TESIS DOCTORAL

DIFFERENTIAL EFFECTS OF ENDOGENOUS AND EXOGENOUS ATTENTION ON INFORMATION PROCESSING

(Efectos diferenciales de la atención endógena y exógena
en el procesamiento de información)

DOCTORADO EUROPEO

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DIFFERENTIAL EFFECTS OF ENDOGENOUS AND EXOGENOUS ATTENTION ON INFORMATION PROCESSING

Tesis doctoral presentada por **Ana Belén Chica Martínez** en el Departamento de Psicología Experimental y Fisiología del Comportamiento, para aspirar al grado de Doctora (dentro del programa de Doctorado Europeo) en Psicología, en el programa de doctorado de Psicología Experimental y Neurociencias del Comportamiento, de la Universidad de Granada.

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La doctoranda	El director de la tesis
Fdo. Ana Belén Chica Martínez	Fdo. Juan Lupiáñez Castillo

A mis padres,
porque derrocháis generosidad y amor.

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Publicaciones de la tesis

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Chica, A. B., Charras, P., y Lupiáñez, J. (remitido-b). Endogenous attention and Illusory Line Motion depend on task set.

Chica, A. B., y Lupiáñez, J. (2004). Inhibition of return without return of attention. *Psicothema, 16*(2), 248-254.

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Chica, A. B., & Christie, J. (en revisión). Spatial attention does improve temporal resolution. *Perception & Psychophysics*.

Chica, A. B., Taylor, T. L., Lupiáñez, J., & Klein, R. M. (en preparación). Two mechanisms underlying Inhibition of Return.

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Resumen amplio

Cada vez que abrimos los ojos llega a nuestra retina mucha más información de la que podemos percibir al mismo tiempo. Nuestro sistema atencional nos ayudará a seleccionar estímulos especialmente salientes o peligrosos, o estímulos relevantes para nuestras metas. Por una parte, podemos orientar nuestra atención de manera voluntaria o **endógena**, de acuerdo con las metas o expectativas que guían nuestro comportamiento. Por ejemplo, podemos prestar atención a la puerta de llegadas del aeropuerto si esperamos la llegada de una persona. Pero nuestra atención también puede dirigirse de manera involuntaria o **exógena** a ciertas localizaciones u objetos debido a su saliencia o relevancia. Por ejemplo, si mientras intentamos buscar a nuestro amigo en la puerta del aeropuerto alguien grita a nuestro lado, nuestra atención se dirigirá rápidamente hacia esa persona, a pesar de que en principio esto nos puede distraer y provocar que no veamos a nuestro amigo salir. Estas dos formas de orientar la atención (endógena y exógena) han sido ampliamente estudiadas, especialmente desde el desarrollo del paradigma de costes y beneficios (Posner, 1980; Posner y Cohen, 1984). Cuando se estudia la atención encubierta (sin movimientos oculares) los participantes deben mantener los ojos en el punto de fijación durante todo el ensayo. Posteriormente aparece una señal atencional, que dirige la atención a una localización en la pantalla. En el estudio de la atención endógena, esta señal consiste en un símbolo presentado en el centro, que los participantes deben codificar para orientar su atención. Por ejemplo, se suele presentar una flecha apuntando a una determinada localización. Normalmente, estas señales predicen con una probabilidad superior al azar dónde se presentará el estímulo relevante para la tarea. Como medida de la orientación atencional endógena, se suele observar que los tiempos de reacción (TR) para responder al estímulo relevante son más rápidos si éste se presenta en el lugar indicado por la señal (igualmente pueden observarse más aciertos en el lugar predicho por la señal). Sin embargo, en el estudio de la atención exógena, la señal consiste en un objeto nuevo que aparece en la pantalla o un cambio de luminancia de uno de los objetos ya presentes. Se considera que estas señales capturan la atención exógenamente ya que aunque no sean predictivas sobre dónde aparecerá el estímulo relevante (ni sobre la respuesta que se tendrá que emitir), aceleran los TR si la señal y el estímulo relevante se presentan en la misma localización (Posner y Cohen, 1984). Sin embargo, cuando el tiempo que transcurre entre la aparición de la señal exógena y el estímulo relevante es lo suficientemente largo (alrededor de

300 ms en las tareas de detección), el TR se enlentece si la señal y el estímulo se presentan en la misma localización. Este efecto, conocido como Inhibición de Retorno (en inglés Inhibition of Return, IOR; Lupiáñez, Rueda, y Tudela, 1999; Posner, Rafal, Choate, y Vaughan, 1985) se considera un efecto atencional mediante el cual se inhibe la reorientación de la atención a posiciones recientemente atendidas, favoreciendo la búsqueda visual de lugares que no han sido explorados (Klein, 2000). Por otra parte, las señales exógenas también pueden hacerse predictivas sobre dónde aparecerá el estímulo relevante. En este caso, se cree que estas señales capturan la atención exógenamente, y posteriormente se mantiene la atención en ellas de manera endógena (Cohen, Bolanowski, y Verrillo, 2005; Posner, Cohen, y Rafal, 1982). Con este tipo de señales no aparece IOR, y se cree que la ausencia de IOR se debe a que la atención no se ha desenganchado del lugar de la señal. Esta hipótesis será ampliamente discutida y refutada en esta tesis (Chica y Lupiáñez, 2004, en revisión; Chica, Lupiáñez, y Bartolomeo, 2006; Lupiáñez y Chica, remitido; ver capítulos II.I., II.II., y III.II.).

Las primeras teorías plantearon la existencia de un sistema atencional único que podía orientarse de manera endógena o exógena (Jonides, 1981; Posner et al., 1985). Es decir, existiría un único sistema encargado de la orientación atencional que podría ser "transportado" bien de manera endógena o de manera exógena. Sin embargo, los datos pronto empezaron a indicar que estas dos formas de orientar la atención tenían características diferentes (ver Klein, 2004; Klein y Shore, 2000). Uno de los objetivos principales de esta tesis es estudiar si la atención endógena y exógena pueden producir sus efectos de manera independiente. Así, siguiendo la lógica de los factores aditivos (Sternberg, 1969), si la atención endógena y exógena son dos sistemas atencionales independientes, éstos deberían producir sus efectos sin interaccionar entre ellos. Como primer paso en el desarrollo de nuestra investigación, desarrollamos un paradigma en el que la atención endógena y exógena pueden disociarse usando el mismo conjunto de estímulos. Usamos una señal periférica informativa que predice, en diferentes bloques de ensayos (aunque también se ha manipulado ensayo a ensayo; ver Anexo I, Chica y Lupiáñez, 2004), que el estímulo se presentará o bien en la misma localización de la señal o en la localización contraria. De esta manera tenemos dos medidas de la orientación atencional: si comparamos las condiciones en las que el estímulo se presenta en la localización predicha por la señal (en el 75% de los ensayos de cada bloque) con aquellas otras condiciones en las que el estímulo se presenta en la localización no predicha (en el 25% de los ensayos de cada bloque), tendremos una medida de la orientación éndogena de la atención. Por otro lado, si comparamos las condiciones en las que el estímulo se presenta en el mismo lugar de la señal (ensayos de lugar señalado) con aquellas en las que el estímulo se presenta en el lugar contrario (ensayos de lugar no señalado), tendremos una medida de la orientación exógena de la atención. Además, con este paradigma, los ensayos endógenamente esperados y no esperados pueden ser a su vez señalados y no señalados (y viceversa), lo que nos permite estudiar las posibles interacciones entre los sistemas de orientación atencional endógena y exógena.

En el capítulo II.I. (Chica y Lupiáñez, 2004; Chica et al., 2006), presentamos este paradigma por primera vez, manipulando también que los participantes tengan que realizar una tarea de detección simple, o una tarea de discriminación de color. Los resultados mostraron que, cuando los participantes tenían que detectar la aparición del estímulo, se producían efectos principales de la orientación atencional endógena y exógena, pero no se encontraba interacción entre ambas medidas. Es decir, demostramos que, al menos en ciertas circunstancias (en tareas de detección), ambos tipos de orientación atencional pueden producir sus efectos de manera independiente sin interaccionar entre ellos, lo que indica la existencia de dos sistemas atencionales independientes. Por otra parte, encontramos efectos significativos de IOR en localizaciones endógenamente esperadas tanto en tareas de detección como de discriminación. Es decir, a pesar de que los participantes estén atendiendo endógenamente al lugar donde se presentará el estímulo relevante y por tanto, no hayan "desenganchado" su atención de esa localización, podemos observar IOR. Este resultado es difícil de explicar desde la hipótesis tradicional que postula que la IOR se debe a la inhibición del retorno de la atención a lugares previamente atendidos.

En el capítulo II.II. (Lupiáñez y Chica, remitido), usamos un paradigma diferente para estudiar el papel del desenganche atencional en la IOR. En el Experimento 1 comparamos los efectos de señalización exógena en una situación control, en la que el estímulo relevante se presenta 500 ms después de la señal, y en una situación de "desenganche atencional", en la que durante los 500 ms entre la señal y el estímulo relevante aparece un flash en el centro. Los resultados mostraron la presencia de IOR cuando se "desengancha" la atención (es decir, cuando se presenta el flash central) mientras que el efecto era facilitatorio en la condición control. Sin embargo, en el Experimento 2, produjimos el "desenganche atencional" en todas las condiciones, haciendo que el estímulo relevante apareciera de manera muy probable en la localización central. Al mismo tiempo, en una de las condiciones se presenta un flash en el centro, mientras que en la otra no se presenta el flash central. En este experimento encontramos que, a pesar de que se estaba induciendo un "desenganche" de la atención debido a la alta probabilidad de que el estímulo se presentase en la localización central, la IOR solamente se presentaba en las condiciones de aparición de un flash en el centro. Estos resultados nos llevan a concluir que el desenganche endógeno de la atención no es una condición suficiente para que aparezca IOR. El "desenganche" debe producirse de manera exógena, lo que nosotros hemos intentado explicar mediante la teoría de la integración-segregación de eventos. En el Experimento 3 de este capítulo, usando el paradigma presentado en el capítulo II.I., también encontramos que incluso cuando la atención se ha "desenganchado", en los ensayos en los que el estímulo relevante se presenta en una localización no esperada endógenamente, podemos medir facilitación en lugar de IOR si la tarea es de discriminación. Por tanto, concluimos que el desenganche endógeno de la atención no es una condición ni necesaria ni suficiente para producir IOR.

Una vez demostrado que la atención endógena y exógena pueden producir sus efectos de manera independiente, el siguiente paso en nuestra investigación es estudiar los efectos de ambos sistemas atencionales sobre etapas tempranas y tardías el procesamiento visual. Para ellos usamos dos aproximaciones, una psicofísica y otra electroencefalográfica. En el capítulo III.I. (Chica, Charras, y Lupiáñez, remitido-a), usamos la Teoría de Detección de Señales para analizar la modulación de la atención endógena y exógena en la sensibilidad perceptual (medida como d'), y los cambios de criterio (medidos como beta). Encontramos que tanto la atención endógena como la exógena (efectos de facilitación) modulan la sensibilidad perceptual, pero de manera independiente y con un curso temporal distinto. Solamente la atención endógena producía otros efectos más tardíos relacionados con el cambio de criterio para responder. Finalmente, la atención exógena interaccionaba con la endógena en las medidas de cambio de criterio, posiblemente debido a la aparición de IOR cuando el tiempo entre la señal y el estímulo relevante era largo. En el capítulo III.II. (Chica y Lupiáñez, en revisión), usando la técnica de electroencefalografía de alta densidad, analizamos la modulación de potenciales evocados tempranos (P1-N1) y tardíos (P3) por ambos sistemas atencionales. Encontramos que solamente la atención exógena (en este caso medida como IOR) modulaba potenciales tempranos del procesamiento (P1-N1). La atención endógena no producía efectos principales en estos potenciales, aunque modulaba el efecto de la atención exógena. En concreto, el marcador electrofisiológico de la IOR (reducción en amplitud del P1 para lugares exógenamente señalados versus no señalados) se observaba especialmente en los lugares endógenamente atendidos. Como comentamos previamente, este resultado indica que la IOR puede encontrarse en lugares de los que la atención no se había desenganchado. Es más, incluso en situaciones en que la señal predecía que el estímulo relevante aparecería en la misma localización de la señal, y los participantes respondían más rápidamente en ese lugar, el P1 presentaba una menor amplitud para esa localización. Este dato indica que la IOR conlleva un deterioro en el procesamiento perceptual que no puede ser contrarrestado por la orientación endógena de la atención. Finalmente, tanto la atención endógena como la exógena modulaban la amplitud de potenciales más tardíos como el P3. En este caso, la amplitud del P3 se reducía cuando se atendía endógenamente a la localización del estímulo relevante, o cuando esa localización se priorizaba debido a la IOR (cuando el estímulo se presentaba en un lugar no señalado).

En el capítulo IV (Chica, Charras, y Lupiáñez, remitido-b), exploramos el efecto del set de tarea en la orientación endógena de la atención. Nos preguntamos si la atención endógena se implementará de la misma manera cuando el sistema está preparado para detectar la aparición de un estímulo versus para discriminar uno de sus rasgos. Para llevar a cabo este objetivo usamos como herramienta un paradigma que reproduce la ilusión de la línea en movimiento (ILM). Esta ilusión se produce cuando una línea estática se presenta cerca de una localización estimulada exógenamente. Por ejemplo, si se presenta un objeto (la señal) y cerca de éste una línea, parece que la línea se mueve hacia la localización contraria de la localización de la señal. Aunque en un principio se pensó que este movimiento ilusorio se debe a que la señal exógena captura la atención hacia un extremo de la línea, lo que acelera la llegada de la información al sistema perceptual (Hikosaka, Miyauchi, y Shimojo, 1993), actualmente se piensa que el efecto se debe más bien a procesos de integración perceptual de la señal y la línea. De hecho, actualmente, existe un debate en la literatura sobre si la atención endógena puede o no modular la ILM (Christie y Klein, 2005; Schmidt, 2000). En nuestro estudio presentamos una señal exógena cerca de uno de los extremos de una línea. Además, la línea contiene un punto de color en uno de sus extremos. Los participantes tienen que responder en primer lugar al punto (tan rápido como puedan), y después indicar si percibieron o no movimiento de la línea. Manipulamos la atención endógena haciendo la señal predictiva de la localización en la que se presentará el punto. La señal puede predecir (75% validez) que el punto se presentará en la misma localización o en la localización contraria (en el

Experimento 2 también incluimos un bloque no predictivo). La lógica de esta manipulación es que si la atención endógena modula el efecto de la ILM, se debería ver más ilusión cuando se atienda endógenamente al mismo lugar de la señal. Además, manipulamos la tarea que se realiza con el punto. Como en el capítulo II.I., los participantes tienen que o bien detectar su aparición, o discriminar su color. Los resultados mostraron que la atención endógena puede modular el efecto de la ILM (más ilusión cuando la señal predice la misma localización versus la localización contraria o cuando la señal no es predictiva), pero esa modulación solamente ocurre cuando se está realizando una tarea de discriminación. Este patrón de datos indica que la atención endógena se implementa de manera diferente para la detección y la discriminación, produciendo una mejor integración perceptual, que da lugar a la modulación de la ILM, solamente cuando el set de tarea implica una discriminación. Por otra parte, en el Experimento 2 analizamos los potenciales evocados por la señal, para estudiar el nivel de análisis al que se produce esta modulación de la ILM por la atención endógena. Encontramos que la latencia de un N200 registrado en zonas parietales mostraba un efecto similar al efecto conductual. En aquellas situaciones en las que se percibía más ilusión, el potencial aparecía más tardíamente. Nosotros postulamos que la latencia de este potencial puede estar relacionado con cuánto tiempo está el sistema visual analizando la señal, de manera que a más tiempo, más integración, y por tanto más ilusión.

Por último, en el capítulo V (Chica, Sanabria, Lupiáñez, y Spence, 2007), estudiamos si la orientación atencional endógena elicitada por señales periféricas es similar cuando los estímulos se presentan en la misma modalidad sensorial o en modalidades sensoriales distintas. Esta cuestión es relevante para comprender si el sistema de orientación en el espacio es supramodal o depende de las características de los estímulos presentados, y por tanto de los sistemas neurales implicados en procesar tanto las señales como los estímulos relevantes. Usamos el mismo paradigma presentado en el capítulo II.I., pero esta vez la señal y estímulo relevante podían presentarse en la misma modalidad sensorial (visual o táctil), o en modalidades sensoriales diferentes (si la señal es visual el estímulo relevante es táctil y viceversa). Los resultados mostraron que a pesar de que nuestra atención endógena puede dirigirse a estímulos de diferentes modalidades sensoriales, el efecto es de mayor magnitud cuando la señal y el estímulo relevante se presentan en la misma modalidad sensorial. Esto nos lleva a concluir que la orientación atencional endógena no es completamente supramodal, y depende de los circuitos cerebrales que implementan el análisis de los estímulos en cada modalidad.

Conclusiones

Nuestros datos apoyan la existencia de dos sistemas atencionales diferenciados que nos permiten explorar nuestro ambiente implementando las metas y expectativas relevantes para la tarea, a la vez que nos permite una orientación rápida e involuntaria hacia estímulos salientes que, en caso de aparecer, podrían ser relevantes para la supervivencia. Estos sistemas modulan de manera diferente el procesamiento de los estímulos.

El desarrollo de un paradigma en el que se puedan estudiar los efectos de ambos sistemas atencionales de manera independiente es una de las estrategias para investigar la independencia de la atención endógena y exógena. Otra de las aproximaciones para estudiar si dos sistemas son independientes consiste en buscar una doble disociación comportamental sobre los efectos de ambos sistemas. En este sentido, Funes y colaboradores (Funes, Lupiáñez, y Milliken, 2007) usaron el paradigma de Stroop espacial por intentar disociar la atención endógena de la exógena. En la tarea de Stroop espacial se presenta una flecha a la izquierda o a la derecha, que apunta también a la izquierda o la derecha. Por tanto, existen ensayos congruentes (por ejemplo, la flecha se presenta a la izquierda apuntando a la izquierda) e incongruentes (la flecha se presenta a la izquierda apuntando a la derecha). El efecto Stroop espacial consiste en un mayor TR, o porcentaje de errores, para los ensayos incongruentes versus congruentes. Funes et al. estudiaron cómo se modulaba el Stroop espacial por la atención endógena y exógena. La atención endógena se manipuló con una señal central informativa del lugar de aparición de la flecha. La atención exógena se manipuló con una señal periférica no informativa del lugar de la flecha. Encontraron que ambos tipos de orientación atencional modulaban el efecto Stroop espacial, pero de manera cualitativamente diferente. Mientras que la atención exógena reducía el efecto Stroop espacial (el efecto era menor en el lugar señalado por la señal exógena), la atención endógena lo incrementaba (el efecto era mayor en el lugar esperado endógenamente). Esta doble disociación constituye una importante evidencia comportamental a favor de la independencia de los sistemas y de sus efectos diferenciales en el procesamiento de información.

En la siguiente tabla (modificada con permiso de Klein, 2004) se muestra un resumen de los efectos diferenciales de la atención endógena y exógena (incluidos los datos presentados en esta tesis).

Tabla 1. Disociaciones entre la atención endógena y exógena

Comportamiento	**Endógena**	**Exógena**
Velocidad (1)	Lenta	Rápida
Disrupción por carga de memoria (1)	SÍ	NO
Probabilidad de la señal (1)	SÍ	NO
Se esparce a los objetos (2)	No necesariamente	SÍ
Efecto de cruce del meridiano (3)	SÍ	NO
Déficit en el desenganche después de daño parietal (4)	NO	SÍ
IOR (5)	NO	SÍ
Potenciación perceptual del estímulo (6)	NO	SÍ
Interacción tareas de búsqueda visual (7)	NO	SÍ
Interacción expectativas no espaciales (7)	SÍ	NO
Stroop espacial (8)	Lo incrementa	Lo reduce
Efectos en etapas tempranas del procesamiento (9)	Menor	Mayor
Efectos en etapas tardías del procesamiento (9)	SÍ	Facilitación: NO IOR: SÍ
Produce la ILM (10)	NO	SÍ

Nota: 1) Jonides (1981) y Müller y Rabbitt (1989). 2) Egly, Driver, y Rafal (1994) y Macquistan (1997), sin embargo véase Abrams y Law (2000) y Goldsmith y Yeari (2003). 3) Reuter-Lorenz y Fendrich (1992). 4) Bartolomeo y Chokron (2002a), véase también la revisión de Losier y Klein (2001). 5) Posner y Cohen (1984). 6) Lu y Dosher (1998), veáse el capítulo III.I. de esta tesis para la discusión de resultados contradictorios (Prinzmetal, McCool, y Park, 2005). 7) Revisado por Klein y Shore (2000). 8) Funes et al. (2007). 9) Véase el capítulo III de esta tesis (Chica et al., remitido-a; Chica y Lupiáñez, en revisión), y Hopfinger y West (2006). 10) Chica et al. (remitido-b).

Los estudios de neuroimagen también han mostrado la existencia de dos sistemas neurales diferenciados que implementan la orientación atencional. Por una parte existe una red dorsal bilateral (que incluye partes del surco intra-parietal y los campos del ojo frontal), implicada en la orientación endógena de la atención. Y una red ventral, lateralizada en el hemisferio derecho (que incluye la unión temporo-parietal y el giro inferior frontal) implicada en la orientación exógena de la atención (Corbetta y Shulman, 2002; ver también Kincade, Abrams, Astafiev, Shulman, y Corbetta, 2005). Por último, los estudios neuropsicológicos indican claras disociaciones entre los sistemas de orientación atencional endógeno y exógeno. Algunos pacientes con daño parietal derecho muestran un síndrome llamado síndrome de heminegligencia. Estos pacientes se encuentran altamente sesgados a atender a la derecha de manera exógena (Bartolomeo y Chokron, 2001, 2002a). Sin embargo, en estos pacientes la orientación atencional endógena se encuentra relativamente preservada aunque enlentecida (Bartolomeo, Siéroff, Decaix, y Chokron, 2001). Además, estos pacientes no presentan IOR para los estímulos presentados a la derecha (Bartolomeo, Chokron, y Siéroff, 1999; Bartolomeo et al., 2001; Lupiáñez et al., 2004), lo que es consistente con su sesgo atencional exógeno.

El futuro esfuerzo investigador deberá centrarse en estudiar en más profundidad los efectos diferenciales de los sistemas atencionales endógeno y exógeno en el procesamiento de la información para que sea posible desarrollar una teoría integrada sobre el funcionamiento de cada uno de los sistemas. Asimismo, se deberá elucidar cómo la atención endógena y exógena interaccionan entre sí para el control de la respuesta de orientación final. En concreto, en determinadas circunstancias la orientación atencional endógena y exógena trabajan de manera coordinada o entran en competición. Los efectos de los sistemas en estos casos no siempre son aditivos, y sería interesante comprender cómo interactúan los sistemas en estas condiciones.

Chapter I

Introduction & aims of the thesis

Introduction

Any time we open our eyes to explore our environment a huge amount of information reaches our retina. However, in order to be effective, our actions must be usually directed to a single location or object at a time. Therefore, a selective mechanism is necessary in order to select relevant information so that only relevant objects are deeply processed in order to respond to them in the appropriate way. This selective role has been given to attention, a mechanism that prioritizes the processing of relevant information. Attended objects are processed to high levels in the system leading to conscious awareness and voluntary reactions to them. In contrast, unattended objects are not processed at this higher level and, even if a response can be given to them, it will be automatic and out of voluntary control. Thus attention has been proposed to be a pre-requisite of consciousness (Dehaene & Naccache, 2001; Driver & Vuilleumier, 2001; Mack & Rock, 1998)[1]. However, in order to maintain coherent behaviour in the face of a continuously changing environment, the attentional mechanisms should (a) allow for the maintenance of goal-directed behaviour in spite of distracting events, while at the same time (b) allowing for the processing of novel, unexpected events, that could be either advantageous or dangerous, in order to appropriately respond with either approach or avoidance behaviour (Allport, 1989).

It is obvious that selecting information that is relevant for our goals is crucial for coherent behaviour. Most theories agree that attention can be oriented at our will to specific locations according to our goals and intentions. However, the goodness of this selective mechanism might become catastrophic if new objects appearing in the scene are effectively ignored, because they might be dangerous and relevant for behaviour. Therefore, this selective attentional mechanism must be complemented with another mechanism able to detect the appearance of new objects or events. Thus, an attentional mechanism orienting to external, salient stimuli, is also thought to have an important ecological role in human beings and other species, allowing animals to be sensitive to novelty and discrepancies in the scene that could mark a predator to be avoided, or prey to be approached (Goschke, 2003).

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[1] We have to make the fist distinction here between endogenous and exogenous orienting (also known as voluntary and involuntary orienting) because it seems that exogenous attention is necessary for conscious perception (Bartolomeo & Chokron, 2002b) while endogenous attention is not (Koch & Tsuchiya, 2007).

Therefore, two modes of orienting attention have been proposed in order to accomplish these two important goals. The orienting of attention is supposed to be controlled either endogenously by the system (**endogenous orienting** of attention), or exogenously, by the external stimulation (**exogenous orienting** of attention). Attention is oriented endogenously either to stimuli that are relevant for the task at hand, because the person has an expectancy of where the relevant stimuli would appear, or given certain incentives for responding efficiently to specific attributes. Additionally, attention can be exogenously captured by salient stimuli (such as luminance changes or onset stimuli) even if the person has no intention of orienting his/her attention to that object or location.

What has to be explored then is how these two forces, exogenous and endogenous orienting, are combined in order to modulate behaviour in an integrated and coherent way. The more extended view in the field was that exogenous and endogenous orienting processes constitute two modes of orienting a single attentional mechanism, the two forces being in a continuous dynamical competition for the control of attention (Yantis, 1998, 2000; Yantis & Jonides, 1990). At each moment, the winner of the competition between the endogenous and exogenous orienting determines the location or object to which attention would be directed. In this case, it is important to know the characteristics or parameters of each orienting mode, in order to be able to determine which would win the competition in different environmental circumstances, and therefore which information will be prioritized.

