (al menos en lo que se refiere a situaciones como las que representa el procedimiento de ODS) y la selección en una tarea de búsqueda visual siguen principios similares. Esto sugiere la importancia de la selección, como proceso independiente y susceptible de ser modulado, en el olvido intencional.

Por otra parte, el ODS implica un segundo proceso responsable de hacer que la información seleccionada sea más difícil de recordar. En el Experimento 4 se puso a prueba la posibilidad de que este segundo proceso fuese el repaso selectivo de la información a recordar. Esto se hizo mediante el uso de una tarea concurrente (supresión articulatoria) que hacía difícil a los participantes el repaso subvocal de la información que debían recordar. La utilización de la tarea concurrente de supresión articulatoria, además, cumplía el requisito de no ser muy demandante de control atencional con la idea de poder comparar dos situaciones de tarea concurrente (Experimentos 3 y 4) en que la demanda atencional fuese mayor o menor. Los resultados del experimento revelaron que la tarea de supresión articulatoria no eliminaba el ODS, y sugieren que el repaso selectivo puede no ser el mecanismo que lo produzca.

Con el fin de arrojar más luz en relación con el posible mecanismo responsable del ODS, en los Experimentos 5, 6 y 7 se comparó el efecto ODS en grupos que diferían en edad (jóvenes universitarios y mayores de alrededor de 65 años) que suelen mostrar diferencias en capacidades de control inhibitorio. Los resultados de los dos primeros experimentos de la serie muestran que los mayores no son capaces de olvidar intencionalmente cuando ha de hacerse de forma selectiva. Dado que el envejecimiento se ha asociado con un deterioro de capacidades de control ejecutivo (entre ellas las relacionadas con la inhibición) (Butler, Zacks, y Henderson, 1999; Hamm y Hasher, 1992; Olincy, Ross, Young, y Freedman, 1997; Ortega et al., 2012; Radvansky, Zacks, y Hasher, 2005; West y Alain, 2000; para una revisión, véase Lustig, Hasher, y Zacks, 2007), estos resultados son compatibles con la idea de que el ODS depende de mecanismos inhibitorios (véase también Gómez-Ariza et al., 2013).

Un aspecto muy interesante de los Experimentos 2 a 7 es la disociación de los procesos de selección y de olvido. Tomados conjuntamente los resultados de los Experimentos 2 y 3 sugieren que incrementos en las demandas de selección resulta más disruptivo (Experimento 2; ausencia general de olvido) que la disminución de recursos generada por la realización de una tarea concurrente (Experimento 3; presencia de olvido generalizado, aunque no selectivo). Así, mientras que en el Experimento 3 parece verse afectado solamente el componente de selección, en el Experimento 2 tanto la selección como el olvido se ven comprometidos por la manipulación experimental.

Por su parte, la comparación de los Experimentos 5, 6 y 7 también sugieren que la mayor dificultad de los procesos de ODS debe estar en la selección de información. Mientras que en el Experimento 7, donde se requiere olvidar de forma no selectiva, el efecto de olvido es similar en jóvenes y mayores, los Experimentos 5 y 6, en los que la instrucción de olvidar era selectiva, muestran que los participantes mayores tienen dificultades para seguir las instrucciones de olvido selectivo de forma efectiva. Así, la ejecución de los jóvenes cuando se dificulta el proceso de selección (de olvidar 2/3 de la información a olvidar 1/3 de la lista) resulta similar al de los mayores cuando pasan de tener que olvidar de forma generalizada a hacerlo de forma selectiva. En ambos casos, la mayor dificultad de las condiciones de la tarea de olvido intencional (mayores requerimientos de selección en los jóvenes; mera selección de la mitad de los elementos en el caso de los mayores) da lugar a un deterioro en la capacidad para seguir las instrucciones de olvido.

4. Olvido dirigido selectivo y el control de la memoria durante el envejecimiento

En primer lugar, como ya se ha descrito en anteriores apartados, los resultados obtenidos en los Experimentos 5, 6 y 7, nos invitan a pensar que el control inhibitorio puede ser el responsable del efecto de ODS. Esta conclusión se encuadra dentro de la hipótesis que propone que, durante el envejecimiento, se produce un deterioro en los procesos de control inhibitorio(Hasher & Zacks, 1988) (Hasher y Zacks, 1988; Hasher, Zacks, y May, 1999). A pesar del gran número de estudios empíricos que apoyan esta teoría (e.g., Butler et al., 1999; Olincy et al., 1997), la evidencia con respecto al control inhibitorio en la memoria no es clara en cuanto a este déficit. Aunque varios estudios no encuentran evidencia del déficit inhibitorio en personas mayores usando el procedimiento de olvido dirigido (Sahakyan, Delaney, y Goodmon, 2008; Sego, Golding, y Gottlob, 2006; Zellner y Bäuml, 2006) otros estudios sí han mostrado que los adultos mayores de 60 años no presentan efecto de OD (Zacks, Radvansky, y Hasher, 1996).