A different possibility is to consider exogenous and endogenous attention as two different attentional systems, which independently modulate performance in order to accomplish the two objectives of accommodating the ongoing individual's goals and environmental circumstances (Funes et al., 2007; Klein, 2004). In this case, it would be important to know how each attentional system modulates performance, i.e. which stages of processing are modulated by endogenous and exogenous attention. Moreover, even if endogenous and exogenous attention are proved to be independent, it has to be understood whether or not they interact, and in which circumstances they do, for the control of behaviour.

In the next pages I will discuss the interaction and coordination between the endogenous and exogenous attentional systems, which for a long time have been considered two different modes of controlling attention, that is, two controlling mechanisms (internal vs. external) for the same attentional operator. First, I will review the earliest experimental studies in the literature that explored the characteristics and parameters of endogenous and exogenous attention, considering them as two modes of orienting the same attentional system. Second, I will review studies in which endogenous attention has been proved to modulate exogenous attention, which argued against the independence of the systems. Third, I will discuss another bunch of studies that have revealed that under certain circumstances, exogenous attention is not modulated by endogenous factors. This evidence indicates that exogenous and endogenous orienting might be in fact two different attentional systems that can work independently of each other. Forth, I will present some studies demonstrating that in fact endogenous and exogenous attention produce different effects on the processing of stimuli, indicating that they might comprise two functionally different mechanisms. And finally, I will present the aims of the present research, in which we have developed a new paradigm in order to disentangle the effects of endogenous and exogenous attention. This paradigm allows us to study the independence of endogenous and exogenous attention as well as their possible interaction for the control of visual orienting. Once we found that endogenous and exogenous attention can produce their effects independently of each other, we explored the differential effects that the two systems seem to have on information processing and whether their implementation depends on factors such as task set or the modality of stimulation.

Endogenous and exogenous orienting mechanisms in competition or coordination for the control of attentional orienting

Characteristics and parameters of endogenous and exogenous orienting

In the late 70s- early 80s, Posner and colleagues developed the widely used "cuing paradigm", in which a cue was used to attract attention before the relevant target was presented (Posner, 1978, 1980; Posner & Cohen, 1984; Posner et al., 1985; Posner, Snyder, & Davidson, 1980). In their paradigm, attention could be oriented either exogenously, using a spatially non-informative peripheral cue, or endogenously, using a spatially informative central cue (Posner, 1980). It was soon discovered that the orienting of attention produced by those two cues was quite different. In a highly impact paper, Müller & Rabbitt (1989) demonstrated that attention is oriented faster when it is drawn exogenously –using peripheral cues, than endogenously –using central cues (see also Chica et al., submitted-a; Chapter III.I.

of the present manuscript). Moreover, endogenous attention can be sustained for longer periods of time than exogenous attention. The effect of exogenous attention is not sustained on time, as it reverses at long cue-target intervals: i.e., RTs become slower at the exogenously attended location (cued location) versus the unattended location (uncued location). This effect, known as Inhibition of Return (IOR; Posner & Cohen, 1984; Posner et al., 1985), has been proposed to be a mechanism that facilitates visual search, avoiding the re-inspection of previously explored locations (Klein, 2000; Thomas et al., 2006). Considering attention as a single mechanism (which may be oriented in two modes, endogenously or exogenously), Posner et al. (1985) postulated that IOR was an attentional mechanism caused by the inhibition of the return of attention to a previously attended position. According to this hypothesis, when a peripheral cue appears, attention is automatically drawn to its position, but because the cue is not informative of where the target would appear, attention is disengaged from that spatial position, and an inhibitory mechanism starts to operate, inhibiting the return of attention to that previously attended position. This hypothesis, which we will call the *reorienting hypothesis* from now on, would predict that IOR would not be observed until attention is disengaged from the cued location. However, challenging the reorienting hypothesis, we have consistently demonstrated that IOR is observed at endogenously attended locations (see Chapters II.I., II.II., & III.II. of the present manuscript; Chica & Lupiáñez, 2004; Chica & Lupiáñez, under review; Chica et al., 2006; Lupiáñez & Chica, submitted; see also, Lupiáñez et al., 2004).

Apart from their different time course, exogenous and endogenous attention have been shown to have different characteristics. For example, unlike endogenous orienting produced by central cues, exogenous orienting produced by peripheral cues is not affected by a secondary memory task, by the frequency with which different kinds of cues are given, and cannot be voluntary suppressed (Jonides, 1981). Additionally, once activated, exogenous orienting is more resistant to interference produced by other peripheral cues than endogenous orienting is (Müller & Rabbitt, 1989). Based on this data, Jonides postulated that exogenous attention was more automatic than endogenous attention, which was under voluntary control.

In relation with the independence of the endogenous and exogenous attentional orienting, at this point in time, Posner et al. (1985) and Jonides (1981) proposed that attention was a unitary mechanism that could be moved ("transported") either exogenously or endogenously. Contrary Müller & Rabbitt (1989) proposed that exogenous and endogenous orienting were in fact two different attentional mechanisms that "addressed the same limitied-capacity attention system", i.e., they postulated that endogenous and exogenous attention constituted separate mechanisms in competition to direct attention to the relevant location. The final product of this competition would be the measured orienting response. However, in both cases the final effect of attention would be the result of the final orienting of a unitary attentional mechanism.

Endogenous modulation of exogenous orienting

In the competition for the control of orienting, it has been shown that endogenous attention can modulate the effect of exogenous orienting. In this section I will review studies that have shown how different endogenous factors modulate exogenous orienting. First, I will review how endogenously attending to a position in space can modulate exogenous attention. Then, I will discuss the effect of practice in the exogenous attentional capture. And finally, I will explore the effect of target frequency and task set in the orienting of attention.

Müller & Rabbitt (1989) studied whether endogenous attention was resistant to the interruption produced by exogenous stimuli. They presented a spatially informative central cue followed by a target at different time intervals (600, 900, 1200 ms). In some trials, a non-informative peripheral cue was presented 500 ms after the central cue. In order to maximize overall performance, participants should try to ignore the peripheral cue and focus attention at the location the central cue was pointing at. Their results showed that endogenous attention enhanced the effect of exogenous attention when the central and the peripheral cue indicated participants to attend to the same location. Moreover, endogenous attention attenuated the effect of exogenous attention when the peripheral cue was presented at a different, invalid, location. They speculated that endogenous attention did not directly modified the effect of exogenous attention, but the modulation occurred by strengthening the effect of exogenous attention. They concluded that the exogenous orienting mechanism was an "autonomous module that can be modified but not suppressed by endogenous attention". Moreover Yantis & Jonides (1990) explored whether the exogenous attentional capture produced by abrupt onsets was automatic or could be modulated by endogenous attention. They demonstrated that when a central cue was completely reliable (indicating the target location with 100% validity), abrupt onsets did not capture attention when they were presented at a distracting location (RTs to discriminate a target did not differ when the distractor was an abrupt onset versus a non-onset). However, abrupt onset distractors did produce an effect on performance, as they slowed down the response to the target when the response associated to them was incompatible with that of the target (see also Theeuwes, 1991, for similar results using a different paradigm). As suggested by Müller & Rabbitt (1989), this result might indicate that exogenous attention is modulated but not completely suppressed by endogenous attention.

Warner, Juola, & Koshino (1990) also explored whether attentional capture can be overridden with practice. Practice might create a different task set in the observer (which is considered an endogenous factor) than might modulate exogenous capture. In one of the conditions of their Experiment 1, they presented an informative peripheral cue in one out of four locations. The cue predicted the target to appear at the opposite location in the display on 80% of the trials. Four SOAs were used: 0, 50, 100 and 150 ms. They found that participants responded faster to the cued location than to the opposite location (which was the endogenously valid location). Thus, participants' exogenous attention was automatically drawn to the cued location, even if this position was not indicating the valid target location. Note also that the SOA used in this study might be too short to endogenously orient attention to the opposite location to the cue. However, when a larger number of trials were introduced in Experiment 2 (576 vs. 288 of Experiment 1), an effect of practice was observed. With practice, RTs were not faster to respond to the cued location at any SOA, showing that participants may have learned to quickly disengage their attention from the cued location in order to endogenously attend to the opposite location. This result indicates that with practice, participants may adopt a different task set that modulates the exogenous orienting of spatial attention.

One of the most striking pieces of evidence of the effect of endogenous factors on exogenous attention is the "contingent attentional capture" hypothesis. Folk, Remington and colleagues (Folk & Remington, 1998; Folk, Remington, & Johnston, 1992) have demonstrated that the exogenous capture of attention critically depends on the task set adopted for responding to the target. Using a modified version of the cuing paradigm, Folk et al. (1992) demonstrated that onset cues only captured attention when the participants' task was to respond to an onset-target but not when they had to respond to a colour-target. Similarly, colour cues only captured attention when participants had to respond to a colour-target versus an onset-target. Based on this data, they have proposed the "contingent capture" hypothesis, which postulates that only those stimuli that are contingent with the attentional set of the observer will capture attention. This hypothesis predicts that when looking for something red, only red things would capture our attention. However, as will be discussed in the next section, the evidence supporting this idea is not conclusive and is currently under debate (Folk & Remington, 2006; Theeuwes, Atchley, & Kramer, 2000; Theeuwes & Godijn, 2002).

Moreover, a different line of research has consistently shown that task set can modulate exogenous cuing effects, both facilitation and IOR. Lupiáñez and colleagues (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997; Lupiáñez & Milliken, 1999; Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001) have consistently demonstrated that facilitation is larger in magnitude in discrimination tasks as compared with detection tasks, while IOR is larger and appears sooner in detection tasks than in discrimination tasks. It has been proposed that the more difficult the task at hand, the greater the orienting of attention produced by the cue (Klein, 2000) and/or the longer attention would remain oriented to the cued location (Lupiáñez, Milliken et al., 2001). Klein (2000) proposed that as discrimination tasks are more difficult than detection tasks, attention is captured in a greater degree by the cue, giving rise to larger facilitatory effects and a later disengagement of attention, which delays the appearance of IOR.

However, Lupiáñez and colleagues have recently demonstrated the orienting and disengagement of attention from the cued location cannot fully explain the differences in exogenous cuing effects (Lupiáñez, Ruz, Funes, & Milliken, 2007). In their experiments, target frequency was manipulated within a block of trials. The within block manipulation ensured that participants could not know in advance what target would be presented, and thus, the processing of the cue would be equal for both frequent and infrequent targets. Moreover, their results showed that cuing effects depended on the frequency of the target, with IOR being observed for frequent targets and facilitation being observed for infrequent targets. This pattern of data cannot be explained by the engagement or disengagement of attention before the target was presented, as the same orienting of attention was ensured, given that participants could not know the identity of the target in advance. The data were accounted for in terms of post-orienting processing regarding the interaction between the processing of the cue and that of the target.

Klein (1994) also explored whether target frequency would interact with endogenous and exogenous attention. He found that exogenous facilitation was similar for frequent and infrequent targets, although endogenous attentional effects were only significant for the frequent stimuli. Thus, target frequency affected endogenous but not exogenous orienting of spatial attention. However, more recently Ivanoff & Klein (2004) explored whether target frequency would interact with another exogenous attentional effect, IOR. They found that IOR interacted with target frequency in the same way as endogenous attention does (i.e. IOR was larger for the frequent target). These results led Ivanoff and Klein to wonder whether IOR might have a component related to endogenous orienting. Alternatively, IOR could also be different in nature to exogenous facilitation, in spite of both being considered as an exogenous attentional effect.

Other factors have been proposed to produce an endogenous modulation of exogenous cuing effects, such as the range of SOAs and the presence of distactors. Cheal & Chastain (2002) reported a reduction in the magnitude of facilitation effects and an earlier appearance of IOR when the range of SOA was large (100, 400 and 700 ms of SOA) as compared to when a range of SOAs was small (100, 250 and 400 ms of SOA). The authors interpreted these effects in terms of an endogenous modulation of the reorienting process: When the range of SOAs is small, participants might find it difficult to reorient their attention before the target appears, producing larger facilitatory effects and a delayed IOR. Similarly, Milliken and colleagues (Milliken, Lupiáñez, Roberts, & Stevanovski, 2003) found that endogenously attending to the point in time when the target would appear modulated exogenous cuing effects in a discrimination task. As in Cheal & Chastain study, facilitation was enhanced when participants expected the target to appear at a short SOA. However, IOR was not delayed.

Regarding the presence of distractors, it has been shown that presenting a distractor at the opposite location to the target reduces the magnitude of the facilitatory effect and produces a sooner appearance of IOR as compared with a no distractor condition (Lupiáñez, Milliken et al., 2001). Increasing the difficulty of target selection shortened the SOA at which IOR was observed, indicating that endogenous factors can modulate exogenous cuing effects.

In summary, the results reviewed in this section suggest that the exogenous orienting of attention is not completely automatic, as it can be modulated by both endogenous attention and task demands (see Ruz & Lupiáñez, 2002; for a review). This evidence can be interpreted as endogenous and exogenous attention consisting of the same attentional system that can be oriented in two modes. However, in the next section I will review other studies that have shown exogenous attention effects in spite of the endogenous orienting of spatial attention.

Exogenous orienting in spite of endogenous orienting

As discussed in the above section, the "contingent attentional capture" hypothesis, which postulates that the exogenous attentional capture can be completely overridden by endogenous factors such as task set, is still under debate. It has been argued that the exogenous capture of attention is a purely stimulus-driven phenomenon that cannot be modulated by endogenous attention (Theeuwes, 1992, 2004). Unlike Folk, Remington and colleagues (Folk & Remington, 1998; Folk et al., 1992), Theewues and cols. propose that exogenous attention is purely automatic and does not depend on the task set of the observer. They postulate that exogenous attention will always be engaged to the most salient stimulus. However, if this stimulus turns out to not be the relevant target for the task at hand, attention can be quickly "disengaged". In order to test this hypothesis, Theeuwes, Atchley, & Kramer (2000) varied the time interval between the onset of the target and the onset of the distractor, and found that the distractor only produced a cost when it was presented either 50 or 100 ms after the target onset, but no cost was observed after 150 ms, indicating that attention had been captured early on and "recovered" by 150 ms (see Lamy & Egeth, 2003, for similar results).

Folk & Remington (2006) also tried to test the "recovery account" using a modified version of the cuing paradigm in which a coloured cue preceded the target. The colour of the cue could or could not match the colour of the target (the participants' attentional set). Additionally, the cued marker contained a character that could or culd not match the identity of the target. The rationale of this manipulation was that if the cue did not capture attention when its colour did not match the colour of the target, the identity of the letter should not affect the target's discrimination. The results revealed that responses to the target were faster when a compatible distractor was presented at the same location than the target, suggesting that distractor identity was being processed. More importantly, this effect was significant both when the colour of the cue matched the colour of the target and when it did not, although the size of the effect was smaller when the colours did not match (see Chen & Mordkoff, 2007; for further evidence against the later disengagement). Yantis (2005) has recently proposed that salient items "win" the competition in primary visual areas, and once they do, this signal propagates to other levels of the visual hierarchy, increasing the likelihood that this stimulus enters visual awareness. These exogenous effects are combined with and modulated by endogenous effects to determine the overall attentive state of the brain.

Lupiáñez and colleagues (Lupiáñez et al., 2004) directly tested the independence of endogenous and exogenous attention. They compared RTs to targets appearing at cued vs. uncued positions at endogenously attended locations (i.e., cued location trials in a predictive cue block and uncued location trials in a counterpredictive cue block), and endogenously unattended locations (i.e., cued location trials in a counterpredictive cue block and uncued location trials in a predictive cue block). The main result that emerged from this study was that IOR was independent of the endogenous orienting of spatial attention. Similarly Lupiáñez et al. (2004) reanalyzed the results of a previous study by Bartolomeo, Siéroff, Decaix, and Chokron (2001) exploring performance of patients with left unilateral neglect. These patients showed a lack of IOR for right, ipsilesional targets, confirming previous findings (Bartolomeo et al., 1999; see also Vivas, Humphreys, & Fuentes, 2003). This result is also consistent with the idea that these patients' attention is biased towards right, ipsilesional objects (Bartolomeo & Chokron, 2002a). Lupiáñez et al.'s (2004) reanalysis of Bartolomeo et al.'s results demonstrated that the lack of IOR was present for both expected and unexpected right-sided targets. These results indicate that endogenous and exogenous attention (IOR) can produce their effects independently, without interacting with each other.

Endogenous and exogenous orienting mechanisms independently contributing to performance

A different approach to study whether endogenous and exogenous attention constitute two different attentional systems is to explore their differential effects on information processing. In particular, finding a double dissociation on the effects of endogenous and exogenous attention would support the idea that both systems can work independently of each other. Klein & Shore (2000) reviewed a double dissociation on the effects of endogenous and exogenous attention on visual search. Briand and Klein examined the role of endogenous and exogenous attention in feature or conjunction visual search tasks (Briand, 1998; Briand & Klein, 1987). In Briand's study (1998), the feature search task consisted of the target letter "O", or a blue letter, presented at one of two locations. A distractor stimulus, presented at the opposite location, consisted of one out of two other possible letters, printed in one of two other possible colours. In the conjunction search task, the target letter was an "O" letter, printed in blue. The distractor was either a different letter in blue, or the letter "O" presented in a different colour. They compared whether endogenous and exogenous attention would affect both search tasks differentially. The results revealed that the effect of exogenous attention interacted with the type of search tasks, while the effect of endogenous attention was additive. In contrast, as described above, when Klein (1994) manipulated the frequency of a non-spatial feature of the target (e.g., the size) and found that the effect of endogenous attention interacted with these non-spatial expectancies, while the effect of exogenous attention (facilitation) was additive. The data of these two experiments together were considered as a double dissociation on the effects of endogenous and exogenous attention on visual processing, which suggest that endogenous and exogenous attention produce qualitatively different effects on the processing of stimuli. In the General Discussion, I will debate in more detail the differential effects of endogenous and exogenous attention that we know so far.

Aims of the present thesis

The present thesis aims at investigating how behaviour is driven by the combined forces of exogenous and endogenous attention. We had three goals in mind: a) to investigate at which extent exogenous and endogenous attention constitute two independent attentional mechanism, b) to investigate whether these two independent mechanisms modulate information processing in different ways and/or stages of processing, and c) to investigate to which extent endogenous orienting of attention, or its effects on performance, are modulated by other endogenous factors such as task set (the same way they seem to modulate the manifestation in behaviour of exogenous orienting).

The first aim of this thesis was to explore the independence of endogenous and exogenous attention. In order to achieve this objective, we developed a paradigm in which endogenous and exogenous attention are manipulated orthogonally while using the same visual stimulation (an informative peripheral cue). Following the additive factor logic (Sternberg, 1969), if the two systems are independent, they should produce their effects without interacting with each other. More specifically, an important aim of our project was to test the nature of IOR, a marker of exogenous attention. As discussed in the Introduction, IOR consists of slower RTs to exogenously cued locations, when the time interval between the cue and target is long enough. Assuming that exogenous and endogenous orienting constitute two ways of orienting the very same attentional mechanism, the most extended view about IOR posits that the effect consists of the inhibition of the return of attention to a previously attended location (Klein, 2000). Consequently, this hypothesis would predict that IOR would not be observed until attention is disengaged from the cued location. However, the paradigm we developed to study the independence between endogenous and exogenous attention was successful in showing that, rather than two ways of orienting, endogenous and exogenous attention might constitute two independent attentional mechanisms. That being true, it makes sense that IOR would be independent of the endogenous orienting of attention. Therefore, we used our paradigm to test the *reorienting* hypothesis about IOR. If IOR consists of the inhibition of the return of attention, and attention is one mechanism (oriented either exogenously or endogenously), no IOR should be observed when the target appears at a location where participants are endogenously attending. In particular, IOR should interact with endogenous orienting, being the effect only observed when attention has been disengaged from the location of the cue.

The second aim of this thesis was to explore the differential modulation of endogenous and exogenous attention on visual processing. If the two systems are independent, it is important to understand the differential modulation that they exert on different cognitive processes. We approach this topic studying whether endogenous and exogenous attention affect perception at different stages of processing. In particular, we have used a psychophysical and electroencephalographic approach to study this topic. In both cases we can explore the effects of endogenous and exogenous attention on early and late stages of perception as well as their independence and possible interactions in each of the stages of processing.

And finally, the third aim of our research was to explore whether the implementation of endogenous attention depends on factors such as task set or the sensory modality in which the stimulation is presented to the system. In particular, we explore the effects of endogenously attending elicited by an informative peripheral cue, under different task's sets and when the information is presented in different sensory modalities. This approach would allow us to study how endogenous attention modulates the effects of exogenous attention and whether this modulation is task independent and supramodal or it rather depends on task's demands and the sensory circuits implied in the analysis of information.

I will start the description of the experimental research with Chapter II.I., in which I will introduce the basic paradigm to disentangle the effects of endogenous and exogenous attention using the same visual stimulation. In Chapter II.II., I will also present a different paradigm to study the relationship between endogenous attention and IOR. The results of the first chapter led us to conclude that endogenous and exogenous attention can produce their effects independently, at least under certain circumstances (Chica & Lupiáñez, 2004; Chica et al., 2006; Lupiáñez & Chica, submitted). Furthermore, IOR was consistently observed at endogenously attended locations, even when endogenous attention was maintained at the cued location. This result challenges the traditional reorienting hypothesis about IOR (see also Chapter III.II., Chica & Lupiáñez, under review). In the following chapters, I will explore the differential effects of endogenous and exogenous attention on information processing. In Chapter III, I will study the effects of endogenous and exogenous attention in perceptual sensitivity and response criterion using the Signal Detection Theory (Chica et al., submitted-a). I will also explore the effects of endogenous and exogenous attention (IOR) in early and late stages of processing using event-related potentials (Chica & Lupiáñez, under review). In Chapter IV, I will investigate whether endogenous attention produces different effects on perception depending on the task at hand. In order to do that, we use the Illusory Line Motion (ILM) effect. This illusion consists of an illusory perception of movement of a line when a peripheral object is presented near one of its edges. It has been proposed that the illusion is caused by the orienting of attention to the cue that produces a gradient of accelerated arrival times at high levels of perceptual processing around its location. When a line is presented all at once across this gradient, the difference in arrival times across the line is interpreted by motion perception systems as a drawing of the line over time (Hikosaka et al., 1993). We explore whether ILM is produced by endogenous attention as well, and if this modulation depends on the task set implemented while the stimulation is being presented (Chica et al., submitted-b). And finally, In Chapter V, I will compare the effects of endogenous and exogenous attention when the stimulation is presented within the same sensory modality or when the stimuli are presented in different sensory modalities. This would allow us to explore whether endogenous and exogenous attention are under control of a supramodal attentional system or if attention is differentially implement in the neural circuit of each sensory modality (Chica et al., 2007). Finally, in the General Discussion, I will summarize all the evidence presented in the present manuscript as well as its implications for the independence of the endogenous and exogenous attentional orienting mechanisms[2].

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[2] Every chapter of this thesis is composed by one or more papers that have either been published or are in the process of being published as research articles. Therefore, the reader might notice certain overlap in the introductions and discussions of the different chapters.

Chapter II

Exploring the independence of endogenous and exogenous attention: Inhibition of return is independent of the endogenous engagement and disengagement of attention

Chapter II.I.

Dissociating Inhibition of Return from endogenous orienting of spatial attention: Evidence from detection and discrimination tasks

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ABSTRACT

In the present series of experiments, peripheral informative cues were used in order to dissociate endogenous and exogenous orienting of spatial attention using the same set of stimuli. For each block of trials, the cue predicted either the same or the opposite location of target appearance. Crucially, using this manipulation, both expected and unexpected locations could be either cued or uncued. If one accepts the hypothesis that Inhibition of Return (IOR) is an attentional effect that inhibits the returning of attention to a previously attended location (Posner & Cohen, 1984), one would not predict an IOR effect at the expected location, from where no disengagement of attention has occurred. Detection and discrimination tasks were used to examine any potential difference in the mechanism responsible for IOR as a function of the task at hand. Two major results emerged: First, IOR was consistently observed at the expected location, where, according to the traditional "reorienting" hypothesis, IOR is not supposed to occur. Second, a different time course of cuing effects was found in detection vs. discrimination tasks, even after controlling for the orienting of attention. We conclude that IOR cannot be solely accounted for by the "reorienting of attention" hypothesis. Moreover, we argue that the observed time course differences in cuing effects between detection and discrimination tasks cannot be explained by attention disengaging later from cues in discrimination than in detection tasks, as proposed by Klein (2000). The described endogenous-exogenous dissociation is consistent with models postulating that endogenous and exogenous attentional processes rely on different neural mechanisms.

Introduction

Unexpected, novel, salient, and potentially dangerous events take high priority in the brain. There is now a wealth of literature showing that these stimuli are typically processed in an automatic (or bottom-up) fashion, involving what has been labelled exogenous or involuntary attention (Corbetta & Shulman, 2002; Egeth & Yantis, 1997; Jonides, 1981; see Ruz & Lupiáñez, 2002; for a review about attentional capture). Spatial attention, however, can be voluntarily directed to a particular location or object depending on the goals or expectancies of the task at hand, involving more endogenous or voluntary forms of attention. According to the spotlight metaphor (Posner et al., 1980), exogenous and endogenous attention are the behavioural expression of the same unitary mechanism. This metaphor assumes that attention is a unique spotlight that can be oriented to a location either voluntarily (endogenously) or involuntarily (exogenously), favouring the processing of objects and locations illuminated by this focus.