Ante esta discordancia, los resultados de los Experimentos 5, 6 y 7 aportan evidencia sobre el déficit inhibitorio en personas mayores y apoyan la idea de que este déficit no es un problema de *todo o nada*, sino que se presenta de manera gradual durante el envejecimiento (Ortega et al., 2012). De esta forma, los mayores que participaron en los Experimentos 5 y 6 no mostraron efecto de ODS. Sin embargo, los mayores que realizaron una tarea de olvido dirigido (no selectivo) presentan un efecto de OD comparable al de los participantes jóvenes. Estos últimos estudios son congruentes con los estudios de Aslan & Bäuml, (2013) que mostraban que el déficit en control inhibitorio es progresivo y más evidente en personas de mayor edad. De forma similar, nuestras conclusiones son congruentes con los resultados de otros estudios que muestran déficits en el control inhibitorio con la edad en otras tareas de memoria episódica (p.e. TNT Anderson, Reinholz, Kuhl, y Mayr, 2011; no obstante, para una posible explicación relacionada véase Murray, Anderson, y Kesinger, 2015).

5. Relación del ODS con los modelos de control de la memoria actuales: hacia un modelo del olvido motivado.

Los experimentos descritos en el presente trabajo se añaden a una fructífera línea de investigación contemporánea sobre el olvido motivado. Hasta el momento, sin embargo, la investigación dedicada a estudiar el posible carácter selectivo del olvido intencional ha sido muy escasa, y con resultados experimentales poco consistentes.

Las formas de olvido motivado estudiadas hasta el momento incluyen la supresión de recuerdos irrelevantes o no deseados durante la codificación y durante el recuerdo (para una revisión, véase Anderson y Hanslmayr, 2014). Además existe un gran cuerpo de datos comportamentales y de neuroimagen que sugieren que mecanismos de control de tipo inhibitorio actúan en el olvido motivado, tanto cuando es implementado durante la codificación como durante el recuerdo.

Las explicaciones sobre el olvido motivado que podemos encontrar se basan en procesos pasivos o dependientes de factores contextuales (Sahakyan et al., 2013; MacLeod, Dodd, Sheard, Wilson, y Bibi, 2003), o en procesos activos que requieren de procesos control ejecutivo (Bäuml et al., 2008; Geiselman et al., 1983; Hanslmayr et al., 2012; Pastötter et al., 2010). Recientes estudios empleando técnicas de neuroimagen sugieren que las instrucciones de olvidar desencadenan un proceso activo que tiene como resultado interrumpir la actividad de la memoria (Bäuml et al., 2008; Hanslmayr et al., 2012; para una revisión, véase Anderson y Hanslmayr, 2014). Bäuml y colaboradores (2008), en un estudio que medía las oscilaciones cerebrales, encontraron que la instrucción de olvidar provocaba un descenso de la sincronía entre redes neurales, que parece señalar la interrupción de procesos neurales que mejoran la retención. Hanslmayr y colaboradores (2012) replicaron estos resultados. Además encontraron que la estimulación directa del córtex dorsolateral prefrontal con estimulación magnética transcraneal repetitiva se reducía la sincronía neural, incrementando significativamente el efecto de olvido dirigido, y dando evidencia del papel causal del DLPFC en olvido motivado. Estos resultados sugieren que el lóbulo prefrontal ejerce un papel causal sobre el control de los recuerdos, y refleja un proceso de control activo en memoria. Estos resultados sugieren que un proceso de control activo contribuye al olvido dirigido.

A la luz de los resultados obtenidos a lo largo de toda la serie experimental descrita, la interpretación del efecto de ODS parece encajar con las teorías que proponen un mecanismo controlado y, en concreto, de tipo inhibitorio, para explicar el olvido motivado. En los Experimentos 2-4 se muestra evidencia de que el control ejecutivo está a la base del efecto de olvido selectivo. En los Experimentos 5-7, aunque indirecta, se deja ver una explicación en base a un posible mecanismo inhibitorio. En futuros estudios se plantea la posibilidad de abordar este problema desde una perspectiva más directa, y localizar marcadores de neuroimagen relacionados con el control inhibitorio de la memoria en una tarea de olvido dirigido selectivo.