In a seminal study, Posner and Cohen (1984) developed the cost and benefits paradigm, in order to investigate the processes that were involved in the orienting of attention. In this paradigm, a fixation point is normally presented at the centre of the screen, and two boxes appear to the left and right of fixation. An uninformative peripheral cue (e.g., a brief flash in one of the boxes) is normally used when investigating exogenous attention, while endogenous cuing studies usually involve central informative cues (e.g., an arrow pointing left or right). Uninformative peripheral cues are supposed to capture spatial attention exogenously (or involuntarily), while central informative cues are presumed to produce a voluntary orienting of spatial attention.

The behavioural effects of both types of cues are clearly different. Central informative cues normally produce faster and/or more accurate target responses at the expected than at the unexpected location, even for long cue-target time intervals (Posner, 1980). However, the use of uninformative peripheral cues leads to two different effects in the detection of a subsequent target across time. If the target appears soon after the appearance of the cue (less than 300 ms), a facilitatory effect is observed, i.e., response times (RTs) are faster at cued than uncued locations. However, if the target appears 300 ms after cue onset or later, an Inhibition of Return (IOR) effect is observed (i.e., RT is slower for cued than uncued trials, Posner & Cohen, 1984).

IOR was proposed to be a mechanism that evolved to maximize sampling of the visual environment. The effect was observed only for peripheral but not central cues. In addition, Posner & Cohen (1984) found IOR when attention was redirected to the central fixation, supposedly producing a disengagement of attention from the cued location. Taking into account these results, and considering attention as a single spotlight (which may be oriented in two modes, endogenously or exogenously), Posner, Rafal, Choate, and Vaughan (1985) concluded that IOR was an attentional effect, consisting of an inhibition of the return of attention to a previously attended position. According to this hypothesis, when a peripheral cue appears, attention is automatically drawn to its position, but subsequently, attention is disengaged from that particular spatial position, and an inhibitory mechanism starts to operate, inhibiting the return of attention to that previously attended position. This hypothesis, which we will call the *reorienting hypothesis* from now on, has been widely accepted by many researchers (see Klein, 2000, for a review).

According to the reorienting hypothesis, no inhibition should be measured until attention is disengaged from the cued location. However, Berlucchi, Tassinari, Marzi, and Di Stefano (1989) reported an experiment in which, even though participants knew in advance where the target would appear, RTs were slower when the target was presented at the same position as the peripheral exogenous cue. In this study, the target always appeared at the same spatial position within a block of trials. Thus, although these results seemed to challenge the reorienting hypothesis, a potential problem with this interpretation could be that a habituation process decreased the effect of the voluntary allocation of attention at the cued position. This concern was solved in a more recent study, in which Berlucchi, Chelazzi, and Tassinari (2000) presented targets at one of four possible locations randomly. Targets were preceded by non-predictive exogenous cues. In each block of trials, participants were asked to voluntarily attend to a position related to the exogenous cue (e.g., to attend to the position symmetrical to the cued location). Overall, RTs were faster at the voluntarily attended position, and slower at the cued location (that is, a main effect of IOR was observed). Importantly, these effects were completely independent from each other: IOR was observed both at the endogenously attended and unattended position.

Recently, Berger, Henik, & Rafal (2005) presented a paradigm in which a central informative cue (an arrow with 80% validity) was followed by a peripheral uninformative cue. After a variable SOA the target was presented, and the participants were asked to either perform a detection task, a two choice localization task, or a saccadic eye movement to the target (Experiment 1, 2 and 3, respectively). The results of the three experiments showed that the endogenous orienting of attention (elicited by the central informative cue) was independent of the exogenous orienting of attention (elicited by the peripheral uninformative cue), with IOR being observed at endogenously attended and unattended locations. These results are opposite to those predicted by the reorienting hypothesis, according to which IOR is not supposed to occur until attention is disengaged from the cued location. No IOR should be observed at the expected location, from where attention has not been disengaged.

It is worth noting here that Posner, Cohen & Rafal (1982) reported an experiment in which the cue predicted either the same or opposite position of target appearance. The authors' highlighted the fact that the appearance of the cue produced an early facilitatory effect even thought the cue predicted the target to appear at the opposite location. However, they did not take into account that the inhibitory effect (IOR) was also observed when the target appeared at the position at which participants were attending to (as was predicted by the cue). Recently, Lupiáñez et al. (2004), employed a similar experimental setting, and compared RTs to targets appearing at cued vs. uncued positions at endogenously attended locations (i.e., cued location trials in a 80% valid condition and uncued location trials in a 20% valid condition). The main result that emerged from this study was that IOR was consistently found at the endogenously attended location. Additionally, a similar IOR effect was also observed when the target appeared at an unexpected location (i.e., cued location trials in the 20% valid condition vs. uncued location trials in the 80% valid condition). Thus, IOR appeared in both endogenously expected and unexpected locations.

Similar findings emerged from the reanalysis (Lupiáñez et al., 2004) of the results of a previous study by Bartolomeo, Siéroff, Decaix, and Chokron (2001) exploring normal individuals' and patients' performance with left unilateral neglect. These patients showed a lack of IOR for right, ipsilesional targets, confirming previous findings (Bartolomeo et al., 1999; see also Vivas et al., 2003). This result is also consistent with the idea that these patients' attention is biased towards right, ipsilesional objects (Bartolomeo & Chokron, 2002a). Lupiáñez et al.'s (2004) reanalysis of Bartolomeo et al.'s results demonstrated that the lack of IOR was present for both expected and unexpected right-sided targets.

In summary, previous research has shown that it is possible to observe cuing effects (specifically IOR at long cue-targets intervals) at a position where attention is being maintained voluntarily (by means of instructions to attend to a position related to a central cue, Berger et al., 2005; or a peripheral cue, Berlucchi et al., 2000; Berlucchi et al., 1989; Lupiáñez et al., 2004).

In the present study, we attempted to further dissociate endogenous and exogenous orienting of spatial attention using the same set of stimuli. As in Lupiáñez et al.'s (2004) study, an informative peripheral cue was used, that predicted, in each block of trials, either the same or the opposite position of target appearance (see Procedure section for details). Crucially, with this manipulation, expected and unexpected positions could be either cued or uncued. If IOR is observed at the position predicted by the cue (at which attention is supposed to be allocated), this effect would be difficult to explain as the inhibition of the return of attention to the cued location (because no return of attention is supposed to take place in this condition).

A second aim of the present study was to investigate the time course of cuing effects (facilitation followed by IOR) in detection and discrimination tasks. It has been shown that IOR appears later in discrimination than in detection tasks (Lupiáñez et al., 1997). Klein (2000) proposed that these differences might be due to a later disengagement of attention in discrimination than in detection tasks. He argued that discrimination tasks are more difficult than detection tasks, making it necessary to implement a more effortful set for the processing of the target in discrimination than in detection tasks. Furthermore, it would be very difficult to adopt and implement a different set for the processing of the cue and target when they are presented very close in time. For that reason, in cuing discrimination tasks, the author proposed that more attentional resources would be allocated to the processing of the cue, and thus the disengagement of attention from the cued location would take longer than in detection tasks. This would delay the occurrence of IOR in discrimination tasks, as compared to detection tasks. In the paradigm used here, the allocation of endogenous attention is controlled by the predictivity of the cue. At the expected location, no disengagement of attention is supposed to occur, whereas at the unexpected location attention should be disengaged, at least at long enough SOAs. If the time course differences in cuing effects between detection and discrimination tasks are due to differences in the disengagement of attention, no such differences should be found with our procedure.

If the results of the present series of experiments show that IOR can be observed at the attended location and/or if IOR still appears later in the discrimination than in the detection task, it could be argued that these effects cannot be solely explained by the orienting-disengagement of attention. Instead, one would have to invoke other processes, perhaps related to the presence or absence of an object (the cue) before the onset of the target (Lupiáñez et al., 2004; Milliken, Tipper, Houghton, & Lupiáñez, 2000).

EXPERIMENT 1

An informative peripheral cue was presented that could predict (with 75% of validity) in each block of trials, either the same or the opposite position of target appearance. With this manipulation, both expected and unexpected locations can be either cued or uncued, making it possible to dissociate endogenous and exogenous orienting of attention using the same set of stimuli. Two SOAs (100-1000 ms) were used, in order to study both facilitation, normally observed at short SOAs, and IOR, usually observed at longer SOAs. Detection and discrimination tasks were used, in order to compare the cuing effect at expected and unexpected locations in both tasks.

Methods

Participants. Forty-eight psychology students from the University of Granada, participated in this experiment (24 performed the detection task and 24 the discrimination task). The average age of the participants was 20 years. All of the participants reported to have normal or corrected to normal vision, were naïve as to the purpose of the experiment, and participated voluntarily for course credits.

Apparatus and stimuli. The stimuli were presented on a 15-inch colour VGA monitor. An IBM compatible PC running MEL2 software (Schneider, 1988) controlled the presentation of stimuli, timing operations, and data collection. The participants sat 57 cm from the monitor with their head resting on a chinrest. At the beginning of each trial a fixation point (a plus sign) was displayed at the centre of the screen, on a black background. Two grey boxes (17 mm in height by 14 mm in width) were displayed to the left and right of fixation. The inner edge of each box was 77 mm from fixation. As the orientation cue, one of the boxes flickered (turned to white) for 50 ms, giving the impression of a brief flash. The target was either a red or yellow asterisk appearing at the centre of one of the boxes. A 400 Hz sound, 100 ms in duration, was used to provide response feedback.

Procedure. A fixation point (plus sign) and two boxes (to the left and right of fixation) were displayed at the beginning of each trial. The peripheral cue appeared 1000 ms later, for 50 ms. After a random variable SOA (100-1000 ms) the target was presented. It could be either a red or a yellow asterisk presented at the centre of one of the boxes for 33 ms. If no response was made after 1800 ms or the wrong response was made, auditory feedback was provided for 100 ms. The intertrial interval (on which the screen remained in black) was 1000 ms duration.

On 20% of the trials (catch trials) no target was presented, and no response was required. On the remaining 80% of the trials a target was presented, and the participants were asked to detect the target or to discriminate its colour (depending on the experimental group). In the detection task the participants were instructed to press the “m” or “z” key on a keyboard as soon as they saw the asterisk (independently of its colour), while in the discrimination task, the participants were asked to press one of the keys when the asterisk was red, and the other key when it was yellow (the response-mapping was counterbalanced across participants).

The experiment consisted of two blocks of trials. In one of them, the cue predicted the likely position of target appearance on 75% of trials (i.e., on 75% of the trials the target appeared at the same position as the cue). These were expected trials (because the target appeared where participants were expecting it to appear) and cued trials (because the cue and target appeared at the same position). However, in the remaining 25% of the trials, the target appeared at the opposite location to the cue. These were unexpected trials (because the target did not appear at the position predicted by the cue) and uncued trials (because the cue and target appeared at different locations). In the other block of trials, the cue predicted the target to appear at the opposite position on 75% of the trials. Thus, when the target was presented at the position opposite to the cue, these were expected but uncued trials. However, when the cue and target were presented at the same position (25% of trials), these were unexpected and cued trials. The order of blocks was counterbalanced across participants. The participants were informed about the most likely location of target appearance at the beginning of each trial, and encouraged to take this information into account. The task lasted for about 45 minutes, and the participants were allowed to take a short break after every 36 trials.

Design. The experiment had a 2(Task) x 2(Expectancy) x 2(Cuing) x 2(SOA) design, with the first variable being manipulated between participants, while the remaining 3 variables were manipulated within participants. *Task* had two levels: Detection and Discrimination. *Expectancy* had two levels: Expected and Unexpected location trials[3]. *Cuing* had two levels: Cued and Uncued location trials. Finally, *SOA* had 2 levels: 100 and 1000 ms.

The experiment consisted of 2 series of 3 experimental blocks of 72 trials. Each series was preceded by a practice block of 36 trials. There were a total of 432 experimental trials. For each experimental condition of cuing and SOA, there were 81 observations for expected trials, and 27 for unexpected trials.

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[3] Note that expected trials refer to expected-cued trials in one block (where the cue predicts that the target would appear at the same position), and expected-uncued trials in the other block (where the cue predicts that the target would appear at the location opposite to the cue). Similarly, unexpected trials refer to unexpected-uncued trials in one block (where the cue predicts that the target would appear at the same position), and unexpected-cued trials in the other block (where the cue predicts that the target would appear at the location opposite to the cue).

Results

False alarms (responses to catch trials: 5.1% of the trials in the detection task and 3.1% in the discrimination task), misses (trials on which no response was made; 1.7% and 1.5% of trials in the detection and discrimination task, respectively), and incorrect responses in the discrimination task (7.06%) were discarded from the RT analysis. Finally, trials with responses faster than 100 ms or slower than 1200 ms were also removed from the RT analysis, which discarded 0.44% and 1.34% of trials in the detection and discrimination task, respectively.

As opposite cueing effects (facilitation vs. IOR) were expected for the short and long SOA, two separate analyses of variance (ANOVA; with the factors: 2(Task) x 2 (Expectancy) x 2(Cuing)) were performed, one for each SOA condition, in order to explore the effect of Task, Expectancy, and Cuing separately for the short and long SOA (see Table 2).

SOA 100 ms. The analysis of the mean RTs showed a significant main effect of Task, *F*(1,46)=98.79, *MSE*=15732, *p*<.0001, with RT being faster in the detection (M=436 ms) than in the discrimination task (M=616 ms). The Expectancy effect was significant, *F*(1,46)=39.88, *MSE*=342, *p*<.0001. Participants responded more rapidly when the target was presented at the expected position (M=518 ms) than at the unexpected position (M=535 ms), revealing that they were able to voluntarily orient their attention to the expected location with an SOA as short as 100 ms. The interaction between Cuing and Task was significant, *F*(1,46)=39.88, *MSE*=342, *p*<.0001. In the discrimination task, a significant facilitatory effect was observed, *F*(1,46)=13.77, *MSE*=787, *p*<.001, while in the detection task, a marginally significant IOR effect was found, *F*(1,46)=3.21, *MSE*=787, *p*=.07. The interaction between Expectancy, Cuing, and Task was significant, *F*(1,46)=6.32, *MSE*=2235, *p*<.01, revealing that, at the expected location, no cuing effect appeared either in the detection or the discrimination task, *F*<1. However, at the unexpected location, the cuing effect was different in the detection and the discrimination task, *F*(1,46)=12.15, *MSE*=2140, *p*<.001, with a significant facilitatory effect being observed in the discrimination task, *F*(1,46)=7.13, *MSE*=2140, *p*<.01, while a significant IOR effect was observed in the detection task, *F*(1,46)=5.10, *MSE*=2140, *p*<.05.

SOA 1000 ms. The analysis of the mean RTs revealed significant main effects of Task, *F*(1,46)=126.18, *MSE*=14834, *p*<.0001, and Expectancy, *F*(1,46)=15.94, *MSE*=514, *p*<.001, with participants responding faster in the detection task and at the expected (M=496 ms) versus the unexpected location (M=509 ms) overall. The Cuing effect also reached significance, *F*(1,46)=53.99, *MSE*=926, *p*<.0001, and interacted with Task, *F*(1,46)=5.38, *MSE*=926, *p*<.05, showing a significant IOR effect both in the detection, *F*(1,46)=46.73, *MSE*=926, *p*<.0001, and in the discrimination task, *F*(1,46)=12.64, *MSE*=926, *p*<.001, although the effect was larger in the former. Expectancy did not interacted with Cuing, *F*<1, but the interaction between Task, Expectancy, and Cuing was marginally significant, *F*(1,46)=3.48, *MSE*=1340, *p*=.06. This interaction showed that, although the IOR effect was significant in both expected and unexpected locations, *F*(1,46)=29.47, *MSE*=739, *p*<.0001, and *F*(1,46)=18.62, *MSE*=1527, *p*<.0001, respectively, at the expected location, the IOR effect was similar in magnitude in the detection and the discrimination task, *F*<1. However, at the unexpected location, IOR was larger in the detection (mean cuing effect, defined as the mean RT difference between uncued and cued trials, -54 ms) than in the discrimination task (mean cuing effect of -14 ms), *F*(1,46)=6.32, *MSE*=1527, *p*<.01 (see Figure 1).

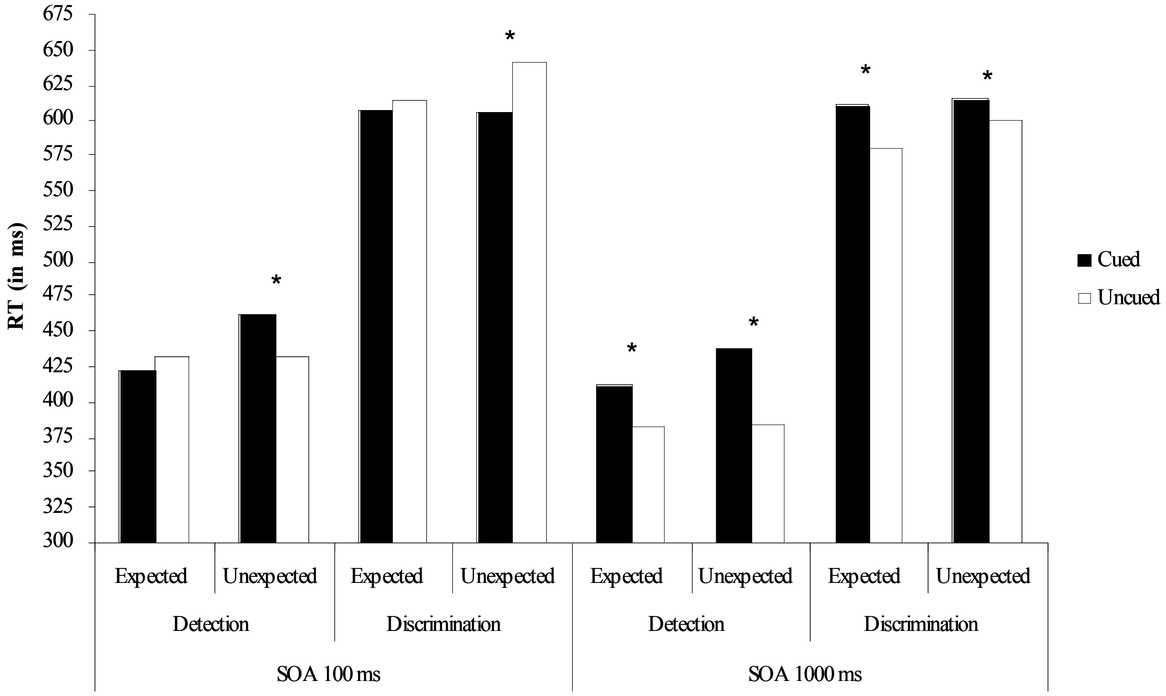


Figure 1. Mean RT (in ms) for cued and uncued trials, in Experiment 1, as a function of Expectancy, Task, and SOA.

The mean error data in the discrimination task were submitted a similar ANOVA with the factors: 2(Expectancy) x 2(Cuing) x 2(SOA). In this analysis only the main effect of Expectancy reached significance, *F*(1,23)=5.66, *MSE*=.001, *p*<.05, with participants' responses being more accurate for expected (M=.06) than for unexpected location trials (M=.07).

Discussion

The results of the present experiment show that participants are able to attend to the likely position predicted by the cue, since the effect of expectancy reached significance at a SOA as short as 100 ms. At this short SOA, when the target appeared at the expected location, no cuing effect was observed either in the detection or the discrimination task. However, when the target was presented at an unexpected position, a facilitatory effect appeared in the discrimination task, while an IOR effect was observed in the detection task. At the longer SOA, a significant IOR effect appeared at both the expected and unexpected location. At the expected location, this IOR effect was similar in magnitude for the detection and discrimination task. However, at the unexpected location, the IOR effect was larger in the detection than in the discrimination task.

These results clearly differ to those predicted by the reorienting hypothesis of IOR. If IOR was a mechanism that inhibits the returning of attention to a previously attended position, no IOR effect should be observed until attention is disengaged from the cued location. At the expected location, as attention has not been disengaged, no IOR effect is supposed to occur. However, in the present experiment, IOR was observed at the expected location in both the detection and discrimination task.

An important result that emerged from this experiment was that at the expected location, the detection and discrimination task yielded similar IOR effects, whereas, at the unexpected location, IOR was larger in the detection than in the discrimination task. Experiment 2 was designed in order to replicate the results of Experiment 1, and to study the temporal course of cuing effects in detection and discrimination tasks while controlling the locus of endogenous orienting of attention.

Table 2. Mean RT (in ms), and percentage of incorrect responses in the discrimination task (in parenthesis), in Experiment 1, as a function of Cuing, SOA, Task, and Expectancy. The bottom row shows the mean cuing effect for each condition.

		EXPERIMENT 1							
SOA		**100**				**1000**			
Task		**Detection**		**Discrimination**		**Detection**		**Discrimination**	
Expectancy		**Expected**	**Unexpected**	**Expected**	**Unexpected**	**Expected**	**Unexpected**	**Expected**	**Unexpected**
Cued	RT	422	462	607	606	412	439	611	615
	(Acc)			(6.0)	(8.4)			(7.0)	(7.5)
Uncued	RT	432	432	614	641	382	384	581	600
	(Acc)			(6.0)	(7.2)			(5.9)	(8.1)
Mean Cuing effect		-10	-30	7	36	-30	-54	-30	-14

EXPERIMENT 2

This experiment was designed to confirm the results of Experiment 1, in which we demonstrated that IOR can be observed both at expected and unexpected positions predicted by an informative peripheral cue. A further aim of Experiment 2 was to study the time course of cuing effects across SOAs in both detection and discrimination tasks. For this purpose, SOA was manipulated at four levels: 100, 300, 500, and 700 ms. Previous research has shown that the time course of cuing effects is different in detection and discrimination tasks (Lupiáñez et al., 1997). As described in the Introduction, the “later disengagement” hypothesis (Klein, 2000) proposes that, as discrimination tasks are more difficult than detection tasks, once attention is engaged at the cued location, the disengagement of attention from that position requires a longer period of time than in detection tasks. As a consequence, IOR is observed at longer SOAs. With our paradigm, the allocation of attention is controlled by the predictivity of the cue, so that attention is held at the expected location (or disengaged from the unexpected location). If cuing effects in detection and discrimination tasks show the same time course differences, even when the disengagement of attention is being controlled and measured by the expectancy effect, the “later disengagement” hypothesis will be challenged.

Method

Participants. Forty psychology students from the University of Granada, participated in this experiment (20 for the detection and 20 for the discrimination task), 22 women and 18 men. Thirty-eight of the participants were right-handed, 1 left-handed, and 1 ambidextrous by self-report. The average age of the participants was 20 years, and all of them reported to have normal or corrected to normal vision. They were naïve as to the purpose of the experiment, and participated voluntarily for course credits.

Apparatus and stimuli. Everything was the same as in Experiment 1 except the following: An IBM compatible PC running E-prime software (Schneider, Eschman, & Zuccolotto, 2002) controlled the presentation of stimuli, timing operations, and data collection. As an orientation cue, the contour of one of the boxes briefly thickened, giving the impression of a flash. When participants made a mistake, a 1997 Hz sound occurred for 50 ms.

Procedure. The procedure was the same as in Experiment 1, except that the SOA variable had four levels: 100, 300, 500 and 700 ms.

Design. The experiment had a 2(Task) x 2(Expectancy) x 2(Cuing) x 4(SOA) design, with the first variable being manipulated between participants, and the remaining three variables being manipulated within participants. *Task* had two levels: Detection and Discrimination. *Expectancy* had two levels: Expected and Unexpected location trials. *Cuing* had two levels: Cued and Uncued location trials. Finally, *SOA* had 4 levels: 100, 300, 500 and 700 ms.

The experiment consisted of two experimental blocks of 320 trials, each being preceded by a practice block of 24 trials. For each experimental condition of cuing and SOA, there were 48 observations for expected trials, and 16 for unexpected trials.

Results

False alarms (0.59% and 0.17% of trials in the detection and discrimination task, respectively), misses (0.88% of trials in the detection and 0.17% in the discrimination task), and incorrect responses in the discrimination task (4.20%), were excluded from the RT analysis. Finally, RTs faster than 100 ms or slower than 1200 ms were also removed from the RT analysis. This resulted in a further 0.66% of trials being discarded in the detection task, and 0.41% of trials in the discrimination task.

The mean RT data were submitted to a repeated-measures ANOVA, with the following factors: Task(2), Expectancy(2), Cuing(2), and SOA(4). The first variable was manipulated between participants, while the remaining 3 variables were manipulated within participants (see Table 3). As in the previous experiment, the RT analysis revealed a significant main effect of Task, $F(1,38)=105.54$, $MSE=47641$, $p<.0001$, Expectancy, $F(1,38)=63.81$, $MSE=763$, $p<.0001$, Cuing, $F(1,38)=5.64$, $MSE=1145$, $p<.05$, and SOA, $F(3,114)=45.91$, $MSE=846$, $p<.0001$. The interaction between Cuing and Task was also significant, $F(1,38)=19.35$, $MSE=22149$, $p<.0001$, as was the interaction between Cuing and SOA, $F(3,114)=9.73$, $MSE=478$, $p<.0001$. Importantly, Expectancy and Cuing did not interacted, $F<1$, the cuing effect being -7 ms at the expected position, and -5 ms at the unexpected position.

In order to test the “later disengagement” hypothesis about IOR (which postulates that IOR appears later in discrimination than in detection tasks because attention is disengaged later from the cued location in the former), it is important to analyse the time course of cuing effects in both tasks at the expected location (from where attention is not supposed to be disengaged in either task), and at the unexpected location (from where attention is supposed to be disengaged in both tasks). To this aim, two repeated-measures ANOVAs, with the factors: Task(2), Cuing(2), and SOA(4), were performed, one for the expected and the other for the unexpected location trials.