6. Conclusiones

En el presente trabajo se expone el efecto de olvido dirigido selectivo y se muestra evidencia experimental de que este fenómeno de olvido refleja la actuación de mecanismos de control ejecutivo que se ven afectados tanto por la dificultad del proceso de selección, como por la falta de recursos atencionales. Además, con respecto a los posibles mecanismos subyacentes, aunque no podamos afirmar de manera inequívoca que el mecanismo controlado subyacente es de tipo inhibitorio, los resultados apuntan a una posible causa inhibitoria. Por otro lado, los resultados de las distintas series experimentales también ponen de manifiesto la importancia de usar una tarea adecuada para evaluar el déficit de control inhibitorio en diferentes poblaciones. Finalmente, los resultados también muestran que el envejecimiento lleva asociado un déficit en el control inhibitorio de la memoria, pero que este deterioro aparece de forma gradual y sólo es evidente a edades más tardías o cuando las condiciones requieren mayores recursos atencionales.

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Chapter V

General discussion

Up to date, a large body of research has been generated around intentional forgetting phenomena. However, the idea that motivated forgetting can be selective has only recently been explored. The studies included in this thesis aimed to investigate the nature of the mechanism underlying the capacity to intentionally and selectively forget. Although some theoretical explanations regarding non-selective directed forgetting effects have been proposed, explanations regarding selective directed forgetting remain unexplored.

Some previous studies have failed to replicate the selective directed forgetting (SDF) effect, and of them have cast doubt on the possibility that motivated forgetting (as assessed through directed forgetting procedures) may be selective. The present work aimed to shed light on this issue. Thus, the seven experiments reported here address four main points: 1) to replicate the experimental effect of selective intentional forgetting; 2) to explore possible modulating factors constraining the capacity to intentionally forget in a selective way; 3) to investigate if intentional and selective forgetting relies on executive control mechanisms; and 4) to identify the cognitive mechanisms that might be responsible for the SDF effect.

After reviewing theories and previous results on directed forgetting in Chapter I[1], in the experimental section we outline three series of experiments framed in three different approaches to the problem. Experiment 1 (as a first replication of the experimental SDF effect) and the rest of the studies in Chapter III allow us to conclude

[1] For an English version, please see Chapter II.

that SDF is a robust phenomenon that can be experimentally addressed. In Experiment 2, the difficulty of the selection task was manipulated. By doing this we pursued the second aim of the thesis: to explore the extent to which the success in intentional selective forgetting is modulated by the relative proportion of information cued to forget. The results of this experiment showed that selectivity depends on the relative amount of memories to update. On the other hand, and in order to explore other modulating factors of SDF and the role of executive control in producing the effect, in Experiments 3 and 4 we manipulated the availability of executive control resources during the task.. The results suggested that executive-control capacities play a role in the SDF effect. Finally, to attempt to identify the concrete mechanism leading to SDF, we used an individual differences perspective by comparing groups of different ages that are thought to differ in inhibitory control capacities. The results of Experiments 5, 6 y 7 endorsed the idea that executive control is involved in SDF and suggested that memory inhibition underlies selective motivated forgetting.

In the next sections we will summarize the empirical findings obtained in the three experimental series and discuss their theoretical implications. This chapter will be organized around five topics. First, we will discuss the relation between our findings and those found in previous research on SDF. Second, we will address the theoretical relevance of our results for the current accounts of non-selective directed forgetting effects. Third, the nature of the putative underlying mechanism will be discussed. In the fourth section we will summarize and discuss the main implications of the findings of the last series of experiments for our understanding of cognitive aging. Finally, in the fifth section, we will discuss how the results of the present work contribute to current theories on memory control.

1. The SDF effect: evidence of motivated and selective forgetting.

Previous experimental research on whether motivated forgetting may be selective has reported mixed results: whereas some studies have shown the SDF effect (Delaney, Nghiem, & Waldum, 2009; Gómez-Ariza et al., 2013; Kliegl, Pastötter, & Bäuml, 2013), others have failed to observe it (Storm, Koppel, & Wilson, 2013; for a study using a related procedure, see Sahakyan, 2004). Hence, and although the reasons behind these divergent findings are not evident, the first aim (essential in order to address the rest of them) of the present work was to replicate SDF. The results of Experiment 1 showed, for the first time, an SDF effect with the same procedure and population as Delaney et al.'s study.

Whereas the mechanism/s responsible for the SDF effect remains unknown, the systematic replication of such an effect across each of the different studies of this dissertation suggests that it is a robust effect. Thus, along with previous research reporting similar results, these present results allowed us to establish the capacity to intentionally forget in a selective way; therefore, there is a the need for the current theories on forgetting and memory control to incorporate SDF phenomena.

2. Implications of the SDF effect for the accounts of motivated forgetting

As described in the introductory chapters, non-selective directed forgetting is currently understood from two different theoretical frameworks. From an inhibitory perspective, the standard directed forgetting effect would be explained as the aftereffect of an inhibition-like mechanism that acts upon the studied items after participants receive the cue to forget whenever new material is to be learned (Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008; Bjork, 1998; Bjork, Bjork, & Anderson, 1998; Geiselman, Bjork, & Fishman, 1983; Hanslmayr et al., 2012; Pastötter & Bäuml, 2007; Soriano y Bajo, 2007). According to this view, inhibition would produce the cost effect of making List 1 items harder to retrieve. From a context change perspective, the memory cost observed for List 1 items with the standard LM-DF procedure is the consequence of a contextual mismatch between List 1 encoding and retrieval, which is produced by the instruction to forget (Sahakyan & Kelley, 2002; Sahakyan, Delaney, Foster, & Abushanab, 2013).

SDF challenges a general context-change account of directed forgetting effects (as obtained with list-method procedures). Given that to-be-forgotten and to-be-remembered information is presented within the same context, while studying List 1 and before receiving the forget cue, the putative mental context change induced by the instruction would be expected to impair the recall of all the items composing List 1 and no SDF effect should be observed.

In principle, however, SDF could be thought a consequence of memory inhibition. If it is assumed that participants in a SDF experiment can encode List 1 information segregating the two subsets of List 1, inhibitory control could selectively act on the to-be-forgotten subset while leaving the to-be-remembered subset unaffected (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013).

Alternatively, the SDF effect could also be interpreted in terms of rehearsal processes. This explanation was first proposed by R. Bjork (1970, 1972) to account for the first results obtained with a directed forgetting procedure. Applied to the SDF effect, the rehearsal account would suggest that after being given the instruction to forget, participants strategically rehearse the List 1 items they were cued to remember, which would end up being encoded better than items cued to forget (Delaney et al., 2009; Gómez-Ariza et al., 2013; Storm et al., 2013).

Given that the SDF effect fits into inhibitory and rehearsal-based accounts of forgetting, one of the aims of the present work was to investigate to what extent SDF requires attentional resources and relies on executive-control capacity. The findings of the three experimental series related to this aim are discussed in the next section.

3. The controlled nature of SDF

The results of Experiments 2-4 suggested that the mechanism underlying SDF draws on attentional control, since the presence of the experimental effect depended on the level of selectivity that the instruction to forget entailed (Experiment 2) as well as on the availability of cognitive resources (Experiments 3 and 4). This conclusion is consistent with evidence showing that non-selective intentional forgetting alto recruits executive control mechanisms (Bäuml et al, 2008; Conway, Harries, Noyes, Pacsmány, & Frankish, 2000; Conway & Fthenaki, 2003; Hanslmayr et al., 2012; Harnishfeger & Pope, 1996; Soriano & Bajo, 2007).

Whereas Experiment 2 aimed to investigate possible modulating factors of the SDF effect, the experimental manipulation also allowed us to glimpse the involvement of cognitive control in SDF. In fact, the main finding of that experiment turns out to be the first evidence that the ability to intentionally forget in a selective way is highly demanding. The SDF effect was only observed when selectivity was made easier.

Further support for SDF's reliance on cognitive resources comes from the second experimental series, in which we used a dual-task approach. As in previous studies on intentional and incidental forgetting using dual-task procedures (Conway et al., 2000; Ortega, Gómez-Ariza, Román, & Bajo, 2012; Román, Soriano, Gómez-Ariza, & Bajo, 2009; Soriano & Bajo, 2007), the assumption was that if the mechanism responsible for SDF involves attentional control, the experimental effect would be smaller (or null) in the presence of a secondary task entailing executive control.