Expected location. The main effects of Task and SOA were significant. The interactions between Cuing and SOA, and Cuing and Task were also significant. The interaction between Task, Cuing, and SOA was not significant, $F<1$, showing that the cuing effect became more negative (or less positive) across SOAs in both the detection and the discrimination task. The absence of Task x Cuing x SOA interaction can be taken as an indication that the orienting of attention was controlled, since the same attentional orienting (Cuing x SOA interaction) occurred in both tasks. However, in the detection task, IOR reached significance beginning at the 500 ms SOA, $F(1,38)=9.54$, $MSE=497$, $p<.005$, while in the discrimination task, no cuing effect appeared at the 500 ms SOA, $F<1$, with IOR being only significant at the 700 ms SOA, $F(1,38)=4.80$, $MSE=428$, $p<.05$ (see Figure 2). Thus, at the expected location (from where attention is not supposed to be disengaged), IOR still appears, and it still does so later in the discrimination than in the detection task.

Unexpected location. Again, the main effects of Task and SOA were significant. Significant interactions between Cuing and SOA, and Cuing and Task were also observed. Once again, the cuing effect became more negative (or less positive) across SOAs in both the detection and the discrimination task, as can be inferred from the absence of Task x Cuing x SOA interaction, $F<1$. However, IOR was observed beginning at the 500 ms SOA in the detection task, $F(1,38)=10.42$, $MSE=1134$, $p<.005$; while, in the discrimination task, no IOR appeared even at the 700 ms SOA, $F<1$.

Table 3. Mean RT (in ms), and percentage of incorrect responses in the discrimination task (in parenthesis), in Experiments 2 and 3, as a function of Cuing, Expectancy, Task, and SOA. The bottom row shows the mean cuing effect for each condition.

EXPERIMENT 2

Expectancy		**Expected**								**Unexpected**							
Task		**Detection**				**Discrimination**				**Detection**				**Discrimination**			
SOA		**100**	**300**	**500**	**700**	**100**	**300**	**500**	**700**	**100**	**300**	**500**	**700**	**100**	**300**	**500**	**700**
Cued	RT (Acc)	371	336	343	365	537 (5.1)	505 (5.7)	515 (3.7)	539 (4.2)	383	359	375	381	548 (4.7)	519 (5.9)	525 (3.8)	549 (4.3)
Uncued	RT (Acc)	364	326	321	334	552 (4.6)	516 (5.1)	511 (6.2)	525 (4.9)	381	349	341	353	564 (5.19	529 (8.79	527 (8.3)	557 (6.5)
Mean Cuing effect		-7	-10	-22	-31	15	11	-4	-14	-2	-10	-34	-28	16	10	2	8

EXPERIMENT 3

Expectancy		**Expected**								**Unexpected**							
Task		**Detection**				**Discrimination**				**Detection**				**Discrimination**			
SOA		**100**	**400**	**700**	**1000**	**100**	**400**	**700**	**1000**	**100**	**400**	**700**	**1000**	**100**	**400**	**700**	**1000**
Cued	RT (Acc)	381	360	366	378	547 (5.2)	533 (4.6)	543 (6.2)	557 (4.7)	411	383	398	407	566 (6.5)	543 (5.9)	563 (5.5)	570 (6.3)
Uncued	RT (Acc)	378	335	341	362	560 (6.6)	522 (4.7)	525 (3.7)	537 (5.3)	386	349	358	363	579 (7.8)	547 (5.3)	562 (8.6)	563 (5.6)
Mean Cuing effect		-3	-25	-26	-16	13	-11	-18	-21	-26	-34	-40	-45	13	4	-1	-7

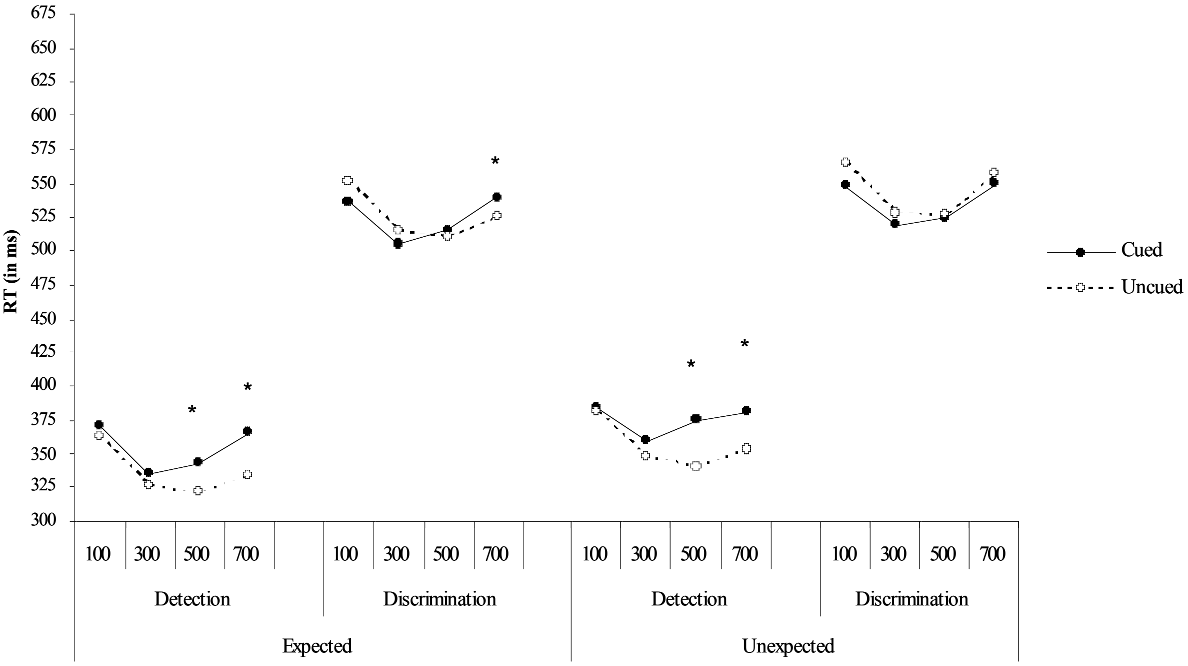


Figure 2. Mean RT (in ms) for cued and uncued trials, in Experiment 2, as a function of SOA, Task, and Expectancy.

The mean error data in the discrimination task were submitted to a repeated-measures ANOVA, with the factors of Expectancy(2), Cuing(2), and SOA(4). In this analysis, only the Cuing effect reached significance, *F*(1,38)=7.55, *MSE*=0.002, *p*<.05, with responses being more accurate for cued (M=.04) than for uncued (M=.06) trials overall.

Discussion

In Experiment 2, as in the previous experiment, participants were able to attend to the likely position predicted by the cue, which can be measured by a main effect of Expectancy. However, at a long enough SOA (700 ms), IOR did occur at the expected location (where attention was being voluntarily allocated) in both detection and discrimination tasks. This IOR effect is difficult to explain by the inhibition of the return of attention to that position, as attention is supposed to be endogenously maintained there.

Concerning the differences in the time course of cuing effects in detection and discrimination tasks, the present results showed that IOR still appears later in the discrimination than in the detection task, even when the orienting of attention is controlled. This result is opposite to the prediction of the “later disengagement” hypothesis, which postulates that IOR is observed later in discrimination tasks because attention is disengaged later from the cued location. With our paradigm, we controlled the allocation of attention at the position predicted by the cue, so the differences in the time course of cuing effects between the detection and discrimination task cannot be explained, at least in the present experiment, by factors related to the disengagement of attention from the cued location.

As in the previous experiment, cuing effects in detection and discrimination tasks were more similar at the expected location than at the unexpected location. At long SOAs (more than 500 ms), when the target appeared at the position predicted by the cue, IOR was observed in both the detection and the discrimination task. A planned comparison revealed that, at the expected location, the IOR effect was not significantly different between tasks, $p > .05$. However, when the target was presented at an unexpected position, the cuing effect was different in both tasks, $p < .05$, with IOR being observed in the detection task but not in the discrimination task.

EXPERIMENT 3

Could IOR be further delayed when participants are asked to discriminate targets appearing at an unexpected location? To test this possibility, we conducted a further experiment, with a larger range of SOAs: 100, 400, 700, and 1000 ms.

Method

Participants. Forty psychology students from the University of Granada, participated in this experiment (20 for the detection and 20 for the discrimination task), 29 women and 11 men. Thirty-six of the participants were right-handed, 3 left-handed, and 1 ambidextrous by self-report. The average age of the participants was 20 years. All of them reported to have normal or corrected to normal vision, were unaware of the purpose of the experiment, and participated voluntarily for course credits.

Apparatus, stimuli, procedure and design. The apparatus, stimuli, set-up, procedure, and design were the same as in Experiment 2, except in the SOA variable, which was manipulated at 4 different levels: 100, 400, 700 or 1000 ms.

Results

Misses (0.97% of trials in the detection task, and 0.89% in the discrimination task), and false alarms (0.52% and 0.50% of trials in the detection and discrimination task, respectively) were excluded from the RT analysis. Responses faster than 100 ms and slower than 1200 ms, were also excluded from the RT analysis, which discarded a further 0.95% and 0.50% of trials in the detection and the discrimination task, respectively. Finally, trials with an incorrect response in the discrimination task (4.03%) were also removed from the RT analysis.

The mean RT data were submitted to a mixed ANOVA, with the factors, Task(2), Expectancy(2), Cuing(2), and SOA(4). Table 3 shows the mean RT and mean error data for each experimental condition. The analysis showed a significant main effects of Task, *F*(1,38)=115.51, *MSE*=44349, *p*<.0001, Expectancy, *F*(1,38)=94.65, *MSE*=693, *p*<.0001, Cuing, *F*(1,38)=37.13, *MSE*=976, *p*<.0001, and SOA, *F*(3,114)=38.76, *MSE*=669, *p*<.0001. The interactions between Cuing and SOA, *F*(1,38)=11.52, *MSE*=336, *p*<.0001, and Cuing and Task, *F*(1,38)=21.94, *MSE*=976, *p*<.0001, were significant. Once again, the interaction between Expectancy and Cuing was not significant. However, the interaction between Expectancy, Cuing, and Task was marginally significant, *F*(1,38)=3.54, *MSE*=2470, *p*=.06. Importantly, this interaction showed that at the expected location, the cuing effect in the detection and discrimination task did not differ, *F*(1,38)=1.14, *MSE*=1213, *p*=.29. However, at the unexpected location, the cuing effect differed between tasks, *F*(1,38)=12.89, *MSE*=2231, *p*<.001. IOR occurred in the detection task, *F*(1,38)=23.04, *MSE*=2231, *p*<.0001, but not in the discrimination task, *F*<1 (see Figure 3).

In order to test the "later disengagement" hypothesis, separate ANOVAs were carried out, for the expected and unexpected location, with the following factors: Task(2) x Cuing(2) x SOA(4).

Expected location. The analysis revealed significant main effects of Task and SOA. The interaction between Cuing and SOA, was also significant. Again, the interaction between Task, Cuing, and SOA was not significant. However, IOR was observed beginning at the 400 ms SOA in the detection task, *F*(1,38)=9.65, *MSE*=652, *p*<.005, while in the discrimination task, no cuing effect appeared at the 400 ms SOA, *F*(1,38)=1.72, *MSE*=652, *p*=.19, with IOR being only significant beginning at the 700 ms SOA, *F* (1,38)=6.26, *MSE*=494, *p*<.05.

Unexpected location. The main effects of Task and SOA were again significant, and the interaction between Cuing and SOA was borderline significant, *F*(3.114)=2.64, *MSE*=524, *p*=.05. Cuing also interacted with Task. Once again, the interaction between Task, Cuing, and SOA was not significant, *F*<1. However, in the detection task, IOR was observed beginning at the 100 ms SOA, *F*(1,38)=6.22, *MSE*=1028, *p*<.05; whereas, in the discrimination task, no such cuing effect was observed even at the 1000 ms SOA, *F*<1.

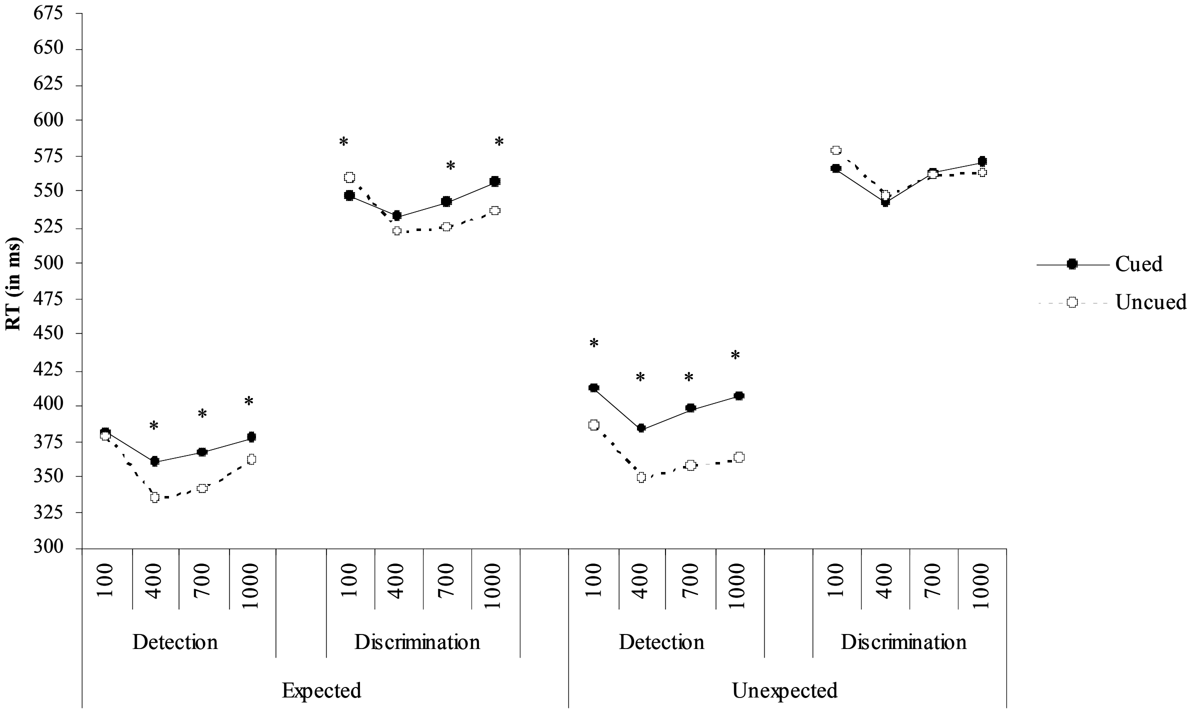


Figure 3. Mean RT (in ms) for cued and uncued trials, in Experiment 3, as a function of SOA, Task, and Expectancy.

The mean error data in the discrimination task were submitted to a repeated-measures ANOVA, with the factors of Task(2), Expectancy(2), Cuing(2), and SOA(4). In this analysis, only the Expectancy effect reached significance, *F*(1,38)=5.00, *MSE*=.002, *p*<.01, with the participants being more accurate when the target appeared at the expected position (M=.04) than when it appeared at the unexpected position (M=.06).

Discussion

Experiment 3 replicated the results from Experiments 1 and 2. IOR was again observed at the expected location in both the detection and the discrimination task. At this expected location, IOR appeared for SOAs greater than 400 ms in the detection task. In the discrimination task, no cuing effect was observed at the 400 ms SOA, with IOR being observed for SOAs greater than 700 ms. At the unexpected location, IOR appeared from the shortest SOA in the detection task, while it did not reach significance in the discrimination task, even at the longest SOA. Thus, as shown by the interaction between Expectancy, Cuing, and Task, which approached significance, at the expected location, the cuing effects were similar in the detection and the discrimination task. However, at the unexpected location, a more negative cuing effect was observed in the detection than in the discrimination task.

General Discussion

In the present series of experiments endogenous and exogenous orienting have been dissociated using the same set of stimuli. An informative peripheral cue was used, that predicted, in each block of trials, that the target would appear either at the same or opposite position to the cue. Crucially, both expected and unexpected locations were either cued or uncued. The results revealed that the Expectancy effect was significant at all the SOAs used here, showing that participants were able to attend to the position predicted by the cue. As noted above, if participants were already attending to the position predicted by the cue, no disengagement of attention from that location was supposed to occur when the target appeared at this position (expected location trials). However, in the three experiments reported here, IOR was observed at the expected location, both in the detection and discrimination task. This result argues against the reorienting hypothesis (Posner & Cohen, 1984), which predicts no IOR effect until attention leaves the cued location (see Klein, 2000, p. 139, line 22).

It could be argued that endogenous attention was not completely engaged at the expected location because the cue was not 100% predictive of target's appearance. In support of this idea, it has been demonstrated that attentional capture (i.e. facilitatory effects) can be overridden by 100% informative cues, but not by 80% informative cues (Yantis & Jonides, 1990). However, in Berlucchi, et al.'s (1989) experiment, although participants knew in advance where the target would appear (it was presented at the same spatial position in all the trials within a block), IOR was still observed at the expected location. In the experiments presented here (75% informative cue) we cannot be sure that attention was completely oriented endogenously at the expected location (as it might be using a 100% informative cue).

Moreover, we reckon that attention might be always more oriented to the position predicted by the cue (expected location) than to the opposite location (unexpected location). Nevertheless, experiments 2 and 3 showed that in the discrimination task IOR was observed at the expected location, but not at the unexpected location. Thus, it can be concluded, at least in the present experiments, that attentional disengagement from the cued location is not necessary to observe IOR.

Moreover, given that the predictivity of the cue was manipulated between blocks of trials, one might wonder whether the expectancy effect observed in the three experiments actually reflects the orienting of attention. Note that, within a block of trials, one type of trial was more frequent that the others, which might have elicited other processes rather than the orienting of attention. For instance, in the block were the cue predicted the target to appear at the opposite location, the participants would have been habituated to a stimulation pattern consisting of the cue and target appearing at opposite locations. A target appearing at the same location as the cue would have broken this pattern, increasing RT on those trials, resulting in an “expectancy effect”. However, we have shown elsewhere that the same pattern of results emerges when the expectancy is manipulated within a block of trials (Chica & Lupiáñez, 2004; see Appendix I). In that study, the central fixation point (either a “+” or “-” sign) informed participants about the predictivity of the upcoming peripheral cue. When the fixation point was a “+” sign, the peripheral cue predicted the target to appear at the same location (75%). In contrast, when the fixation point was a “-” sign, the peripheral cue predicted (75%) the target to appear at the opposite location. Therefore, all kinds of cue-target combinations were equally frequent. The only way to account for the expectancy effect that was observed in our study is to assume that participants were taking into account the information provided by the fixation point, and orienting attention according to it, either to the same location of the cue or to the opposite location. As in the experiments presented here, the results of Chica & Lupiáñez showed that IOR could be observed at endogenously attended locations, from where attention is not supposed to be disengaged.

The second important aim of the present study was to test the “later disengagement” hypothesis about the later appearance of IOR in discrimination than in detection tasks (Klein, 2000). According to this hypothesis, since discrimination tasks are more difficult than detection tasks, more attentional resources are needed for the processing of the target. Klein proposed that it would be difficult to implement a different set for the processing of the cue and target, since they are normally presented very close in time. Thus, more attentional resources are also allocated to the processing of the cue when discrimination instead of detection tasks are used. As a consequence, the disengagement of attention from the cued location, and thus IOR, occurs later in discrimination than in detection tasks.

The results of Experiments 2 and 3, in which orienting of attention was controlled (in both tasks, attention could be allocated either to the position predicted by the cue, or to the opposite location), showed that IOR still appears later in discrimination than in detection tasks, especially in unexpected location trials, in which attention is already disengaged from the cued location when the target appears. It is important to note that the interaction Task x Cuing x SOA did not approach significance (in either experiment). This can be taken as an indication that the orienting of attention was controlled, since the same orienting of attention (Cuing x SOA interaction) appeared in the two tasks (Lupiáñez, Milliken et al., 2001). In expected location trials, attention was allocated to the position predicted by the cue (i.e., no disengagement of attention from that location is supposed to occur when the target appears). At the unexpected location, attention is supposed to be already disengaged from the cued location when the target appears. However, at both the expected and unexpected location, IOR appeared later in the discrimination than in the detection task. Therefore, the time course differences between the detection and the discrimination task observed in these experiments cannot solely be explained by attention being disengaged later from the cued location in the discrimination than in the detection task.

The present results (i.e., IOR at the expected location and IOR appearing later in the discrimination than in the detection task) are difficult to explain solely by the orienting of attention, the disengagement from the cued location, and the subsequent inhibition of the return of attention. Alternatively, we propose that the appearance of a cue shortly before the target can capture spatial attention so that it is oriented to its position, but other perceptual processes can also affect the processing of the subsequent target (see e.g., Handy, Jha, & Mangun, 1999; Hawkins, Hillyard, Luck, & Mouloua, 1990; Li & Lin, 2002). When the cue appears, it is encoded as a new perceptual event. If the target is presented shortly after the cue, at the same spatial position, it is possible to encode the two objects as the same perceptual event (Kahneman, Treisman, & Gibbs, 1992; Lupiáñez, Milliken et al., 2001). This would lead to a facilitatory effect at short cue-target SOAs. However, at a longer SOA, if the target appears at the same position as the cue, the perceptual analysis of the cue would have finished, and no integration within the same perceptual event will occur. Alternatively, the target could be labelled as an "old" object, since that location has been recently analysed. Moreover, if the target is presented at the opposite location to the cue, it could be labelled as a "new" object, since that position has not been recently analysed, and therefore will benefit from attentional capture. This would lead to a faster processing of the target at uncued locations (i.e. IOR). Thus, IOR is not conceived as the inhibition of the return of attention to the cued location, but as the loss of advantage for objects appearing at "old" (previously cued) locations (Milliken et al., 2000).

In addition, the analysis of the cue and its influence on target processing could be different when detection and discrimination tasks are used. Lupiáñez et al. (2004) proposed that when performing a detection task, the most important process might be to dissociate the new object (the target) from the previous one (the cue). Thus, participants would need to implement a set to dissociate events. For that reason, the presence of an object before the target usually produces a "*detection cost*" at very short SOAs. However, when performing a discrimination task, it is not so important to dissociate events, as it is to analyse the features of the target required to select the appropriate response. Here, the presence of the cue before the target might facilitate its discrimination, by helping to select the spatial position where the features' analysis is going to occur. This "*spatial selection benefit*" finishes when the analysis of the cue is completed, giving rise to a later appearance of IOR in discrimination than in detection tasks.

In Experiments 1 and 3, IOR was observed at the unexpected location at a SOA as short as 100 ms. Although this result is not common in cuing studies (Lupiáñez et al., 1997; Lupiáñez, Milliken et al., 2001; Posner & Cohen, 1984), Danziger and Kingstone (1999) obtained similar results using a cuing paradigm with four possible locations. In Danziger & Kingstone's experiment, the cue was presented in one of the locations, and the participants were told to attend to the clockwise position related to its location. With this manipulation, IOR was found at a SOA as short as 50 ms. The authors proposed that, in a typical cuing paradigm (e.g., Posner & Cohen, 1984), the IOR effect at short SOAs is masked by the orienting of attention to the peripherally cued location: When the cue appears, attention is automatically summoned to its position (Posner et al., 1982). But if the cue predicts that the target would appear at another location, attention quickly moves away from that position. Thus, when the target appears at the cued location, a cost in performance (IOR) is observed.

However, Danziger and Kingstone's results can also be explained by factors related to the perceptual analysis of the cue. As the cue predicted a clockwise position, its perceptual analysis would have to be fast, in order to start the analysis of the target at the other location. This would lead to an early appearance of IOR, since the cued location becomes "old" when the analysis of the cue finishes. This effect is bigger in detection than in discrimination tasks, as IOR was observed from very short SOAs in the former task.

It is important to note that Danziger and Kingstone (1999) proposed IOR was unmasked by their procedure. However, using detection and discrimination tasks, we have shown that it is not always IOR that is unmasked. Facilitation can be unmasked under some conditions. Therefore, one may conclude that it is cuing effects that are unmasked by making the cue counterpredictive. At unexpected locations, IOR was observed in the detection task, while a facilitatory effect emerged in the discrimination task. Therefore, cuing effects manifest differently depending on the task at hand (detection vs. discrimination). These cuing effects are usually more negative in detection than in discrimination tasks. In fact, we have constantly found that at the expected location there were no differences in cuing effects between the detection and discrimination task. However, at the unexpected location cuing effects were more negative in the detection than in the discrimination task.

A reanalysis of the 3 experiments described in this paper confirmed these results. We pooled together the data for short SOA (i.e., 100 ms) and compared them with those for long SOAs (i.e., 700 ms for Experiment 2, and 1000 ms for Experiments 1 and 3) (see Figure 4). At the expected location, the cuing effect was not significantly different between the detection and discrimination task, either at the short or at the long SOA, $F(1,126)= 2.66$, $MSE=677$, $p=.10$, and $F<1$, respectively. However, at the unexpected location, the effect of cuing was significantly different between the tasks, both at the short and at the long SOA, $F(1,126)= 17.40$, $MSE=1656$, $p< .0001$, and $F(1,126)= 19.06$, $MSE=1204$, $p< .0001$, respectively. Therefore, when attention has been already disengaged (unexpected locations), it is not IOR that is unmasked, but the cuing effect, which could be either negative (IOR) or positive (facilitation) depending on other factors such as the type of target or the task at hand.

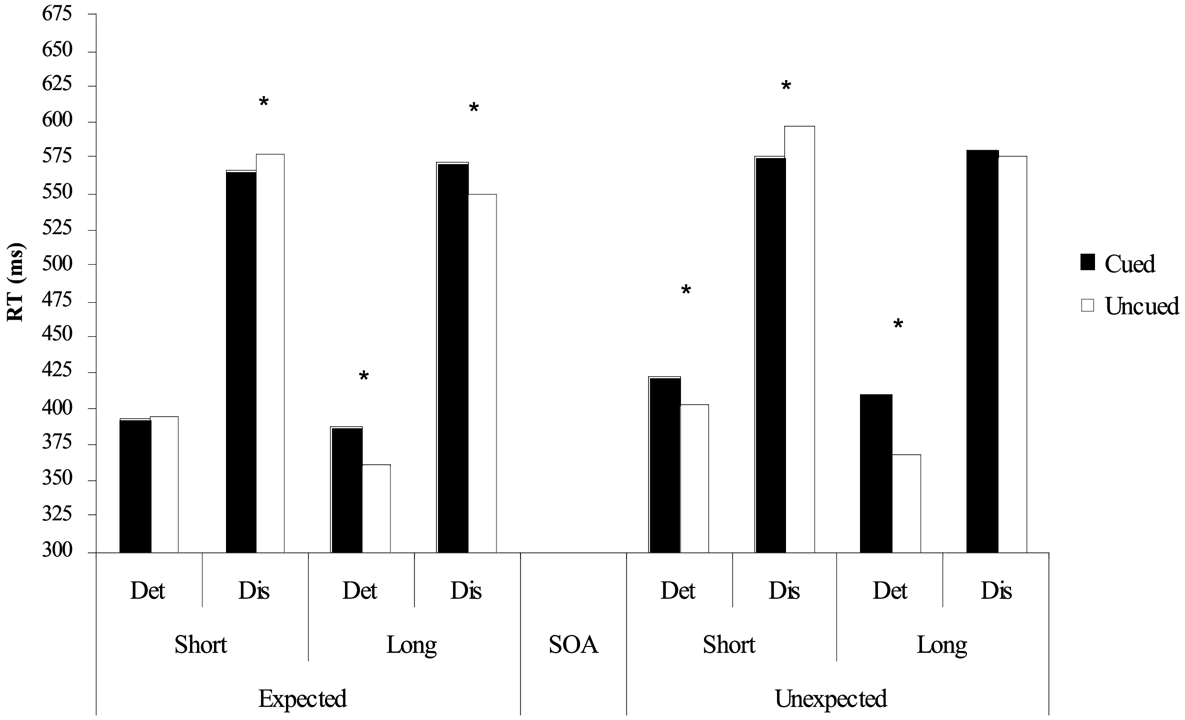


Figure 4. Mean RT (in ms) for cued and uncued trials, in the three experiments, as a function of Expectancy, SOA, and Task. Note that the short SOA refers to the 100 ms SOA, while the long SOA refers to the 1000 ms SOA in Experiment 1 and 3, and the 700 ms SOA in Experiment 2.

The dissociation of IOR from endogenous orienting that we show in the present study is not consistent with views of spatial attention as a single spotlight, which could be oriented either endogenously or exogenously. However, the described dissociation fits nicely with the mounting evidence suggesting the presence of distinct neurocognitive systems for endogenous and exogenous attention. There is now extensive behavioral evidence (e.g., Funes, Lupiáñez, & Milliken, 2005; see Klein & Shore, 2000 for a review) that exogenous and endogenous attention are in fact two qualitatively different processes. Consistent with behavioral results, neuroimaging studies suggest that the brain contains two partially segregated systems for visual orienting; a dorsal network (including parts of the intra-parietal sulcus and frontal eye field), bilaterally represented, and concerned with endogenous orienting, and a more ventral, right-lateralized network (temporo-parietal junction and inferior frontal gyrus) subserving exogenous orienting (Corbetta & Shulman, 2002). There is also some suggestion that IOR might correlate with activity in right-hemisphere frontal regions such as the right medial frontal gyrus (SEF) and the right inferior prefrontal sulcus (FEF) (Lepsien & Pollmann, 2002;

see also Ro, Farné, & Chang, 2003). Compelling neuropsychological evidence also indicates dissociations between exogenous and endogenous attention. In left unilateral neglect, exogenous orienting is heavily biased rightward (Bartolomeo & Chokron, 2001, 2002a). However, endogenous processes are largely spared, if slowed, in neglect patients (Bartolomeo et al., 2001). Importantly, as mentioned in the Introduction of this paper, these same patients may show a lack of IOR for right, ipsilesional stimuli (Bartolomeo et al., 1999; Bartolomeo et al., 2001; Lupiáñez et al., 2004), consistent with their rightward exogenous bias.

The possible preferential implication of right-hemisphere regions in IOR suggests a relation of this phenomenon with exogenous attention. This relationship was initially suggested by Maylor and Hockey (1985), and was recently confirmed by the demonstration of the tendency of normal individuals to make micro-saccades away from a task-irrelevant, peripherally presented visual stimulus (Galfano, Betta, & Turatto, 2004). Micro-saccades are small, automatic eye movements occurring during fixation, and their direction may correlate with covert exogenous orienting of attention (Engbert & Kliegl, 2003; Hafed & Clark, 2002). Also the well-established importance of the activity of the superior colliculus to the expression of IOR (Dorris, Klein, Everling, & Munoz, 2002; Posner et al., 1985; Sapir, Soroker, Berger, & Henik, 1999) underlines the relationship of this phenomenon to exogenous attention.

Taken together, the evidence suggests the brain may contain multiple attentional mechanisms that influence perception and action independently from one another, by biasing the competition among objects in the visual field (Desimone & Duncan, 1995). In this framework, IOR could be seen as one (or perphaps several; Sumner, 2006; Sumner, Nachev, Vora, Husain, & Kennard, 2004) processes decreasing attentional capture for "old" visual objects (Lupiáñez et al., 2004; Milliken et al., 2000), which are less likely to constitute a menace for the exploring organism. It makes ecological sense that such a basic ability for survival would be automatic and independent of more top-down influences on perception as it is the case of endogenous attention.

Chapter II.II.

Inhibition of return and attentional disengagement

The content of this chapter has been submitted as Lupiáñez, J., & Chica, A. B. (submitted). Inhibition of return and attentional disengagement.

ABSTRACT

When the time interval between two peripheral stimuli is long enough, reaction times (RTs) to targets presented at previously stimulated locations are slower that RTs to targets presented at new locations. This effect is widely known as Inhibition of Return (IOR). The effect is usually explained as an inhibitory bias against returning attention to previously attended locations. Thus, attentional disengagement is considered to be a necessary condition to observe IOR (Klein, 2000). We report data from three experiments in which, with 2 different paradigms, we show that IOR can be dissociated from the endogenous disengagement of spatial attention. Two main results are reported: 1) IOR is observed at an endogenously attended location in some situations, and 2) even after the endogenous disengagement of attention, facilitation instead of IOR is observed in other situations. We conclude that the endogenous disengagement of attention is neither sufficient nor necessary for IOR to be observed. These results are interpreted on the basis of cue-target event integration and event segregation processes.

Introduction

Attentional processes play an important role in the rapid and efficient scanning of visual environments. Behavioural, neuropsychological, and imaging studies suggest that two separate attentional systems support the exogenous and endogenous orienting of spatial attention (e.g., Bartolomeo & Chokron, 2001; Corbetta & Shulman, 2002; Funes et al., 2005; Kincade et al., 2005; Klein, 2004). The cost and benefit paradigm has been widely used to study these two mechanisms for the orienting of spatial attention (Posner, 1980). In *endogenous orienting* studies, a spatially informative central cue predicts the most likely location of target appearance. Participants are encouraged to endogenously orient attention towards the location predicted by the cue (i.e., the expected location). Usually, reaction times (RTs) to targets appearing at the expected location are faster than those to targets presented at the unexpected location, even at long cue-target stimulus onset asynchronies (SOAs, Posner, 1980). In *exogenous orienting* studies, a spatially uninformative peripheral cue, that is supposed to involuntarily capture spatial attention, is presented. At short SOAs, RTs are usually faster for targets appearing at the same location as the peripheral cue (i.e., cued location) as compared to RTs for targets presented at the opposite location (i.e., uncued location). This effect is thought to reflect the facilitation of the target's perceptual processing due to the capture of attention by the cue (e.g., Cameron, Tai, & Carrasco, 2002).

At longer SOAs, however, the opposite pattern of results is observed: RTs are faster for targets appearing at the uncued location as compared to the cued location. This effect, first reported by Posner & Cohen (1984), and named *Inhibition Of Return* (IOR) by Posner, Rafal, Choate and Vaughan (1985), is thought to reflect a bias against attention returning to previously explored locations. The IOR effect has been observed using a great variety of dependent variables and tasks (see Klein, 2000; Lupiáñez, Klein, & Bartolomeo, 2007; for reviews). The effect was first reported in detection tasks (Posner & Cohen, 1984), but it has also been observed in discrimination tasks (e.g., Lupiáñez et al., 1997; Pratt, Kingstone, & Khoe, 1997). However, the time-course of the effect is different, with IOR being observed at longer SOAs in discrimination tasks than in detection tasks (Lupiáñez et al., 1997).

Following the general metaphor of attention as a spotlight (Cave & Bichot, 1999), the delayed appearance of IOR in discrimination tasks, as compared with detection tasks, has been generally explained on the basis of a bigger attentional capture and/or a later disengagement of attention from the cued location in discrimination tasks than in detection tasks. Klein (2000) postulated that more attentional resources are assigned for processing the target in discrimination tasks than in detection tasks. Thus, at short SOAs, the attentional capture by the cue might be larger, producing a greater facilitatory cuing effect in discrimination than in detection tasks. At longer SOAs, this facilitatory effect turns into IOR but later in discrimination tasks. Alternatively, Lupiáñez & cols (Lupiáñez, Milliken et al., 2001) have argued that, independently on the effectiveness of the initial attentional capture, attention might be disengaged later in discrimination tasks than in detection tasks. Importantly, some manipulations can lead to a larger positive cuing effect at short SOAs (supposedly bigger capture), which is followed nevertheless by an earlier disengagement, and larger IOR at longer SOAs (Milliken et al., 2003). This finding suggests that a greater attentional capture is not always followed by a later appearance of IOR. Thus, attentional capture and attentional disengagement might be different processes rather than the two sides of the same coin (Klein, 2000).

Posner & Cohen (1984) proposed the reorienting hypothesis about IOR, in which IOR is conceived as the inhibition of the return of attention to a previously attended location. In spite of recent accumulative evidence showing that this hypothesis might not be correct (Berlucchi, 2006), this way of thinking about IOR is maintained by most researchers in the field. According to this view, attentional disengagement would be a necessary condition to observe IOR. Consequently, if IOR is a bias against attention returning to a previously attended location, no IOR should be observed until attention leaves the cued location (Klein, 2000; Posner & Cohen, 1984).

Overview of the present experiments

The main aim of this study is to investigate the relationship between IOR and attentional disengagement. In the first two experiments, we aimed at investigating whether presenting a second cue at fixation (after the peripheral cue) would lead to IOR in a situation where otherwise facilitation is observed. In Experiment 1, a standard exogenous cuing procedure was used. The SOA was fixed at 500 ms. Participants' task was to discriminate a target letter (either X or O). According to our previous research (Lupiáñez, Milliken et al., 2001), facilitation was expected to occur. Furthermore, the presentation of a cue at fixation after the peripheral cue was manipulated in different groups of participants. The presentation of a central fixation cue is known to favour the appearance of IOR (Faust & Balota, 1997; MacPherson, Klein, & Moore, 2003; Pratt & Fischer, 2002; Sapir, Henik, Dobrusin, & Hochman, 2001). According to the reorienting hypothesis, the central fixation cue attracts attention back to the centre, producing the inhibition of the return of attention to the cued location. According to that hypothesis, IOR should also be observed if attention is moved to the centre by other means. Experiment 2 was very similar to Experiment 1, but the target was highly probable to be presented at the central location, so participants were encouraged to endogenously disengage attention from the peripherally cued location and move it back to the centre. If attentional disengagement is the crucial factor for observing IOR, the effect should be observed both when attention is disengaged either endogenously (due to the likely appearance of the target at the central location) or exogenously (by presenting the fixation cue).

Experiment 3 was designed to further explore the relation between IOR and attentional disengagement. We used a paradigm in which endogenous and exogenous orienting of attention are manipulated orthogonally using the same set of experimental stimuli (Chica & Lupiáñez, 2004, under review; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004). A spatially informative peripheral cue was used that predicted (in different blocks of trials) the target to appear at either the same or the opposite location. Using this manipulation, both expected and unexpected locations could be either cued or uncued. Thus, if IOR consists of a mechanism that inhibits the reorienting of attention to a previously attended location, no IOR should be observed at the expected location, since attention is supposed to be maintained at that position. Similarly, at the unexpected location (from where attention has already been disengaged), IOR should always be observed.

EXPERIMENT 1

In Experiment 1, a standard exogenous cuing procedure was used in order to investigate the role of a central fixation cue on IOR. In this experiment, participants were asked to discriminate between two target letters (X and O). The cue-target SOA was fixed at 500 ms, a SOA at which facilitation is usually observed in a discrimination task (Lupiáñez et al., 1997; Lupiáñez, Milliken et al., 2001). Two groups of participants took part in the experiment. In one group, nothing was presented during the cue-target inter-stimulus interval (ISI). We predicted a facilitatory effect to be observed in this condition. In the other group, a second cue was presented at fixation during the ISI (after the peripheral cue disappearance and before the target appearance). We predicted an IOR effect to be observed in this condition.

Method

Participants. Sixteen psychology students from the University of Granada participated in the experiment, eight in each group. All of them were naïve as to the purpose of the experiment and participated voluntarily for course credits.

Apparatus and stimuli. Stimuli were presented on a 14-inch colour VGA monitor. An IBM compatible PC running MEL software (Schneider, 1988) controlled the presentation of stimuli, timing operations, and data collection. Three boxes (displayed in grey on a black background) were presented on the screen. Each box was 17 mm in height by 14 mm in width (subtending 1.62 and 1.33 degrees of visual angle at a viewing distance of 60 cm). The inner edge of each box was 77 mm (7.31 degrees) from the centre of the central box. The target was either the letter “X” or “O”.

Procedure. The sequence of events on each trial is depicted in Figure 5. The three boxes appeared at the beginning of the trial, and remained on the screen until the disappearance of the target. After 1000 ms, the exogenous peripheral cue was presented (one of the two peripheral boxes was displayed in white for 50 ms). In the group without fixation cue, the three boxes remained on the screen for 450 ms after the cue disappeared (i.e. 500 ms SOA). In the group with a fixation cue, the central box flickered after 100 ms (it was displayed in white for 50 ms), and the three boxes remained on the screen for 300 after the fixation cue, in order to maintain constant the 500 ms SOA. The target was displayed for 100 ms in one of the two peripheral boxes with equal probability. Auditory feedback (a 400 Hz computer-generated tone, 100 ms duration) was provided when a mistake was made. The inter-trial interval, in which the screen remained black, was 1000 ms in duration. Participants were instructed to press the appropriate response key on the keyboard as fast as possible, according to the target letter (either the "Z" or "B" key; the letter-key assignment was counterbalanced across participants). All possible combinations of cue and target location, and target letter variables were randomly presented within a block of trials. Thus, the target location was cued in half of the trials and uncued in the other half. Participants were allowed to take a rest after every 32 trials, and were instructed to press the space bar to continue the experimental session.

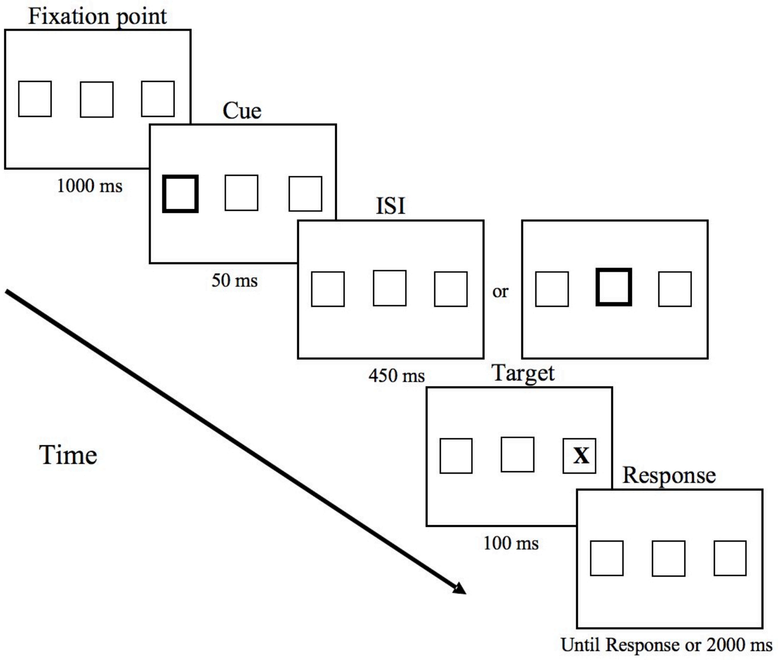


Figure 5. Example of one of the trials in Experiments 1 and 2. In the group without fixation cue, three boxes were presented for 50 ms during the ISI, while in the group with fixation cue, the central box was display in white for 50 ms during the ISI.

Design. The experiment consisted of a three-factor mixed design. Cuing and Block of trials were manipulated within participants, while Fixation Cue was manipulated between participants. Fixation cue had two levels: With and without fixation cue after the peripheral cue. Cuing had two levels: Cued and uncued location trials. Finally, Block was introduced in the analysis with 4 levels: Block 1, 2, 3 and 4, in order to study the influence of practise in the cuing effect (Lupiáñez, Weaver, Tipper, & Madrid, 2001).

Each of the 4 blocks of experimental trials consisted of 128 trials, 64 cued and 64 uncued. Before the experimental trials started, participants completed 16 practice trials (2 trials for each combination of target-letter, target-location, and cuing).

Results

Trials with incorrect responses (19%), those in which no response was made (3%), and those with RTs shorter than 200 ms (0.00%) or longer than 1800 ms (0.32%), were excluded from the RT analyses.

The mean RT data were submitted to a mixed analysis of variance (ANOVA) with the following factors: 4(Block) x 2(Cuing) x 2(Group: With vs. Without fixation cue). Table 4 shows the mean RTs and percentage of errors for each experimental condition. As can be observed in Figure 6, the cuing effect was modulated by the presentation of the fixation cue, $F(1, 14)=17.86$, $MSE=6026$, $p<.001$. Whereas the group without fixation cue showed a significant facilitatory effect (RT was 58 ms faster for cued than uncued trials, $F(1, 14)=9.08$, $MSE=6026$, $p<.01$), the group with fixation cue showed the opposite, IOR effect (RT was 58 ms slower for cued than for uncued trials, $F(1, 14)=8.79$, $MSE=6026$, $p<.02$).

There was also a main effect of Block, $F(3, 42)=16.66$, MSE=4844, p<.0001, indicating a gradual decrease in RT with practice in the task, and a Block x Cuing interaction, $F(3, 42)=7.11$, $MSE=1218$, $p<.001$, revealing a linear shift of the cuing effect toward facilitation with practice, $F(1, 14)=10.97$, $p<.01$ ($F< 1$, for both the quadratic and cubic tendencies): As can be seen in Figure 6, in the group without fixation cue, the facilitatory cuing effect increased with practice, whereas in the group with fixation cue, the IOR effect decreased with practice.

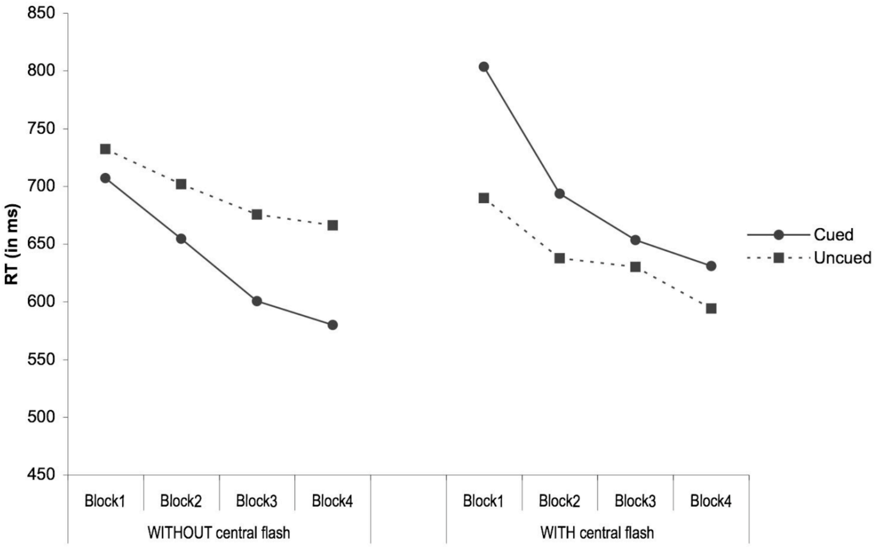


Figure 6. Mean RTs for cued and uncued trials across blocks of trials, as a function of the presence/absence of the Fixation Cue, in Experiment 1 (in which all targets were presented at one of the two peripheral locations).

A similar ANOVA was performed on the mean percentage of errors. This analysis showed a main effect of Block, *F*(3, 42)=8.28, *MSE*=35.40, *p*<.001. The Block x Cuing, and the Fixation Cue x Cuing interactions were also significant, *F*(3, 42)=3.75, *MSE*=29.35, *p*<.05, and *F*(1, 14)=5.12, *MSE*=307.27, *p*<.05, respectively. These interactions showed the same pattern as the RT data (see Table 4). Thus, facilitation was observed (6.13% fewer errors for cued than uncued trials) when no fixation cue was presented, while IOR emerged (8.75% more errors for cued than uncued trials) in the group with fixation cue.

Discussion

The results of the present experiment revealed that the cuing effect was significantly modulated by the presentation of a fixation cue during the interval between the peripheral cue and target. Participants showed a significant facilitatory effect when no fixation cue was presented, while IOR was observed in the fixation cue group. The effect of the fixation cue seems to be a robust result, as it has been observed in several studies using both discrimination and detection tasks (Faust & Balota, 1997; MacPherson et al., 2003; Pratt & Fischer, 2002; Sapir et al., 2001). Quite recently, Prime, Visser and Ward (2006) directly investigated this issue. They observed that whereas the fixation cue had no effect on detection and localization tasks, it had an important role in discrimination tasks, in which IOR was only observed after a fixation cue. According to the authors, the role of the fixation cue "is consistent with its putative role in reorienting attention away from the cued location".

Thus, considering the IOR effect as the result of a bias against attention returning to a previously attended location, the facilitatory effect observed in our group without fixation cue can be easily explained by assuming that, due to the perceptual difficulty of our discrimination task (Lupiáñez, Milliken et al., 2001), participants maintained attention at the cued location, even though the cue was not spatially informative about the location of the target. The observed pattern of cuing effects across blocks of trials seems to support this explanation. Previous research has shown that the facilitatory effect observed at a short SOA with spatially uninformative cues does not increase but decreases with practice in both detection and discrimination tasks (Lupiáñez, Weaver et al., 2001). Contrary to this finding, in the present experiment we have observed that the facilitatory effect observed in the group without fixation cue increased across blocks of trials. This clearly seems to support the hypothesis that attention was maintained at the cued location due to the difficulty of the task. Therefore, in the following experiment, participants were encouraged to endogenously disengage attention and move it back to fixation.

Table 4. Mean RT (in ms), percentage of errors, and cuing effect for each experimental condition of Fixation Cue, Block, and Cuing, in Experiment 1.

	Block 1		**Block 2**		**Block 3**		**Block 4**	
Fixation Cue	**C**	**U**	**C**	**U**	**C**	**U**	**C**	**U**
NO	659	679	611	669	560	635	543	628
	(20,6%)	(22,0%)	(17,6%)	(21,8%)	(9,6%)	(19,9%)	(12,4%)	(21,1%)
	20		**58**		**75**		**86**	
	(1,4%)		**(4,1%)**		**(10,3%)**		**(8,8%)**	
YES	770	650	653	604	613	589	594	573
	(34,1%)	(19,8%)	(24,5%)	(16,2%)	(24,3%)	(17,2%)	(19,5%)	(14,1%)
	-120		**-49**		**-24**		**-21**	
	(-14,4%)		**(-8,3%)**		**(-7,0%)**		**(-5,4%)**	

Note: C = Cued, U = Uncued. Cuing effect (Uncued - Cued), in bold

EXPERIMENT 2

By presenting a central cue at fixation after the peripheral cue, the facilitatory effect observed in Experiment 1 reversed into IOR. This might be due to the disengagement of attention from the peripherally cued location after the fixation cue was presented, which would then result in a bias against returning attention to the cued location. In order to test this hypothesis, a second experiment was carried out, in which the target was presented at fixation on 50% of the trials. Participants were informed that these central targets were the most important, and therefore attention should be kept at fixation all the time. On the remaining 50% of trials, the target appeared at one of the peripheral locations (25% of trials at the cued location, and 25% at the uncued location). Note that a similar strategy was implemented by Posner and Cohen (1984) to ensure that attention was disengaged from the cued location. If the lack of IOR observed in Experiment 1 when no fixation cue was presented was due to the maintenance of attention at the cued location, IOR should be observed in this experiment, since attention would have been disengaged from the cued location and oriented back to the centre. In other words, if the role of the fixation cue is to reorient attention back to the centre it should have no effect in this experiment, as attention will be endogenously reoriented back to the centre in all conditions, because the target is more likely to appear at the central location.

Method

Participants. Two different groups of sixteen students each participated in the experiment. Participants were naïve as to the purpose of the experiment, and participated voluntarily for course credits.

Procedure and design. The procedure was the same as in Experiment 1, except in the following: There were two groups of participants, one with fixation cue and the other without fixation cue. In both groups, the peripheral cue was always presented at one of the peripheral locations. However, on 50% of the trials the target was presented at fixation, and participants were informed that those trials were the most important, so they should always keep their attention at fixation. On the remaining 50% of the trials, the target appeared at one of the two peripheral locations (25% cued and 25% uncued). There were 4 blocks of experimental trials (128 trials each). In each block, there were 32 cued and 32 uncued location trials. Only cued and uncued location trials were considered in the analysis, so the design was the same as in Experiment 1.

Results

Trials with incorrect responses (17.7%), those in which no response was made (0.28%), and those with RTs shorter than 200 ms (0.41%) or longer than 1800 ms (0.19%) were excluded from the RT analysis. The remaining RTs were averaged per experimental condition and participant, and introduced into a 4(Block) x 2(Cuing) x 2(Group: With vs. Without fixation cue) mixed ANOVA. The mean RT and percentage of errors for each experimental condition are presented in Table 5.