Thus, in Experiments 3 and 4, a secondary task was introduced during List 2 study. In Experiment 3, the secondary task required participants to update working memory contents (Miyake et al., 2000), and the results showed that compromising attentional control after instructions regarding List 1 hindered the ability to selectively forget (as it hinders List 2 learning). Interestingly, the results of Experiment 3 and 4 suggested that it is not performing a secondary task during List 2 learning per se that prevents SDF from being observed, but the fact that this task compromises executive control. Thus, in Experiment 4, where the secondary task was an articulatory suppression task entailing lower attentional control (Baddeley, 1986; Baddeley & Larsen, 2007; Murray, 1968), the SDF effect was present despite affecting List 2 learning. Taken together, Experiments 3 and 4 suggest that, like other forgetting effects that have been related to memory control (e.g., Anderson y Levy, 2009; Conway et al., 2000 Román et al., 2009), SDF is the result of an executive control mechanism that depends on the availability of attentional resources.

It is important to note that it is selectivity that is affected by the concurrent task in Experiment 3, given that we observed a generalized forgetting effect for List 1. On the basis of previous studies showing that concurrent tasks disrupt (non-selective) directed forgetting (Conway et al., 2000; Soriano and Bajo, 2007), our results might in principle seem surprising. However, the fact that our experimental procedure required selecting information suggests that it was precisely this selection process that was affected by performing the secondary task. On the other hand, Soriano and Bajo (2007) showed that the abolition of DF effect caused by the presentation of a secondary task occurred only for participants with low working memory capacity (WMC). In this line, Aslan, Zellner, and Bäuml (2010) observed that WMC predicted DF effect in young participants and children. Because we did not assess WMC in our study, it is entirely possible that the presence of a general forgetting effect in Experiment 3 was due to our participants being medium-high WM span participants and, on average, having enough cognitive resources to globally forget, despite being unable to do it selectively.

In summary, Experiments 2, 3 and 4 highlight the relative independence between selection and forgetting processes and indicate that increasing the cognitive demands of the SDF task by making selection harder (Experiment 2), or by overstressing attentional resources (Experiments 3), modulates the effect of the instruction to forget. This is of theoretical relevance and strongly suggests that selective intentional forgetting is more complex than its non-selective counterpart.

3.1. Selective directed forgetting: dissociation between the selection and forgetting processes.

The results of Experiments 1 and 2 replicated the basic SDF effect found in previous studies (Delaney et al., 2009; Gómez-Ariza et al., 2013; Kliegl et al., 2013) and suggest that executive control processes might be involved in selective forgetting. On the other hand, these results also indicated that the amount of information classified as irrelevant (to-be-forgotten information), compared to the amount targeted as relevant (to-be-remembered information), modulates the success of the instruction to selectively forget.

This pattern of results was consistent with those obtained by Reijnen, Wolfe, and Krummenacher (2013) in the realm of visual selective attention, indicating that the efficiency in the selection of information is determined by the target/distractors ratio. Specifically, they found an asymmetry effect whereby searching for a smaller number of items among a large set was harder than searching for a larger number among a smaller set of items. Based on the similarities that can be established between visual search and the processes involved in memory search, our results suggest that episodic memory selection (at least regarding situations represented by the SDF procedure) and visual search might be regulated by similar factors. This also indicates the importance of selection as an independent process susceptible to being modulated in intentional forgetting. The fact that increments in selectivity impaired the ability to select the information to forget, but not forgetting itself (overall forgetting was obtained), stressed the dissociation between selection and forgetting. Thus, SDF seems to involve not only selection processes but also additional processes in charge of rendering the selected information harder to retrieve.

Although Experiment 2 and 3 were consistent with an inhibitory explanation of the forgetting effect, in Experiment 4 we tried to further investigate the mechanism underlying the effect by exploring the role of selective rehearsal of the to-be-remembered information in producing SDF. We accomplished this aim by using articulatory suppression as the secondary task to disrupt sub-vocal rehearsal of the to-be-remembered information. Furthermore, we selected articulatory suppression because it entails relatively lower demands of executive control than the secondary task used in Experiment 3. Thus, we were able to compare articulatory suppression (low attentional demanding task) with an updating secondary task involving high executive demands. The results of these experiments revealed that the articulatory suppression task did not impair the SDF effect, and suggested that selective rehearsal might not be the mechanism underlying selective voluntary forgetting. In addition, dual tasking itself does not seem to impair SDF, but executive control needs to be involved to affect selective forgetting.

In Experiments 5, 6 and 7 we changed the approach and tried to explore the nature of the mechanisms underlying SDF by comparing different age groups (younger students and older adults around 65 years) that have been shown to differ in inhibitory control capacities. The results of the two first experiments of the series showed that older adults were not able to intentionally forget when asked to do it in a selective way. Given that aging has been associated with a decline in executive control capacities (especially those related to inhibitory control) (Murray et al., 2015; Butler, Zacks, & Henderson, 1999; Hamm & Hasher, 1992; Olincy, Ross, Young, & Freedman, 1997; Ortega et al., 2012; Radvansky, Zacks, & Hasher, 2005; West & Alain, 2000; for a review, see Lustig, Hasher, & Zacks, 2007), these results are in line with the idea that SDF relies on inhibitory mechanisms (see also Gómez-Ariza et al., 2013).

In general, the results of Experiments 2 to 7 stress the dissociation between selection and forgetting. Experiments 2 and 3 indicated that increasing selection demands was more disruptive (Experiment 2; no general forgetting effect) than increments in attentional resources produced by dual task performance (Experiment 3; generalized forgetting effect, but not selective). Thus, while in Experiment 3, selectivity but not forgetting was affected, in Experiment 2, both selection and forgetting processes were harmed by the experimental manipulation. Although it is not obvious why increments in selection seem to be more disruptive than dual tasking, the obtained pattern of results suggests a dissociation between selection and forgetting.

It is interesting that the results from Experiments 5, 6 and 7 also indicated that the major difficulty of the processes involved in SDF lie in the selection of the to-be-forgotten information. Thus, in Experiment 7, where non-selective forgetting was required, the forgetting effect was similar for the younger and older adults. In contrast, in Experiments 5 and 6 involving selective forgetting, older adults showed difficulties to successfully accomplish the instructions to selectively forget. Once again, selection to intentional forget seems to be a highly demanding component of memory control.

4. Selective directed forgetting and memory control on aging

As mentioned in previous chapters, the results obtained in Experiments 5, 6 and 7 lead us to think that inhibitory control might be underlying SDF. This conclusion is framed into the hypothesis that aging brings a decline in inhibitory control (Hasher & Zacks, 1988, Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). Despite the large number of empirical studies supporting this idea (e.g., Butler et al., 1999; Olincy et al., 1997), the evidence regarding non-selective directed forgetting is unclear. Although some studies did not find evidence of an inhibitory deficit in older adults when using the directed forgetting procedure (Sahakyan, Delaney, & Goodmon, 2008; Sego, Golding, & Gottlob, 2006; Zellner & Bäuml, 2006), others did not find the DF effect in older adults over 60 years (Zacks, Radvansky, & Hasher, 1996).

Considering this pattern, the results of Experiments 5, 6 and 7 provide evidence regarding inhibitory deficits in older adults as well as a potential explanation as to why intentional forgetting is not always impaired in older people. As suggested by Ortega et al. (2012), our data support the idea that executive-control deficits are not an *all or nothing* matter, but gradually appear in the course of healthy aging and may be more evident in highly demanding situations. Thus, older participants in Experiments 5 and 6 did not show the SDF effect. However, older participants in Experiment 7, who performed a non-selective directed forgetting task, showed a DF effect similar to that shown by younger adults. These results are also congruent with Alsan and Bäuml's study (2013) showing that inhibitory control declines in a progressive way and it is more evident at older ages. Similarly, our conclusions are congruent with other studies that show inhibitory deficits with aging when using other episodic memory tasks (e.g., Anderson, Reinholz, Kuhl, y Mayr, 2011; Murray, Anderson, & Kesinger, 2015).

5. Relation of SDF with the current models in memory control: towards a motivated forgetting model

The experiments described in the present work are framed into the growing line of research on motivated forgetting. Although research focusing on the selective component of intentional forgetting has been limited, motivated forgetting has been largely studied and many studies suggest that inhibition of irrelevant or undesired memories may act during encoding and retrieval (for a review, see Anderson & Hanslmayr, 2014).