As in Experiment 1, the RT analysis showed a main effect of Block, $F(3, 87)=3.87$, $MSE=4710$, $p<.05$. More importantly, as can be observed in Figure 7, the cuing effect was again significantly modulated by the Fixation Cue, $F(1, 29)=8.13$, $MSE=6298$, $p<.01$. In the group without fixation cue, there was a significant facilitatory effect, comparable to that obtained in Experiment 1 (47 ms faster RT for cued than for uncued trials), $F(1, 14)=6.18$, $MSE=6297$, $p<.05$. This facilitatory effect was independent of the block of trials, $F<1$. In sharp contrast, in the group with fixation cue, IOR was observed, and marginally modulated by block, $F(3, 45)=2.48$, $p=.073$. The IOR effect (mean RT was 23 ms slower for cued than uncued trials) was only present in the first two blocks of trials, $F(1, 15)=6.31$, $p<.05$.

The percentage of error analysis showed that the only significant effect was the Cuing x Fixation Cue interaction, $F(1, 29)=8.50$, $MSE=121.12$, $p<.01$. The cuing effect was positive in the group without fixation cue (3.87% fewer errors for cued trials than for uncued trials), although the effect was only marginally significant, $F(1, 29)=3.26$, MSE=121.19, $p<.081$. However, when a fixation cue was presented, IOR was observed (4.11% more errors for cued trials than uncued trials), $F(1, 29)=5.41$, $MSE=121.19$, $p<.05$.

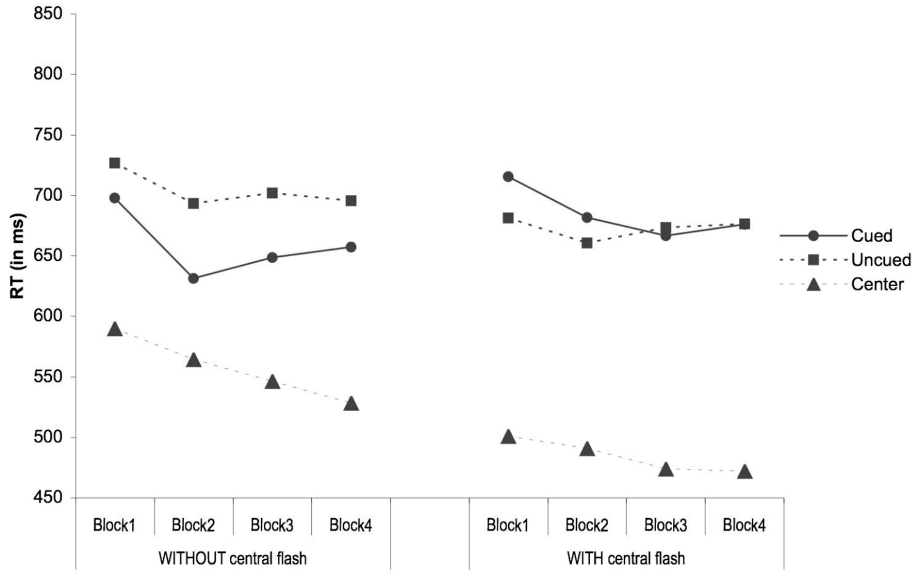


Figure 7. Mean RTs for peripheral target trials, cued and uncued, and for central location targets, across blocks of trials, as a function of the presence/absence of the Fixation Cue, in Experiment 2 (where 50% of the targets were presented at the central location).

Discussion

In this experiment, the effect of the fixation cue on IOR was replicated: Facilitation was observed when no fixation cue was presented, and IOR appeared after the presentation of the fixation cue. However, the presentation of 50% of the targets at fixation, together with the instructions to keep attention at that central position, did not affect the overall cuing effect. In Experiment 1, the fact that the cuing effect turned into IOR in the group with fixation cue could be interpreted, according to the reorienting hypothesis of IOR, by assuming that the fixation cue produced an automatic disengagement of attention from the peripherally cued location. However, if this were the case, we should have observed IOR in the group without fixation cue in Experiment 2, given that in this experiment, participants were encouraged to endogenously disengage attention from the cued location, and the 500 ms SOA is a long enough SOA to move attention endogenously (Müller & Rabbitt, 1989; Theeuwes, Godijn, & Pratt, 2004). In contrast, in the group without fixation cue, the same facilitatory effect as in Experiment 1 was observed. Therefore, the IOR effect produced by the central fixation cue does not seem to be due to the disengagement of attention. If this were the case, the same IOR effect should have been obtained when attention was disengaged by other means, such as by encouraging participants to move attention back to the centre after the presentation of the peripheral cue.

It could be argued that attention was not fully disengaged from the cued location, in spite of the target being highly probable at the central location, and participants being encouraged to keep attention always there. Note that the fact that the facilitatory effect was independent of practice in this experiment, whereas it increased with practice in Experiment 1, might be taken as indirect evidence that attention was maintained at the cued location in Experiment 1, but not in Experiment 2. Apart from this, we do not have any direct evidence that attention was in fact disengaged from the cued location in the group without fixation cue of Experiment 2. In order to ensure the disengagement of attention, and to be able to measure it, in the following experiment we used a different procedure in which the effects of peripheral cuing (correspondence between the location of the cue and the target) is measured orthogonally to the endogenous orienting of attention (Chica & Lupiáñez, 2004, under review; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004).

Table 5. Mean RT (in ms), percentage of errors, and cuing effect for each experimental condition of Fixation Cue, Block, and Cuing, in Experiment 2.

	Block 1			**Block 2**			**Block 3**			**Block 4**		
Fixation Cue	**Cen T**	**C**	**U**	**Cen T**	**C**	**U**	**Cen T**	**C**	**U**	**Cen T**	**C**	**U**
NO	567	656	707	535	612	665	518	623	671	505	632	665
	(5,6%)	(21,6%)	(28,8%)	(3,6%)	(21,9%)	(24,7%)	(3,1%)	(23,0%)	(25,8%)	(5,2%)	(20,3%)	(23,0%)
		51			**53**			**48**			**34**	
		(7,2%)			**(2,8%)**			**(2,8%)**			**(2,7%)**	
YES	481	686	656	471	652	636	463	630	646	456	649	643
	(5,6%)	(28,4%)	(23,7%)	(3,4%)	(26,6%)	(24,1%)	(3,1%)	(26,3%)	(20,7%)	(2,3%)	(26,3%)	(22,7%)
		-30			**-17**			**17**			**-6**	
		(-4,7%)			**(-2,6%)**			**(-5,6%)**			**(-3,6%)**	

Note: Cen T = Central Target, C = Cued, U = Uncued. Cuing effect (Uncued - Cued), in bold

EXPERIMENT 3

Experiments 1 and 2, it has been demonstrated that attentional disengagement is not a sufficient condition to observe IOR. The effect is reported when attention is disengaged by means of a fixation cue, but no IOR effect is observed when participants endogenously disengage attention because the target is more likely to be presented at the central box, and explicit instructions are given to keep attention at that central position.

The purpose of Experiment 3 was to further study the relationship between IOR and attentional disengagement. To this aim, we used a paradigm in which endogenous and exogenous orienting are manipulated orthogonally, while using the same set of stimuli. A peripheral cue is presented that predicts, in different blocks of trials, either the same or opposite location of target appearance. With this manipulation, endogenously attended and unattended locations can either be cued or uncued by the peripheral cue. Importantly, using this design we can measure where attention is oriented to, by measuring the expectancy effect (i.e., we can measure RTs to targets presented at expected versus unexpected locations).

Additionally, we can directly test the reorienting hypothesis of IOR. If IOR consists on the inhibition of the return of attention to previously attended locations, no IOR should be observed when attention is maintained at the expected location. Similarly, IOR should always be observed when attention has been disengaged from the cued location (unexpected location trials). Detection and discrimination tasks were used in order to test these two predictions. Based in previous research (Berger & Henik, 2000; Berger et al., 2005; Berlucchi et al., 2000; Berlucchi et al., 1989; Chica & Lupiáñez, 2004; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004) we expected to observe independent expectancy and cuing effects. Additionally, IOR is expected to be larger and to appear earlier in the detection task than in the discrimination task (Lupiáñez et al., 1997; Lupiáñez, Milliken et al., 2001).

Methods

Participants. Thirty-two psychology students, from the University of Granada, participated in this experiment (16 for the detection task and 16 for the discrimination task). As in the previous experiments, all participants were unaware of the purpose of the experiment, and participated voluntarily for course credits.

Apparatus, stimuli, procedure, and design. Everything was the same as in Experiment 1, except in the following: E-Prime software (Schneider et al., 2002) was used to control the presentation of stimuli and data collection. No fixation cue was presented in any block of trials. Task (detection versus discrimination) was manipulated between participants. In the detection task, participants were asked to detect the appearance of a target letter by pressing either the "Z" or "B" key on the keyboard (half of the participants pressed the "Z" key and the other half pressed the "B" key). In the discrimination task, participants had to discriminate the identity of the letter by pressing the appropriated key (also "Z" or "B"). The response-key mapping was counterbalanced across participants.

Catch trials (20% of trials) were included in both tasks. Each task consisted of two blocks of trials. In one of them, the peripheral cue predicted that the target would appear at the same spatial location as the cue on 75% of the target-present trials. Thus, when the target was presented at the same position as the cue, these were expected location trials (because the participants were expecting the target to appear at that location), and cued location trials (because the cue and target were presented at the same spatial position). However, on the remaining 25% of the target-present trials, the target was presented at the opposite location to the cue. These were unexpected location trials (because the target was not expected to appear at this location), and also uncued location trials (because the cue and target appeared at different spatial locations). In the other block, the cue predicted that the target would appear at the opposite location on 75% of trials. Thus, when the target was presented at the opposite location as the cue, these were expected location trials but uncued location trials. On the remaining 25% of the trials, the cue appeared at the same location as the cue, conforming the unexpected location trials but cued location trials. As can be observed, by using this manipulation, both expected and unexpected location trials can be either cued or uncued, making it possible to dissociate endogenous orienting from exogenous cuing. Note that expected and unexpected trials can be either cued or uncued; similarly, cued and uncued trials can also be either expected or unexpected. Participants were asked to attend to the position predicted by the cue, although they were not informed about the exact predictive value of the cue.

Each block consisted of 160 trials, preceded by 20 practice trials. Participants were allowed to take a break after every 80 trials. For each experimental condition of cuing (cued vs. uncued location trials), there were 32 observations for unexpected location trials, and 96 observations for expected location trials.

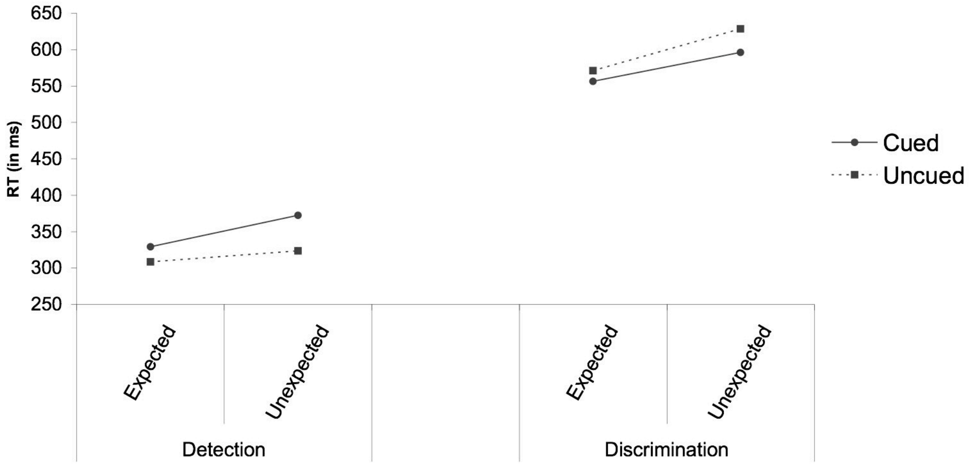
The factors in the design were: 2 (Task; Detection vs. Discrimination) x 2 (Expectancy; Expected vs. Unexpected location trials) x 2 (Cuing (Cued vs. Uncued location trials), with the first variable being manipulated between participants, and the remaining 2 variables being manipulated within participants.

Results

False alarms accounted for 0.96% and 1.30% of trials in the detection and the discrimination task, respectively. Participants missed the target on 1.31% and 0.71% of the target-present trials in the detection task and the discrimination task, respectively. Responses faster than 200 ms (2.69% and 0.00% of trials in the detection task and the discrimination task, respectively) or slower than 1200 ms (0.0% and 1.17% of trials in the detection task and the discrimination task, respectively) were eliminated from the RT analysis. Incorrect responses in the discrimination task (5.71% of trials) were also removed from the analysis.

The mean RT data were submitted to a 2 (Task) x 2 (Expectancy) x 2 (Cuing) mixed ANOVA (see Table 6). The analysis revealed a significant main effect of Task, *F*(1, 30)=145.71, *MSE*=14244, *p*<.0001, with participants being faster in the detection task than in the discrimination task (M=333 ms and M=587 ms, respectively). Importantly, the main effect of Expectancy was also highly significant, *F*(1, 30)=39.24, *MSE*=1226, *p*<.0001, showing that RT was faster when the target was presented at the position predicted by the cue –expected location, than at the unexpected location (M=441 ms and M=479 ms, respectively). Importantly, the expectancy effect did not interact with task, *F*(1, 30)=2.44, *MSE*=1226, *p*=.129, being statistically significant in both the detection and the discrimination task (*F*(1, 30)=11.06, *MSE*=1225, *p*=.002 and *F*(1, 30)=30.63, *MSE*=1225, *p*<.001, respectively). In agreement with previous research on tasks effect, Cuing interacted with Task, *F*(1, 30)=19.65, *MSE*=1403, *p*<.001. IOR was observed in the detection task (mean cuing effect of -35 ms), *F*(1, 30)=13.96, *MSE*=1403, *p*<.001, while facilitation was observed in the discrimination task (mean cuing effect of 23 ms), *F*(1, 30)=6.41, *MSE*=1403, *p*<.05.

The interaction between Task, Expectancy, and Cuing was significant, *F*(1, 30)=5.24, *MSE*=802, *p*<.05. As shown in Figure 8, this interaction revealed that, in the detection task, although a significant IOR effect was observed at both expected and unexpected location trials, *F*(1, 30)=4.66, *MSE*=755, *p*<.05, and *F*(1, 30)=13.25, *MSE*=1449, *p*<.01, respectively, the effect was bigger at the unexpected location, *F*(1, 15)=4.74, *MSE*=663, *p*<.05. In the discrimination task, the effect of cuing (facilitation instead of IOR) was bigger, and only significant, at the unexpected location, *F*(1, 30)=5.87, *MSE*=1449, *p*<.05. Although also positive, the effect of cuing was not significant at the expected location, *F*(1, 30)=2.32, *MSE*=755, *p*=.13.



<u>Figure 8</u>. Mean RTs for cued and uncued trials, as a function of Expectancy and Task, in Experiment 3 (in which endogenous and exogenous orienting of attention were manipulated orthogonally using an informative peripheral cue).

The mean percentage of errors in the discrimination task were also submitted to a 2 (Expectancy) x 2 (Cuing) repeated-measures ANOVA. Similarly to the RT analysis, the main effects of Expectancy, *F*(1, 15)=12.59, *MSE*=13.16, *p*<.01, and Cuing, *F*(1, 15)=10.98, *MSE*=27.49, *p*<.01, were significant. Importantly, the interaction between Expectancy and Cuing was marginally significant, *F*(1, 15)=3.59, *MSE*=23.13, *p*=.07, revealing that although the facilitatory effect was significant at both expected and unexpected locations, *F*(1, 15)=5.46, *MSE*=6.23, *p*<.05, and *F*(1, 15)=7.90, *MSE*=44.39, *p*<.05, respectively, the effect was larger at the unexpected than at the expected location (cuing effect of 2.06 and 6.62, respectively).

<u>Table 6</u>. Mean RT (in ms), percentage of errors in the discrimination task, and mean cuing effect for each experimental condition of Task, Expectancy, and Cuing, in Experiment 3.

	Detection		Discrimination	
	Expected	Unexpected	Expected	Unexpected
Cued	329	372	556 (3,9%)	596 (4,8%)
Uncued	308	323	571 (5,9%)	628 (11,4%)
Mean Cuing effect	**-21**	**-49**	**15** **(2,1%)**	**33** **(6,6%)**

Discussion

In the present experiment, the effect of expectancy was highly significant, both in the detection task and the discrimination task, showing that at a 500 ms SOA participants had time enough to orient attention according to the information provided by the cue. Previous research with our paradigm, in which we used several levels of cue-target SOA, has shown that the effect of expectancy does not increase with SOAs longer than 300 or 400 ms (Chica & Lupiáñez, 2004; Chica et al., 2006). Therefore, we can be confident that the orienting of attention was completed by 500 ms. This fact increases the importance of the two relevant results observed in relation to spatial orienting. On the one hand, IOR was observed at the expected location when a detection task was required. That is, IOR can be observed at a position from where attention has not been disengaged, revealing that the disengagement of attention is not a necessary condition in order to observe IOR. On the other hand, even after the disengagement of attention (when the target is presented at the unexpected location), facilitation instead of IOR was observed in the discrimination task. Therefore, in agreement with the data from Experiment 2, attentional disengagement is not sufficient to observe IOR: Facilitation, instead of IOR, can be observed at locations from where attention has been disengaged (i.e., unexpected locations).

General Discussion

The present study aimed at investigating the relationship between IOR and attentional disengagement. It has been proposed that IOR consists of a mechanism that inhibits the reorienting of attention to a previously attended location (Posner & Cohen, 1984). Thus, no IOR should be observed until attention leaves the cued location (Klein, 2000). From this hypothesis, the disengagement of attention is a necessary condition to observe IOR, an idea shared by most researchers in the field. Accordingly, using the cost and benefit paradigm, Posner & Cohen (1984) presented a cue at fixation after the peripheral cue, in order to ensure that attention was disengaged from the cued location when the target was presented (the so-called cue-back procedure). However, later on, other researchers have used a different procedure in which no fixation cue was used, and the usual IOR effect was also observed (e.g., Lupiáñez et al., 1997). In this case it is assumed that, given the lack of spatial predictivity of the peripheral cue, after several hundreds of milliseconds, participants disengage attention spontaneously from the cued location. Nevertheless, the fixation cue could anticipate the disengagement of attention, and therefore lead to an earlier appearance of the IOR effect (MacPherson et al., 2003; Pratt & Fischer, 2002; Sapir et al., 2001), specially in discrimination tasks, in which IOR appears much later if no cue is presented at fixation (Prime et al., 2006).

In the first two experiments presented here we manipulated the presentation of a fixation cue after the non-informative peripheral cue. A 500 ms SOA was used, and participants were asked to discriminate a target letter. A significant facilitatory effect was observed in the group without fixation cue, although this facilitatory effect reversed into IOR when a fixation cue was presented. However, when participants were encouraged to disengage attention from the cued location by making the target highly probable to appear at the central location (and by giving explicit instructions to maintain attention at that central location), no IOR effect was reported (Experiment 2). These results clearly show that the endogenous disengagement of spatial attention is not a sufficient condition to observe IOR. A similar result has been observed with IOR triggered by gaze cuing. This seems to be the only case in which IOR is observed with central cues (a face presented at fixation looking either left or right). However, in order to get IOR with this type of cues, a cue must be presented at fixation (a long SOA is also necessary but not sufficient). Importantly, the effect is not observed if no fixation cue is presented, even if the face looks strait ahead (after the peripheral looking cue) in order to disengage attention (Frischen, Smilek, Eastwood, & Tipper, 2007; Frischen & Tipper, 2004).

Furthermore, in Experiment 3, we used a paradigm in which an informative peripheral cue predicted either the same or opposite location of target appearance (Chica & Lupiáñez, 2004, under review; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004). Using this manipulation, both expected and unexpected location trials (endogenous attention) can either be cued or uncued (exogenous attention). This paradigm allows us to isolate the effects of cuing from the endogenous orienting of spatial attention. The reorienting hypothesis about IOR will predict that IOR should always be observed at the unexpected location, from where attention has been already disengaged. However, in line with the results of the previous experiments, when participants performed a discrimination task, facilitation instead of IOR was observed at the unexpected location, even after the disengagement of spatial attention. This results reveals that attentional disengagement is not sufficient to observe IOR. Additionally, the reorienting hypothesis will predict that no IOR effect should be observed at the expected location, where attention is supposed to be maintained. However, in the detection task, a significant IOR effect was reported both at the expected and the unexpected location. Therefore, IOR can be observed at a position where attention is being maintained, revealing that the disengagement of attention is not a necessary condition to observe IOR. These results are consistent with other studies that have reported, with a variety of paradigms, IOR at endogenously attended locations (Berger & Henik, 2000; Berger et al., 2005; Berlucchi et al., 2000; Berlucchi et al., 1989; Lupiáñez et al., 2004).

Previous evidence with different paradigms has also shown that IOR is <u>not</u> always related to the disengagement of attention from the cued location. For example, Tassinari, and cols. (Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994) reported IOR at a 0 ms SOA. This IOR effect cannot be accounted for an attentional disengagement, as neither attentional capture nor attentional disengagement might have occurred when the cue and target are presented simultaneously (Lupiáñez & Weaver, 1998). In addition, IOR have been consistently reported with no evidence of previous facilitation (Danziger & Kingstone, 1999; Pratt, Hillis, & Gold, 2001; Tassinari et al., 1994; Tassinari & Campara, 1996). This IOR effect is difficult to interpret as the inhibition of the return of attention to a previously attended location, if no orienting of attention (facilitation) has been previously measured at the cued location.

Our finding that the endogenous disengagement of attention is not sufficient to observe IOR is similar to the one reported by Danziger & Kingstone (1999). They observed that at a 50 ms SOA (where facilitation is usually reported in detection tasks), IOR was observed when participants were asked to disengage attention from the cued location. This result led them to conclude that by disengaging attention from the cued location, the IOR effect was unmasked. However, in their second experiment, in which a discrimination task was used, facilitation instead of IOR was observed (even at longer SOAs). Taken together Danziger & Kingstone's results and the results of the three experiments reported here, it can be concluded that it is not IOR that is unmasked by the disengagement of attention, but the cuing effects, facilitation or IOR depending on task's demands. That is, cuing effects can be dissociated from the endogenous orienting of spatial attention and they manifest differently depending on factors such as task's demands.

The counterargument might be, however, that when the task is manipulated between participants, or between blocks of trials or sessions, participants will adopt a particular task set that is applied not only to the processing of the target but also to the processing of the cue (Klein, 2000; Lupiáñez, Milliken et al., 2001). Therefore, it is difficult to know whether the tasks differences observed in the measured cuing effect are due either to the fact that the cue captures attention differently depending on the task, or to different manifestations of the cuing effect. This problem was directly tested in a recent study by Lupiáñez et al. (Lupiáñez, Ruz et al., 2007) who demonstrated that the same attentional capture produced by a peripheral cue can lead to either facilitation or IOR depending on the task at hand. In their experiments, a spatially non-informative peripheral cue was presented, followed by one of several possible target letters. Participants were asked to "detect" one of the letters (e.g., "X"), which was presented in most of the trials (i.e., 80% of the trials) and differed from the other letters in a single feature. In the remaining trials, however, one of two alternative letters was presented (either "O" or "U") and participants were asked to "discriminate" them, by pressing one of two keys on the computer keyboard. Note that, by the time the cue appears, no information is provided about the future identity of the target, so the same attentional capture must have taken place for both "detection" (i.e. detection of the frequent target) and "discrimination" (i.e., discrimination of the infrequent target) tasks. In spite of attentional capture (and subsequent reorienting processes) being controlled, the results revealed that the measured cuing effects depended on the task to be performed (i.e., the type of target that was presented), with a significant IOR effect observed in the detection of the frequent target, and a significant facilitatory effect in the discrimination of the infrequent target. That is, the same attentional capture can manifest differently in performance depending on factors such as the task at hand.

To summarise, taking into account all the evidence, it can be concluded that the endogenous disengagement of attention is neither sufficient nor necessary to observe IOR. The results of the present experiments revealed that in order to observe the IOR effect: 1) The endogenous disengagement of attention seems not to be *sufficient*, as facilitation instead of IOR is observed in discrimination tasks even when attention is disengaged from the cued location, and 2) the endogenous disengagement of attention seems not to be *necessary*, as IOR can be observed at a location where attention is being endogenously maintained.

It is important to make explicit that we do not argue that peripheral cues do in fact attract attention automatically, as most researchers in the field would consider. What we argue is that peripheral cues, apart from orienting attention automatically to the cued location, produce other effects, which seem to be independent of the orienting of the attentional spotlight. The important pieces of evidence for this argument are that a) both cuing effects, facilitation and IOR, can be dissociated from the orienting of attention (see Experiments 1 to 3 reported in this paper, see also, Berger & Henik, 2000; Berger et al., 2005; Chica & Lupiáñez, 2004; Chica et al., 2006; Danziger & Kingstone, 1999; Riggio & Kirsner, 1997), and b) when the attentional capture and subsequent orienting processes are controlled, opposite cuing effects (facilitation vs. IOR) can be observed depending on the task at hand (Lupiáñez, Ruz et al., 2007).

One might argue that the same way as IOR is only observed with exogenous cues, attention should be disengaged exogenously in order to observe the effect. This would explain why the presentation of central fixation cue leads to IOR, whereas the endogenous disengagement of attention does not. However, one should then explain what does it mean to disengage attention exogenously as something different to disengage attention endogenously. Our perceptual event integration-segregation hypothesis is an attempt to move in this direction.

Event Integration-Segregation Hypothesis

Figure 9 represents our framework for understanding the general pattern of results of cuing effects. We propose that the measured cuing effect is the overall contribution of different processes triggered by the cue, which also have a different time-course. When a peripheral cue is presented, attention will be quickly oriented to its location, improving target's perception and/or responses to it. When the cue is not informative about the target's location, this effect is short lasting and vanishes at longer SOAs.

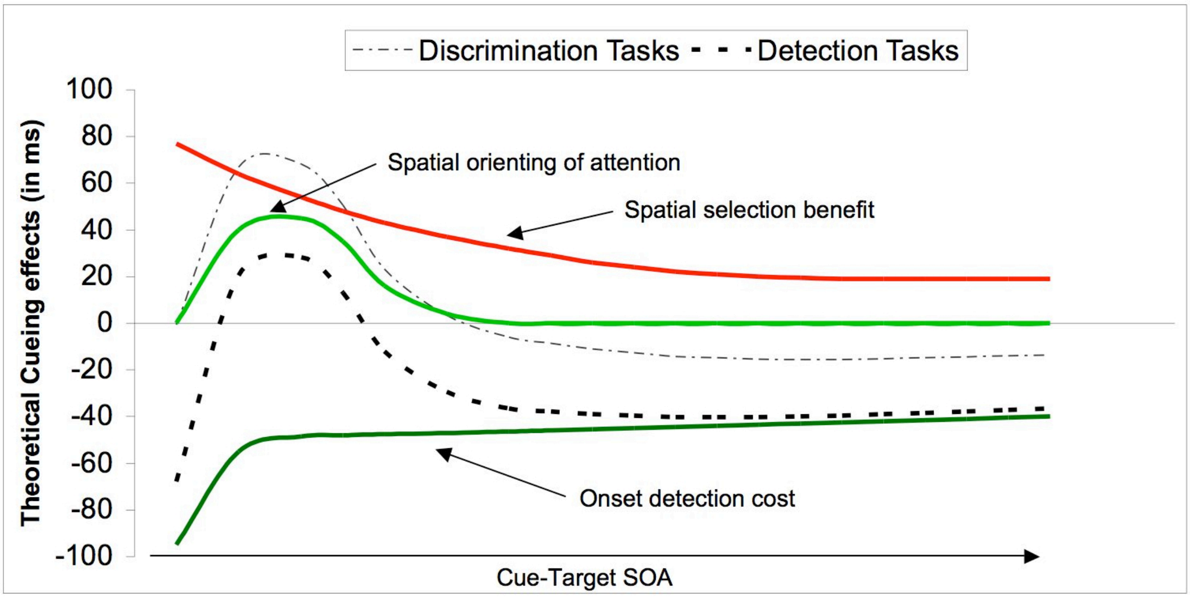


Figure 9. Theoretical cuing effects (in broken lines) usually observed for detection and discrimination tasks as a function of cue-target SOA. In full lines the cue-triggered processes, which underlay the cuing effects are represented: Spatial Orienting of attention, Onset Detection costs and Spatial Selection benefits. The different cuing effects for the two tasks are computed as a different contribution of each process for detection and discrimination tasks. Basically, whereas onset detection processes contribute mostly to detection tasks, spatial selection processes are tapped mainly by discrimination tasks.

Note that this "Spatial Orienting" process is the only one usually considered for explaining cuing effects produced by spatially non-predictive peripheral cues. However, we reckon that a peripheral cue is an event, an object that occupies a specific location, and this object can produce other effects on the processing of subsequent stimuli appearing at the same location. In particular, the subsequent target could be integrated within the same object file when it appears in spatio-temporal proximity to the cue, thus helping to select it as a relevant object for processing (to further discriminate its features). This facilitatory effect is represented in Figure 9 as the "Spatial Selection" benefit. Cue-target integration processes would be beneficial to determine *what* the target is, as they would help to select the target location in advance.

Following the object-file view (Kahneman et al., 1992), when the target appears in spatial and temporal correspondence with the cue (at the same position and shortly after it) there is no need of opening a new object representation in order to fully process the target. The cue representation can instead be updated incorporating the target's features. This would lead to faster and/or more accurate responses. When the cue and target do not share any features, cue-target integration does not interfere with the discrimination of the target's features, the same way as the opening of an object file by a dot in the sky does not interfere with the final discrimination of the dot as a bird (or an airplane) once the object file is updated with subsequent information. However, when the cue and target's features overlap, integration can lead to positive effects (when the same object repeats as the cue and the target) or negative effects (when cue and target are different objects, Milliken et al., 2000; Pratt & Abrams, 1999; Taylor & Donnelly, 2002).

The tendency to integrate the target within the cue representation as part of the same event would in fact constitute a cost in detecting the onset of the target. This negative effect is represented in Figure 9 as the "Onset Detection cost". Note that detecting the presence of the second event (the target) will be easier the more different the second event is as compared to the cue (Lupiáñez & Weaver, 1998). As stated above, spatial and temporal parameters seem to be the more important determinants of integration processes (Pratt et al., 2001). Therefore, we should expect that the greater the correspondence in space and time, the greater cost in detecting the target. In fact this is what has been observed with experimental procedures that have emphasized the importance of detecting the target (as compared to discriminating its features). Thus, Bennet and Pratt (2001) asked participants to detect a dot, which could appear randomly over the screen, at different distances form the cued location. Results clearly showed that the closer the target was to the cue, the slowest the responses. On the other hand, Tassinari, et al. (1994) manipulated the SOA between the cue and the target, from simultaneous appearance to long SOAs between them. Although IOR was observed at all SOAs, the effect was larger at the 0 ms SOAs (simultaneous presentation). As Lupiáñez and Weaver (1998) argued, we should expect the maximal cost at the 0 ms SOA: In a detection task, participants are in fact discriminating one versus two events, i.e., when only one event (the cue) is detected no response is given. However, when the two events are close in time (simultaneous) it is quite difficult to detect the presence of the two events unless they are in quite different locations (uncued trials). Note that in these two studies, the target was rather simple (a dot, so onset detection was emphasized), and participants were highly practised. These are appropriate conditions to measure what we have called the detection cost.

In discrimination tasks, target detection is not sufficient to perform the task, and discriminating the target's features is necessary. In this case, the cuing effect is not always negative, as other processes also contribute to performance. Generally, the final effect on the response to the target at the cued location will be sum of the net contribution of each of the three outlined processes: spatial orienting, detection cost, and spatial selection benefit. Depending on the task to be performed with the target stimulus, some processes will contribute to performance more than others. Carpenter (2004) has also proposed the existence of two processes in the discrimination of a given stimulus: The first one would be a mechanism related with the detection of individual stimulus fragments, and the second would be a process that embodies a linear raise to threshold which decides the existence of an entire object that requires a response. In the same vein, it has been proposed (Huk & Shadlen, 2005) that decision making is not an all-or-none process but is related with a temporal integration of information until a decision is taken. Importantly, the authors highlighted that such integration does not hold for all visual tasks: In simple detection tasks, linear accumulation of signal plus variance is often restricted to very short durations, under 80 ms (Watson, 1984).

To recapitulate, we have tested the reorienting hypothesis about IOR, which propose that inhibition of return consists of the inhibition of the return of attention to previously attended locations. This hypothesis predicts no IOR effect until attention is disengaged from the cued location. We have reported evidence that IOR can be observed at a location where endogenous attention is oriented to, and therefore no reorienting is necessary. Furthermore, we have shown that even after endogenous attention is removed from the cued location (in discrimination tasks) no IOR is observed. Thus, we have shown that the endogenous disengagement of attention from the cued location is neither sufficient nor necessary in order to observe IOR. Therefore, perceptual consequences of peripheral cuing (which might be considered as spatial priming) should be dissociated from its role in orienting attention.

Chapter III

Effects of endogenous and exogenous attention on early and late stages of visual processing

Chapter III.I.

Effects of endogenous and exogenous attention in perceptual sensitivity and response criterion

The content of this chapter has been submitted as Chica, A. B., Charras, P., & Lupiáñez, J. (submitted-a). Effects of endogenous and exogenous attention in perceptual sensitivity and response criterion.

ABSTRACT

Converging evidence has shown that exogenous attention affects early perceptual stages (such as feature binding, Briand & Klein, 1987; or stimulus enhancement, Lu & Dosher, 1998), while endogenous attention produces effects in later perceptual processes (such as external noise reduction, Lu & Dosher, 2005) or decisional stages of processing (Klein & Shore, 2000). However, very recently, Prinzmetal and cols. (2005) have argued that endogenous attention produces signal enhancement, while exogenous attention affects response selection. Using the Signal Detection Theory (SDT), the present experiment explores this recent controversy. Our results showed that both exogenous and endogenous attention increase perceptual sensitivity, but independently of each other and with a different time course. Endogenous attention also produced further effects on response criterion. Our findings challenge those of Prinzmetal et al., but are consistent with the claims of recent electrophysiological studies (Chica & Lupiáñez, under review; Hopfinger & West, 2006).

Introduction

There is a general consensus about the existence of two different attentional systems in the brain. One of these systems is involved in the exogenous orienting of spatial attention while the other one directs attention to locations in space endogenously (see Klein, 2004, for a review). Importantly, when the two attentional systems have been manipulated orthogonally, independent effects have been observed for exogenous and endogenous attention, no matter whether endogenous attention has been manipulated by either central predictive cues (Berger et al., 2005), instructions and non-predictive peripheral cues (Berlucchi et al., 2000), or instructions and predictive peripheral cues (Chica & Lupiáñez, 2004; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004).

Further evidence about the independence of the endogenous and exogenous attentional systems has been gained by exploring their differential effects on the processing of stimuli. For example, Lu & Dosher analysed the effects of endogenous and exogenous attention in perceptual tasks (see Lu & Dosher, 2005; for a review). In their studies, endogenous attention is oriented by a central cue while exogenous attention is drawn by a peripheral cue. They reported that both endogenous and exogenous attention excluded external noise, but only exogenous attention produced stimulus enhancement. It has also been shown that both exogenous (Hawkins, Hillyard, Luck, Mouloua et al., 1990; Theeuwes, Kramer, & Kingstone, 2004) and endogenous (Ciaramitaro, Cameron, & Glimcher, 2001) attention enhance perceptual sensitivity. Ciaramitaro and colleagues (who manipulated endogenous attention by varying within a block of trials the probability of the target location) argued that endogenous attention did not modulate later stages of processing related with response criterion measures. However, it is worth noting that two out of their four human participants in fact showed significant response criterion changes, which make their conclusion questionable.

Briand & Klein examined the role of endogenous and exogenous attention on visual perception, exploring the effect of both attentional systems in feature and conjunction visual search tasks (Briand, 1998; Briand & Klein, 1987). Endogenous attention was oriented using an informative central cue, while exogenous attention was oriented using either an informative peripheral cue (Briand & Klein, 1987) or a non-informative peripheral cue (Briand, 1998). In feature search tasks, the target could be discriminated from distractors by a single feature, while in conjunction search tasks the conjoining of features is necessary in order to find the target. In their studies, the effect of peripheral cues (both informative and non-informative) interacted on these search tasks, being larger in conjunction than in feature search tasks. However, there was no interaction between the search tasks when attention was drawn endogenously via central cues. Later on, Klein (1994) manipulated the frequency of a non-spatial feature of the target (e.g., the size) and found that the effect of endogenous attention interacted on the processing of these non-spatial expectancies, while the effect of exogenous attention was additive. Klein & Shore (2000) interpreted this double dissociation postulating that exogenous attention involved operations at early visual stages related with feature binding, while endogenous attention involved operations at decision stages.

All the results outlined above underline a common characteristic: exogenous attention seems to produce early effects on perception (stimulus enhancement, perceptual sensitivity, feature binding), while endogenous attention appears to have consequences on later perceptual (external noise reduction) or decisional stages of processing (response criterion, decisional stages). However, very recently, Prinzmetal et al. (2005) have argued that endogenous attention enhances the perceptual representation of the attended stimuli while exogenous attention affects the decision of where to respond. In their experiments, attention was always manipulated using a peripheral cue. The cue was spatially non-informative about the target location to measure the effects of exogenous attention, whereas it was made spatially informative about the target location to measure the effects of endogenous attention. Moreover, depending on the experiment, either accuracy or speed was emphasized. The authors assumed that accuracy experiments provide a measure of perceptual processes (signal enhancement), while RT experiments measure both perceptual and decisional processes (response selection). Their results demonstrated that endogenous attention modulated performance in both accuracy and RT experiments, whereas exogenous attention only affected performance in RT experiments. Thus, against a broad part of the previous literature, the authors proposed that endogenous attention modulates signal enhancement, while exogenous attention only affects later processes related to the decision of where to respond.

It is worth noting that Prinzmetal et al. (2005) used a spatially informative peripheral cue to orient attention endogenously to the cued location. These cues attract both endogenous and exogenous attention to the cued location, which makes it impossible to disentangle the effect of both systems in the final response observed (Posner et al., 1982). Thus, the final response measured at the endogenously attended location (the location of the cue) might be either the result of additive effects of both endogenous and exogenous attention, or might be the interaction between the effects of the two systems.

In order to avoid this potential confound we used a paradigm that, as stated above, has shown to be successful in providing evidence about the independence of endogenous and exogenous attention. More specifically, our paradigm uses a spatially informative peripheral cue that predicts, in different blocks of trials, that the target would appear at either the same or the opposite location to the cue. Using this manipulation, both endogenously attended (expected) and endogenously unattended (unexpected) locations can be either cued or uncued. In this design, expectancy about the target location is taken as a measure of endogenous orienting, while "cuing" or cue-target correspondence (i.e., same vs. opposite location) is taken as an index of exogenous attention. This allows us to isolate the effect of endogenous attention and cuing (exogenous attention) using the same visual stimulation, and thus equating the perceptual processes involved in the processing of the cue and target (Chica & Lupiáñez, 2004, under review; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004).

The aim of the present paper was to further explore the independence of the exogenous and endogenous attention mechanisms and, more importantly, to shed some light on the controversy regarding the stage (perceptual vs. decisional) at which endogenous and exogenous attention modulate target processing. The Signal Detection Theory (SDT) was used in order to test how exogenous and endogenous attention affected perceptual sensibility and response criterion. By combining SDT and our paradigm for testing the independence of endogenous and exogenous attention, we expected to be able to test whether the two attentional mechanisms produce their effect independently of each other, and at which stages of processing. Based on previous findings (Chica & Lupiáñez, under review; Chica et al., 2006), we predict expectancy and cuing to affect different stages of processing and in different moments in time (Müller & Rabbitt, 1989).

Methods

Participants. Thirty-two psychology students, from the University of Granada, took part in the experiment as part of a course requirement. Twenty-nine of the participants were female, 3 left handed, and with a mean age of 21 years.

Apparatus and materials. Groups of a maximum of 10 participants were seated in a dimly illuminated room. The participants were seated side by side in a row and dividers were used to prevent participants from seeing each other. Additionally, the experimenter was present during the whole session to control that participants concentrated on their task. E-prime software (Schneider et al., 2002) was used to control the presentation of stimuli, timing operations, and data collection. The fixation point consisted of a grey plus sign (6 x 6 mm). Two grey boxes (60 mm in width by 45 mm in height) were displayed to the left and right of fixation. As a cue, one of the boxes flickered by becoming white and thicker. The target consisted of a horizontal and a vertical line, forming an inverted “T”. The participants’ task was to press the “yes” key when the horizontal and the vertical line were judged similar in length, and to press the “no” key when one of the lines was judged longer than the other. The “z” and “m” key of the computer keyboard were used for responding and counterbalanced across participants. In a previous psychophysics experiment, using the method of constant stimuli, 3 critical lengths for the vertical line were calculated: The Point of Subjective Equality (PSE), the superior threshold, and the inferior threshold. The PSE corresponds to the value at which the comparison stimulus (in this experiment the vertical line) is deemed equal to the standard stimulus (the horizontal line). The superior threshold refers to the line length at which participants judged, on 75% of the trials, the comparison stimulus (vertical) larger than the standard line (horizontal). And the inferior threshold refers to the line length at which participants judged, on 75% of the trials, the comparison stimulus (vertical) shorter than the standard line. The horizontal line was always of the same standard length (19 mm), whereas the vertical one could take the value of either the PSE (14 mm), the superior threshold (17 mm) or the inferior threshold (11 mm)[4]. This method was used to ensure that participants made enough errors and false alarms for the calculation of d' and beta. The PSE was used as the "signal" for the Signal Detection Theory (SDT, Green & Swets, 1966), while both the superior and the inferior thresholds were used as the "noise". Thus, hits consisted of responding "equal length" for the PSE stimulus and correct rejections consisted of responding "non-equal length" for the superior and inferior threshold. False alarms consisted of responding "equal length" for the superior and inferior threshold, and misses consisted of responding "non-equal length" for the PSE.

Visual feedback was provided when an anticipatory response occurred or when no response was detected (the words "*Anticipación*" -"anticipation" in Spanish-, and "*No respuesta*" –"no response", respectively, were presented on the computer screen for 500 ms). No feedback was presented for correct or incorrect responses.

Procedure. The sequence of events in a given trial can be observed in Figure 10.

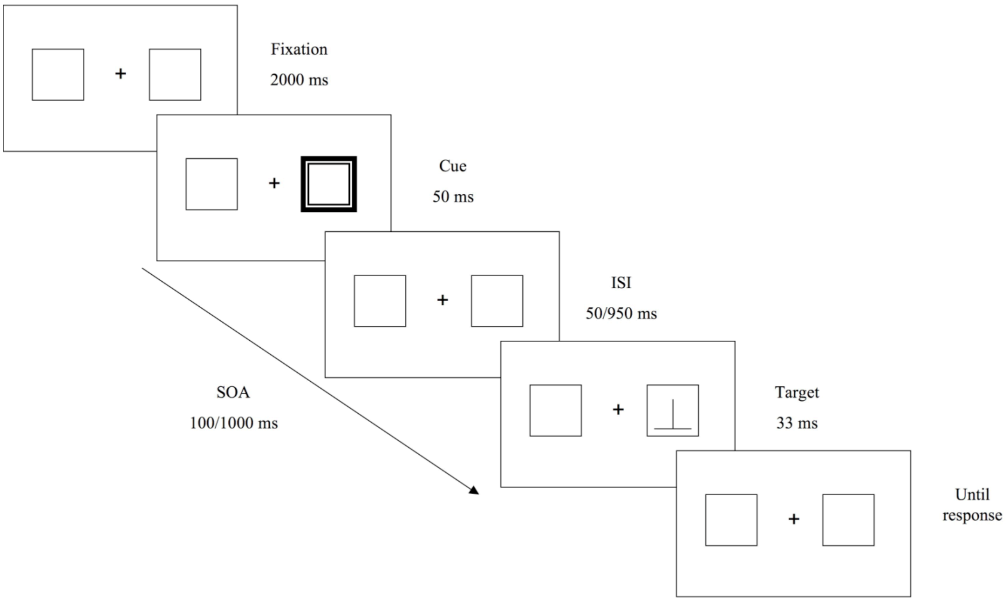


Figure 10. Sequence of events in a given trial. Participants judged whether the lines were equal in length. Speed was not emphasized and the next trial did not start until a response was detected.

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[4] Note that the vertical line is perceived as longer than its actual length in this configuration. This is known as the Horizontal-Vertical Illusion (Fick, 1851; Kunnapas, 1955).

There were two blocks of trials. In one of them, the cue predicted that the target would appear at the same location as the cue on 75% of the trials. When the target was presented at the same spatial location as the previous peripheral cue (on 75% of trials), these were expected location trials (because the target appeared at the location predicted by the cue) and cued location trials (because the cue and target were presented at the same spatial location). However, on the remaining 25% of trials of this block, the target was presented at the opposite location to the cue. These were unexpected location trials (because the cue predicted the target to appear at the opposite location), and also uncued location trials (because the cue and target appeared at different locations). In the other block of trials, the cue predicted the target to appear at the opposite location to the cue on 75% of the trials. Thus, when the target appeared at the opposite location to the cue, these were expected location trials but uncued location trials. However, when the target appeared at the same location as the cue (on the remaining 25% of trials of this block), these were unexpected and cued location trials. Participants were instructed as to whether the cue would predict either the same or opposite target position on the majority of trials (although they were not informed about the exact cue validities), and were encouraged to take this information into account. The order of presentation of the blocks was counterbalanced across participants.

Each of the two blocks consisted of 256 experimental trials, preceded by 16 practice trials each. For each experimental condition of Expectancy, Cuing and SOA, there were 32 observations for unexpected location targets and 96 observations for expected location targets, for each condition of signal (PSE) and noise (superior threshold and inferior threshold). Three different dependent measures were analyzed: d’, Beta, and RT.

Results

Three participants were eliminated from the analysis because their mean d’ was below 0. **Mean d’** data from the remaining 29 participants were submitted to a repeated measures analysis of variance (ANOVA) with the factors of expectancy, cuing, and SOA, as within participant factors. The analysis revealed a significant main effect of expectancy, *F*(1, 28)=13.36, *MSE*=0.29, *p*=.001, showing that d’ was higher for targets presented at the expected location versus the unexpected location. The main effect of cuing only approached significance, *F*(1, 28)=3.04, *MSE*=0.28, *p*=.093, d’ being larger for targets presented at the cued versus the uncued location. The main effect of SOA was also significant, *F*(1, 28)=13.38, *MSE*=0.26, *p*=.001, showing that perceptual sensitivity was enhanced at the long SOA as compared to the short SOA. However, both the expectancy and cuing effects critically depended on the SOA condition, as shown by the interactions expectancy x SOA, and cuing x SOA, *F*(1, 28)=8.78, *MSE*=0.37, *p*=.006, and *F*(1, 28)=4.04, *MSE*=0.34, *p*=.054, respectively. Planned comparisons revealed that the expectancy effect on d' was significant at the long SOA, *F*(1, 28)=15.26, *MSE*=0.46, *p*<.001, but not at the short SOA, *F*<1. The cuing effect, however, was only significant at the short SOA, *F*(1, 28)=11.12, *MSE*=0.20, *p*=.002, but not at the long SOA, *F*<1 (see Figure 11). None of the other interactions were significant.

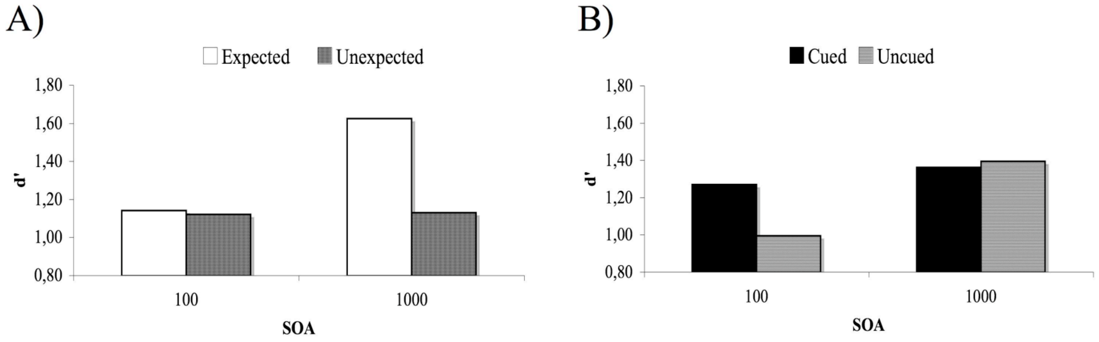


Figure 11. Mean d' values for targets presented at the expected and the unexpected location, expectancy effect (A) and at the cued and the uncued location, cuing effect (B), for each SOA condition.

A similar analysis of **response criterion data** (mean beta values) revealed a main effect of expectancy, *F*(1, 28)=5.97, *MSE*=3.10, *p*=.021. Participants adopted a more lenient criterion to respond to targets presented at the expected location versus the unexpected location (see Figure 12A). The interaction between expectancy, cuing, and SOA was marginally significant, *F*(1, 28)=3.69, *MSE*=3.60, *p*=.065. As can be observed in Table 7, the expectancy effect just described was observed for all conditions of cuing and SOA but reversed at the long SOA in cued trials. Neither the main effect of cuing nor the interaction between cuing and SOA were significant, *F*<1, and *F*(1, 28)=1.70, *MSE*=2.70, *p*=.20, respectively (see Figure 12B). None of the other main effects or interactions were significant.

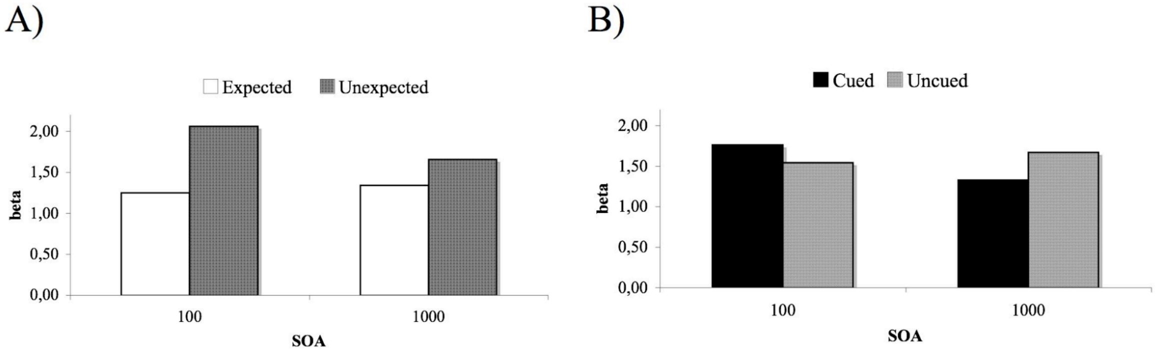


Figure 12. Mean beta values for targets presented at the expected and the unexpected location, expectancy effect (A) and at the cued and the uncued location, cuing effect (B), for each SOA condition.