Whereas current explanations of motivated forgetting include both passive context-dependent (Sahakyan et al., 2013; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003) and active mechanisms requiring attentional control (Bäuml et al., 2008; Geiselman et al., 1983; Hanslmayr et al., 2012; Pastötter et al., 2010), recent studies using brain-related techniques suggest that the forget instructions trigger an active process that interrupts mnemonic activity (Bäuml et al., 2008; Hanslmayr et al., 2012; for a review, see Anderson & Hanslmayr, 2014). Bäuml et al. (2008), using electroencephalography (EGG) and oscillation analyses, found that the instruction to forget decreased the large-scale synchrony in a widespread cortical network that seems to be involved in memory retention. Hanslmayr et al. (2012) replicated these results and also found that repetitive transcranial magnetic stimulation of the dorsolateral prefrontral cortex reduced neural synchrony and significantly increased the effect of directed forgetting. These results suggest the involvement of the prefrontal cortex in motivated forgetting and point to the role of active control mechanisms in regulating memory accessibility.

In this line, the results of Experiments 2 to 7 also add to the evidence indicating that motivated forgetting is an active process involving executive control. Our findings seem to also fit into theories proposing that inhibitory-control mechanisms are responsible for motivated forgetting. Experiments 2-4 suggest that increments in selectivity and executive control affect SDF. Similarly, Experiments 5-7 support an inhibitory account of the effect by showing that older people's capacity to selectively forget was reduced relative to younger people. Future studies should more directly address this issue by exploring neural markers directly related to inhibitory control in selective directed forgetting tasks.

6. Conclusions

In the present work we provide evidence that selective directed forgetting involves executive control mechanisms that are modulated by the difficulty of the selection process and by the availability of attentional resources. In this line, although we cannot unequivocally conclude that the underlying controlled mechanism is inhibitory in nature, the overall pattern of results seems to be better explained by inhibitory frameworks. On the other hand, the results of the experimental series also highlight the importance of using an appropriate task when assessing inhibitory deficits (and other possible deficits) in different populations since these deficits might only be evident on highly demanding tasks. Finally, our results also show that aging brings an inhibitory control deficit in memory control that gradually appears, being only evident later in life or when conditions require a high degree of attentional resources.

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Chapter VI

Appendices

Appendix I

Materials used in Experiments 1, 3, 4 and 5[1]

List 1

Character 1

<*Tomás /Alex*> voló una cometa

<*Tomás /Alex* > escucha música

<*Tomás /Alex* > trabaja en su despacho

<*Tomás /Alex* > fue a un cumpleaños

<*Tomás /Alex* > se tomó su medicina

<*Tomás /Alex* > corre todas las mañanas

<*Tomás /Alex* > está casado

<*Tomás /Alex* > vio la televisión

<*Tomás /Alex* > visitó Barcelona

Character 2

<*Tomás /Alex*> regó el jardín

<*Tomás /Alex* > se lavó los dientes

<*Tomás /Alex* > se comió un bocadillo

<*Tomás /Alex* > alquiló un coche

<*Tomás /Alex* > puso la lavadora

<*Tomás /Alex* > fue a un concierto

<*Tomás /Alex*> echó gasolina

<*Tomás /Alex*> es creativo

<*Tomás /Alex*> se compró unos zapatos

[1] In Experiment 5 both Spanish and English sentences were used for the Spanish/English sample.

List 2

José navegó por internet
José montó a caballo
José cogió el autobús
José plantó un árbol
José jugó al tenis
José fue a nadar
José sacó la basura
José jugó a los videojuegos
José aparcó en el centro
José hizo un dibujo
José tuvo una cita
José se despertó tarde
José se cepilló el pelo
José terminó un puzle

Materials used for the English sample in Experiment 5

List 1

Character 1

<*Tom /Alex*> flew a kite

<*Tom /Alex* listens to music

<*Tom /Alex* > writes in a study

<*Tom /Alex* > had a birthday party

<*Tom /Alex* > took his medicine

<*Tom /Alex* > jogs every morning

<*Tom /Alex* > is married

<*Tom /Alex* > watched television

<*Tom /Alex* > visited Colorado

Character 2

<*Tom /Alex*> watered his garden

<*Tom /Alex* > brushed his teeth

<*Tom /Alex* > ate a sandwich

<*Tom /Alex* > rented a car

<*Tom /Alex* > did his laundry

<*Tom /Alex* > went to a concert

<*Tom /Alex*> refueled his car

<*Tom /Alex*> is creative

<*Tom /Alex*> bought shoes

List 2

Joe went online
Joe rode a horse
Joe sat on the coach
Joe planted a tree
Joe played tennis
Joe went swimming
Joe took out the trash
Joe played videogames
Joe parks downtown
Joe drew a picture
Joe made an appointment
Joe woke up late
Joe brushed his hair
Joe completed a puzzle

Appendix II

Materials used in Experiment 2

List 1

Character 1

<*Tomás /Martin /Alex*> trabaja en su despacho

<*Tomás /Martin /Alex*> voló una cometa

<*Tomás /Martin /Alex*> compró unos zapatos

<*Tomás /Martin /Alex*> escucha música

<*Tomás /Martin /Alex*> se lavó los dientes

<*Tomás /Martin /Alex*> visitó Barcelona

Character 2

<*Tomás /Martin /Alex*> corre todas las mañanas

<*Tomás /Martin /Alex*> fue a un cumpleaños

<*Tomás /Martin /Alex*> echó gasolina

<*Tomás /Martin /Alex*> regó el jardín

<*Tomás /Martin /Alex*> alquiló un coche

<*Tomás /Martin /Alex*> se tomó su medicina

Character 3

<*Tomás /Martin /Alex*> es creativo

<*Tomás /Martin /Alex*> se comió un bocadillo

<*Tomás /Martin /Alex*> vio la televisión

<*Tomás /Martin /Alex*> puso la lavadora

<*Tomás /Martin /Alex*> se fue a un concierto

<*Tomás /Martin /Alex*> se está casado

List 2

José navegó por internet

José montó a caballo

José cogió el autobús

José plantó un árbol

José jugó al tenis

José fue a nadar

José sacó la basura

José jugó a los videojuegos

José aparcó en el centro

José hizo un dibujo

José tuvo una cita

José se despertó tarde

José se cepilló el pelo

José terminó un puzle

Appendix III

Materials used in Experiment 6

List 1

Character 1

<*Tomás /Alex*> voló una cometa

<*Tomás /Alex* > escucha música

<*Tomás /Alex* > trabaja en su despacho

<*Tomás /Alex* > fue a un cumpleaños

<*Tomás /Alex* > se tomó su medicina

<*Tomás /Alex* > corre todas las mañanas

Character 2

<*Tomás /Alex*> regó el jardín

<*Tomás /Alex* > se lavó los dientes

<*Tomás /Alex* > se comió un bocadillo

<*Tomás /Alex* > alquiló un coche

<*Tomás /Alex* > puso la lavadora

<*Tomás /Alex* > fue a un concierto

List 2
José navegó por internet
José montó a caballo
José cogió el autobús
José plantó un árbol
José jugó al tenis
José sacó la basura
José jugó a los videojuegos
José aparcó en el centro
José hizo un dibujo
José se despertó tarde
José se cepilló el pelo
José terminó un puzle

Appendix IV

Materials used in Experiment 7 for the Spanish sample

List 1

Tomás escucha música

Tomás voló una cometa

Tomás está casado

Tomás trabaja en su despacho

Tomás fue a un cumpleaños

Tomás vio la televisión

Tomás se tomó su medicina

Tomás visitó Barcelona

Tomás corre todas las mañanas

Tomás regó el jardín

Tomás echó gasolina

Tomás se lavó los dientes

Tomás se comió un bocadillo

Tomás es creativo

Tomás alquiló un coche

Tomás puso la lavadora

Tomás se compró unos zapatos

Tomás fue a un concierto

List 2
José navegó por internet
José montó a caballo
José cogió el autobús
José plantó un árbol
José jugó al tenis
José fue a nadar
José sacó la basura
José jugó a los videojuegos
José aparcó en el centro
José hizo un dibujo
José tuvo una cita
José se despertó tarde
José se cepilló el pelo
José terminó un puzle

Materials used in Experiment 7 for the English sample

List 1

Tom listens to music

Tom flew a kite

Tom is married

Tom writes in a study

Tom had a birthday party

Tom watched television

Tom took his medicine

Tom visited Colorado

Tom jogs every morning

Tom watered his garden

Tom refueled his car

Tom brushed his teeth

Tom ate a sandwich

Tom is creative

Tom rented a car

Tom did his laundry

Tom bought shoes

Tom went to a concert

List 2
Joe went online
Joe rode a horse
Joe sat on the coach
Joe planted a tree
Joe played tennis
Joe went swimming
Joe took out the trash
Joe played videogames
Joe parks downtown
Joe drew a picture
Joe made an appointment
Joe woke up late
Joe brushed his hair
Joe completed a puzzle