Finally, although **RT** was not emphasized, it was also analysed to explore any speed-accuracy trade-off that might have occurred. Trials with RTs faster than 200 ms were considered outliers and removed from the analyses. Incorrect responses were also eliminated from the RT analysis. The ANOVA revealed a main effect of expectancy, $F(1, 28)=26.64$, $MSE=9005$, $p<.001$, RTs being faster when the targets were presented at the expected versus the unexpected location. Responses were also faster at the cued versus the uncued location, as indicated by the main effect of cuing, $F(1, 28)=6.06$, $MSE=2670$, $p=.020$. The main effect of SOA was also significant, $F(1, 28)=25.55$, $MSE=3919$, $p<.001$, with faster RTs at the longest SOA. Consistent with the d’ and beta analysis, the interaction between expectancy and SOA was significant, $F(1, 28)=26.66$, $MSE=2918$, $p<.001$, showing that the expectancy effect was larger at the longest SOA (see Figure 13A). Finally, the interaction between cuing and SOA was also significant, $F(1, 28)=27.40$, $MSE=3395$, $p<.001$, revealing a significant facilitatory effect at the short SOA, $F(1, 28)=32.41$, $MSE=2882$, $p<.001$, and a significant IOR effect at the long SOA, $F(1, 28)=4.96$, $MSE=3183$, $p=.034$ (see Figure 13B). None of the other interactions were significant.

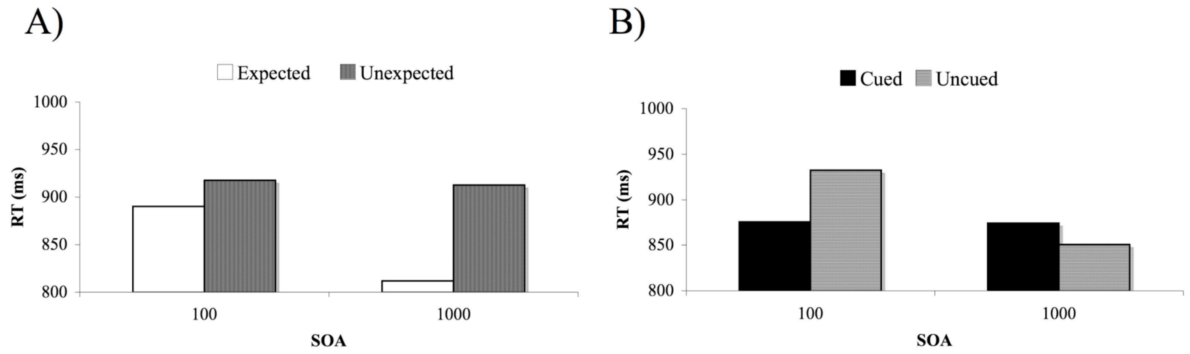


Figure 13. Mean correct RT data (in ms) for targets presented at the expected and the unexpected location, expectancy effect (A) and at the cued and the uncued location, cuing effect (B), for each SOA condition.

Table 7. Mean d', beta and correct RT values as a function of SOA, expectancy and cuing.

	Perceptual sensitivity (d')			
SOA	100		1000	
	Expected	Unexpected	Expected	Unexpected
Cued	1,27	1,27	1,61	1,11
Uncued	1,01	0,98	1,64	1,15

	Response criterion (beta)			
SOA	100		1000	
	Expected	Unexpected	Expected	Unexpected
Cued	1,27	2,25	1,56	1,09
Uncued	1,22	1,86	1,12	2,22

	RT (in ms)			
SOA	100		1000	
	Expected	Unexpected	Expected	Unexpected
Cued	855	896	817	931
Uncued	925	940	806	895

General Discussion

The aim of the present experiment was to further investigate the independence of the exogenous and endogenous attentional mechanisms, and go a step further in our understanding of the way they modulate processing, by elucidating the recent controversy about the differential effects of endogenous and exogenous attention on early-perceptual vs.

later-decisional stages of processing. Converging evidence has shown that exogenous attention produced its effects at early-perceptual stages while endogenous attention produced further effects on later perceptual and decisional stages (see e.g., Ciaramitaro et al., 2001; Klein & Shore, 2000; Lu & Dosher, 2005). However, Prinzmetal et al. (2005) have recently argued that endogenous attention produces signal enhancement, while exogenous attention affects the decision of where to respond. As discussed in the Introduction, Prinzmetal et al.'s experiments used a spatially non-informative peripheral cue to attract attention exogenously, and a spatially informative peripheral cue to direct attention to the cued location endogenously. Thus, it is important to note that their dissociation between endogenous (or voluntary) and exogenous (or involuntary) attention is in fact a dissociation between predictive and non-predictive peripheral cues. However, it seems reasonable to argue that informative cues attract both endogenous and exogenous attention, making it impossible to disentangle the effects of endogenous and exogenous attention to the final response observed.

In order to avoid this confound, we have used a paradigm that allows us to isolate the effects of endogenous and exogenous attention while using the same visual stimulation. This paradigm has been successful to show that exogenous attention (peripheral cueing) and endogenous attention (spatial expectancy) can produce their effects independently of each other (Chica & Lupiáñez, 2004; Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004). The present research has also showed a general independence between the effects of our manipulations of exogenous and endogenous attention (specially for the TR and d' measures). More importantly for the main aim of our research, our results have shown that both endogenous and exogenous attention modulated perceptual sensitivity, but in very different ways and independently of each other. The effect of exogenous attention appeared early in time and was short lasting, while the effect of endogenous attention was only observed at longer time intervals, thus reflecting the usual differences in time course between exogenous and endogenous orienting (Funes et al., 2007; Müller & Rabbitt, 1989).

Furthermore, endogenous attention also modulated later stages of processing related with changes in response criterion. In particular, a more lenient response criterion was generally adopted to respond when the target appeared at the expected location as compared with unexpected location targets. However, at long SOAs the effect of endogenous attention was modulated by exogenous attention, reversing the expectancy effect at cued location trials: The response criterion became more conservative for expected-cued targets than for unexpected-cued targets. This modulation of exogenous cuing might be related to the IOR effects observed at long SOAs in the RT analysis, which can produce perceptual uncertainty to detect the target (Lupiáñez, Ruz et al., 2007; Milliken et al., 2000). This interpretation is consistent with Hawkins et al.'s study (1990). They used a spatially informative peripheral cue and found both perceptual sensitivity and response criterion modulations. They postulated that the appearance of the cue might have produced a perceptual confusion in the brain, mistaken the onset of the cue with the onset of the target. In fact, when endogenous attention was manipulated using a central cue instead of a peripheral cue, no effects on decision criterion were found.

The modulation of exogenous and endogenous attention that we have reported here is also consistent with recent electrophysiological studies. Hopfinger & West (2006) used a central cue to direct attention to one of the peripheral locations. A spatially non-informative peripheral cue was then presented, followed by the target. They showed that exogenous attention (facilitation) modulated early stages of processing, in particular the late phase of the P1 component. In contrast, endogenous attention modulated both early (the occipito-parietal N1 component) and late (the P3 component) stages of processing. Using the same paradigm as the one presented in this paper, Chica & Lupiáñez (under review) compared the modulation on early (P1/N1) and late (P3) stages of processing by endogenous and exogenous attention (in this case IOR instead of facilitation). Our results showed that IOR modulated both early and late stages of visual processing. Additionally, endogenous attention modulated late stages of processing, but did not produce a main effect on early stages. Moreover, endogenous and exogenous attention interacted in both Hopfinger & West and Chica & Lupiáñez studies, with the electrophysiological markers of facilitation and IOR being enhanced at the endogenously attended location.

The consequences of manipulating the SOA in our SDT experiment are also very interesting. In fact, RT was faster at the long SOA as compared to the short SOA, showing the usual increase in preparation, and reduction of temporal uncertainty (Niemi & Näätänen, 1981). This foreperiod effect was measured as shorter RTs but also increased d' at the long SOA, revealing that temporal expectancy not only affected speed but also lead to an enhancement in perceptual sensitivity. In contrast to the general hypothesis supporting the idea that temporal expectancies only concern motor preparation (Coull, Frith, Buchel, & Nobre, 2000), our results are in agreement with recent research using psychophysical (d';

Correa, Lupiáñez, & Tudela, 2005) and electrophysiological measures (P1; Correa, Lupiáñez, Madrid, & Tudela, 2006), showing an enhancement in perceptual processes at the expected temporal interval.

Our data, however, argue against Prinzmetal et al.'s (2005) results. They used a peripheral cue followed by a target at either a 0 ms SOA (simultaneous presentation of the cue and target) or a 300 ms SOA. In the accuracy experiments (Experiment 2: informative cue, and Experiment 4a: non-informative cue), the 0 ms SOA was characterized by more accurate responses at uncued locations (both endogenously and exogenously unattended) versus cued locations (attended locations). This result can be explained by a difficulty in detecting two events (the cue and the target) at the same location versus two events at opposite locations, when they are presented simultaneously (Lupiáñez & Weaver, 1998). At the 300 ms SOA, informative cues produced more accurate responses at endogenously attended versus endogenously unattended locations. However, exogenous attention did not produce any significant effects on accuracy (even when more participants were run with a 50 and a 150 ms SOA). We analysed the raw accuracy data of our experiment to compare them to that of with Prinzmetal et al., and found that exogenous attention enhanced perceptual sensitivity at the short SOA (100 ms; 68% and 64% correct responses respectively at the cued vs. the uncued location), $F(1, 28)=9.89$, $p<.01$, but not at the longer SOA (1000 ms), $F<1$. Moreover, in the block were the cue predicted the target to appear at the opposite (uncued) location, there was a significant interaction between cuing and SOA, $F(1, 28)=8.67$, $p=.008$. This interaction revealed the fact that when the SOA was short (and thus, there was no time to orient attention endogenously to the location opposite to the cue –the uncued location), accuracy was higher at cued versus uncued locations (68% and 65% correct responses respectively at the cued vs. the uncued location), $F(1, 28)=5.62$, $p=.027$. RTs were also faster at this cued location, $F(1, 28)=6.10$, $p=.022$, showing that there was no speed accuracy trade-off. At the long SOA, however, accuracy was higher for uncued locations, indicating that participants were able to orient their attention to that location endogenously, $F(1, 28)=6.04$, $p=.023$. In sum, both our d' and raw accuracy data have demonstrated that exogenous attention can produce an effect on perception, modulating both the accuracy to respond and perceptual sensitivity (as measured by d'). Importantly, the observed increased accuracy at the cued location is similar to the one observed with peripheral non-predictive cues and discrimination tasks (Lupiáñez et al., 1997).

In summary, the results of the present paper revealed that both endogenous and exogenous attention modulated perceptual sensitivity (although independently of each other and with a different time-course), while endogenous attention produced further effects on response criterion. Exogenous attention (IOR) also modulated the effect of endogenous attention in response criterion measured at the long SOA. These results provide additional evidence in relation to the different modulation of endogenous and exogenous attention on the processing of stimuli. The two attentional systems seem to be independent and mainly exert their modulation at different stages of processing. However, they surely work not in isolation but in a coordinate way, in order to provide coherent behaviour. One example of this coordinated working is the case of peripheral predictive (or counterpredictive) cues, where the effects of exogenous attention might be maintained longer in time by the endogenous system, or might be overridden by it in the case of counterpredictive cues. Therefore, when dissociating between endogenous (i.e., voluntary) and exogenous (i.e., involuntary) attention, further research should differentiate between the different way the two mechanisms are triggered (endogenous generations of expectancies vs. automatic activations of location and/or object representations), the different effects that the two mechanisms might have on information processing, and the way the two mechanisms might interact. Regarding this latter issue, and knowing that the two attentional systems do produce independent and different effects (Funes et al., 2007), the way endogenous attention might affect exogenous attention might be much more complex than redirecting attention to a different, expected location or maintaining attention at the location where exogenous attention has been automatically captured. Alternatively, one effect of endogenous attention might be to extend in time or enhance the effects of exogenous attention. It could be the case that Prinzmetal et al.'s results can alternatively be explained by endogenous attention to the cued location enhancing the exogenous effect produced by the cue, producing significant effects on accuracy experiments.

Chapter III.II.

Effects of endogenous and exogenous attention on visual processing: An Inhibition of Return study

The content of this chapter is under review as Chica, A. B. & Lupiáñez, J. (under review). Effects of endogenous and exogenous attention on visual processing: An Inhibition of Return study. *Journal of Cognitive Neuroscience.*

ABSTRACT

We investigate early (P1/N1) and late (P3) modulations of event-related potentials produced by endogenous (expected vs. unexpected location trials) and exogenous (cued vs. uncued location trials) orienting of spatial attention. A 75% informative peripheral cue was presented 1000 ms before the target in order to study inhibition of return (IOR; slower responses to peripherally cued versus uncued locations). Endogenous attention produced its effects more strongly at later stages of processing, while IOR (an index of exogenous orienting) was found to modulate both early and late stages of processing. The amplitude of P1 was reduced for cued versus uncued location trials, especially when endogenous attention was oriented to the location where the target would appear. This result indicates that the perceptual effects of IOR are not eliminated by endogenous attention, suggesting that IOR produces a perceptual decrement on the processing of stimuli at the cued location that cannot be counteracted by endogenous attention.

Introduction

Spatial attention can be oriented to a location in the visual space either exogenously (due to the salience of a given stimulus) or endogenously (via verbal instructions to attend to a spatial location or given the high probability of the target's appearance at that position). Recently, there has been a growing consensus that endogenous and exogenous orienting consist of two different attentional systems, with different effects on the processing of stimuli (Funes et al., 2007; Klein, 2004), as well as different neural substrates (Bartolomeo et al., 2001; Corbetta & Shulman, 2002; Kincade et al., 2005).

The Posnerian cuing paradigm (Posner, 1980) has became a very useful tool to study both endogenous and exogenous orienting. Exogenous attention has been studied using spatially non-informative peripheral cues, which are supposed to capture spatial attention automatically (Ruz & Lupiáñez, 2002; Yantis & Jonides, 1990). The use of spatially non-informative peripheral cues leads to two different effects in the detection of a subsequent target across time. If the target appears soon after the appearance of the cue, a facilitatory effect is observed, i.e., reaction times (RTs) are faster when the target appears at the same location as the cue (cued location) as compared to uncued locations. However, if the target appears after a longer cue-target interval, an Inhibition of Return (IOR) effect is observed (i.e., RT is slower for cued than uncued location trials, Posner & Cohen, 1984). We will use this terminology (cued vs. uncued location) to refer to exogenous orienting.

Although IOR has been considered a stimulus-driven effect, it has been consistently shown that the effect can be modulated by endogenous factors. Among them, the factor having a greater effect might be the task set: The size and time-course of IOR has been proved to depend on task's demands, with IOR being delayed in discrimination tasks as compared to detection tasks (Lupiáñez et al., 1997). IOR has been proposed to be a mechanism that inhibits attention to be reoriented to a previously attended location (Klein, 2000; Posner et al., 1985). After the initial attentional capture by the cue, attention is supposed to be disengaged from the cued location, and inhibited to return to that position. Thus, a later appearance of IOR is easily explained by a later disengagement of attention from the cued location, or a greater capture of attention by the cue (Klein 2000). This hypothesis, that we will call the *reorienting hypothesis,* is assumed by most researchers in the field, although it does not seem to accommodate some important findings of the literature (Berlucchi, 2006).

Supporting the *reorienting hypothesis*, IOR is not usually observed when the peripheral cue predicts the target to appear at that location (Cohen et al., 2005; Posner et al., 1982), RTs being faster at the cued than at the uncued location, even at long cue-target intervals. As explained by this hypothesis, when attention is not disengaged from the cued location (because the target is likely to be presented there), the mechanism producing the IOR effect is cancelled out and does not start to operate in the system. However, if we consider that exogenous and endogenous attention might be subserved by independent attentional systems, it is possible that the IOR mechanism is immune to endogenous orienting and IOR is not observed behaviourally because the endogenous orienting of spatial attention masks its effects. If IOR is not cancelled by endogenous attention but masked, its effects should be measured with techniques such as event-related potentials (ERPs).

Previous ERPs studies have investigated the modulation of different ERP components by both endogenous and exogenous attentional orienting. P1 and N1 components have been interpreted as a sensory gain mechanism that enhances perceptual processing of stimuli (Mangun, Hansen, & Hillyard, 1987). Supporting this interpretation, P1 and N1 modulations have been reported when attention was oriented endogenously by central cues (Doallo et al., 2005; Eimer, 1993; Luck, 1995; Mangun, 1995). Similarly, P1 modulations have also been reported when attention was oriented exogenously by peripheral uninformative cues, revealing an enhanced P1 for cued versus uncued location trials at short stimulus onset asynchronies, SOAs (i.e., facilitatory effects, Hopfinger & Mangun, 1998) or a reduced P1 for cued versus uncued location trials at longer SOAs (Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999; Prime & Ward, 2004, 2006; Wascher & Tipper, 2004). Some other studies have used informative peripheral cues to endogenously orient spatial attention. These studies have found an enhanced P1 for cued trials (where the target was more likely to appear) versus uncued trials (where the target was less likely to appear), at least when the SOA was shorter than 500 ms (Doallo et al., 2004, 2005). However, note that this modulation could be due to endogenous attention, given the predictability of the cue, and/or to exogenous attention being automatically drawn to the cued location, and/or to the combination of both.

In the present study, we aimed at investigating the ERP modulations of both endogenous and exogenous orienting of spatial attention. We have recently developed a paradigm in which both endogenous and exogenous orienting are manipulated using the same set of experimental stimuli (Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004). In this paradigm, an informative peripheral cue predicts (in different blocks of trials, although see Chica & Lupiáñez, 2004) that the target would appear at either the same or the opposite location to the cue. Using this paradigm, endogenous and exogenous orienting can be isolated, as both endogenously attended and unattended locations can be either cued or uncued. Similarly, both cued and uncued locations can be either endogenously attended or not (see Berger et al., 2005; Berlucchi et al., 2000; Hopfinger & West, 2006; Riggio & Kirsner, 1997, for similar results using different paradigms). At the same time, this paradigm might reveal interactions between the two attentional systems; even if they are proved to be independent, they can work in coordination to produce the final attentional effect. Our previous research has consistently demonstrated that exogenous orienting (i.e., facilitation and IOR) can be observed independently of endogenous orienting. For example, in a detection task, when a long enough SOA is used, IOR is observed at both endogenously attended (expected) and unattended (unexpected) locations. However, in a discrimination task, IOR is observed at endogenously attended locations, but not at endogenously unattended locations (Chica et al., 2006). In the present experiment, we were especially interested in studying whether IOR, a critical marker of exogenous attention (which mainly produces P1 modulations, Hopfinger & Mangun, 1998; McDonald et al., 1999; Prime & Ward, 2004, 2006; Wascher & Tipper, 2004), would be observed at endogenously attended locations. According to the reorienting hypothesis, disengaging attention from the cued location is a necessary condition for the IOR mechanism to operate. However, if IOR is not eliminated but masked by endogenous attention, P1 should be reduced for cued versus uncued location trials (indexing IOR) even at endogenously attended locations. This result will indicate that attentional disengagement is not a necessary condition for IOR to emerge.

Finally, both detection and discrimination tasks were used in order to investigate the role of task set on both expectancy and cuing ERP modulations, as specially cuing effects have been shown to depend on task demands. Note that previous research has consistently shown that IOR not only appears later but it is also smaller in discrimination tasks than in detection tasks (Lupiáñez et al., 1997; 2001). It has been argued that the exogenous cue might capture attention in a greater degree in discrimination tasks as compared with detection tasks (Klein, 2000), or that, being attentional capture similar in detection and discrimination tasks, it behaviourally manifests more negatively (i.e., smaller facilitation and bigger IOR) in detection tasks than in discrimination tasks (Lupiáñez, Ruz et al., 2007). By using ERPs with both detection and discrimination tasks we might be able to test whether the modulation of exogenous cueing on the early ERP components (e.g. reduced P1 for cued versus uncued location trials), previously associated to IOR, and perhaps indexing smaller capture of attention by the target at the cued location, does depend on the task at hand.

Method

Participants. Twenty volunteers (mean age of 21 years, 4 males, and 1 left-handed), from the University of Granada, participated in the experiment for course-credits. All of them reported having normal or corrected to normal vision, and non-known neurological problems. The experiment was conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada.

Materials and procedure. The stimuli were presented on a 15-inch colour VGA monitor. An IBM compatible PC running e-prime software (Schneider et al., 2002) controlled the presentation of stimuli, timing operations, and behavioural data collection. The participants sat at approximately 57 cm from the monitor. At the beginning of each trial a fixation point (a plus sign) was displayed at the centre of the screen, on a black background. Two grey boxes (17 mm in height by 14 mm in width) were displayed to the left and right of fixation. The inner edge of each box was 77 mm from fixation. As the orientation cue, one of the boxes flickered (became thicker and turned white) for 50 ms, giving the impression of a brief flash.

The target was either the letter X or O, appearing at the centre of one of the boxes. A 500 Hz sound, 50 ms in duration, was used to provide response feedback.

The fixation point and two boxes were displayed at the beginning of each trial. The peripheral cue appeared for 50 ms after a random interval of 1000 to 1500 ms. After 950 ms (SOA of 1000 ms) the target was presented for 100 ms. If no response was made after 2000 ms or the wrong response was made, auditory feedback was provided for 50 ms. Auditory feedback was also provided for anticipatory responses. After the participant's response (or 2000 ms after the appearance of the target), an inter-trial interval of 750 ms duration was presented. During this interval the screen remained black.

On 20% of the trials (catch trials) no target was presented, and no response was required. On the remaining 80% of the trials a target was presented, and the participants were asked either to detect the target or to discriminate its identity (the participants' task was manipulated between sessions, half of the participants run the detection task first and the other half run the discrimination task first). In the detection task, participants were instructed to press the left bottom of the response box with their left hand (or the right one with their right hand, depending on the counterbalance condition), independently of the letter identity. In the discrimination task, the participants were asked to press the right key with their right hand for one of the letters, and the left key with their left hand for the other letter (the response-mapping was counterbalanced across participants in both tasks). Participants were encouraged to respond to the target as fast and as accurately as possible.

The experiment consisted of two blocks of trials. In one of them (predictive cue block), the cue predicted the likely position of target appearance (i.e., on 75% of the trials the target appeared at the same position as the cue). These were expected location trials (because the target appeared where the participants were expecting it to appear) and cued location trials (because the cue and target appeared at the same position). However, on the remaining 25% of the trials of this block, the target appeared at the opposite location to the cue. These were unexpected location trials (because the target appeared at the opposite position to that predicted by the cue) and uncued location trials (because the cue and target appeared at different locations). In the other block of trials (counter-predictive cue block), the cue predicted the target to appear at the opposite position on 75% of the trials. Thus, when the target was presented at the opposite position to the cue in this block of trials, these were expected but uncued location trials. However, when the cue and target were presented at the same position (25% of trials), these were unexpected but cued location trials. The order of blocks was also counterbalanced across participants. The participants were informed about the most likely location of target appearance (i.e., at the same or opposite location to the cue) at the beginning of each block of trials, and encouraged to take this information into account. All participants performed the detection and the discrimination task in different sessions. Each experimental session lasted for about 90 minutes, with the experimental task itself lasting 45 minutes.

Participants performed 7 predictive and 7 counterpredictive cue blocks, with 40 trials each. Each predictive and counter-predictive cue blocks consisted of 168 expected location trials, 56 unexpected location trials, and 56 catch trials. Each block was preceded by 20 practice trials.

Recording and analysis. The electroencephalogram (EEG) was recorded using a 128-channel Geodesic Sensor Net of Ag/AgCl electrodes (Tucker, Liotti, Potts, Russell, & Posner, 1994). The head-coverage included sensors lateral to and below both eyes, to monitor horizontal and vertical eye movements. Impedances for each channel were measured and kept below 50 KΩ before testing. All electrodes were referenced to the Cz electrode during the recording and were averaged re-referenced off-line. The EEG was amplified with a band pass of 0.1-100 Hz (elliptic filter) and digitized at a sampling rate of 250 Hz. EEG was filtered offline by using a 30 Hz low-pass filter, and then segmented in epochs from 200 ms before target appearance to 650 ms after the target presentation. All trials containing eye movements, blinks, or artefacts, as well as trials that did not meet behavioural performance criteria were rejected. A 200 ms segment previous to the target presentation was used to calculate the baseline.

Results

Behavioural results

Trials on which no response was made (misses; 0.29% of the total of trials in the detection task and 0.08 % of trials in the discrimination task) and false alarms (i.e., erroneous responses to catch trials; 0.29% of trials in the detection task and 0.04% of trials in the discrimination task) were eliminated from the data analysis. Trials on which a wrong key press was made in the discrimination task (3.42%) were also discarded from the RT analysis.

Finally, RTs faster than 200 ms or slower than 1200 ms (6.46% and 0.62% of trials in the detection and the discrimination task, respectively) were considered outliers and were eliminated from the RT analysis.

Table 8 shows the mean RT data for both tasks, and percentage of erroneous responses in the discrimination task, for each experimental condition of expectancy, and cuing. Mean RT data were submitted to a repeated-measures ANOVA, with the factors of task (detection vs. discrimination), expectancy (expected location trials vs. unexpected location trials), and cuing (cued location trials vs. uncued location trials). The main effect of task was significant, and revealed that RTs were overall 168 ms faster in the detection task than in the discrimination task, $F(1,19)=94.42$, $p<.001$. The main effect of expectancy was also significant, $F(1,19)=50.14$, $p<.001$. RTs were 22 ms faster when the target was presented at the expected location as compared to the unexpected location. The main effect of cuing also reached significance, $F(1,19)=28.85$, $p<.001$, revealing an IOR effect, i.e., longer RTs for responding to cued location trials versus uncued location trials (M=398 and 384 ms, respectively). Importantly, the task x cuing interaction was significant, $F(1,19)=27.60$, $p<.001$, whereas the task x expectancy interaction was not, $F<1$. Although larger RTs for cued versus uncued trials (i.e., IOR) were observed in both the detection and the discrimination task (mean cuing effect, i.e., mean RT for uncued minus cued location trials, of -22 and -4 ms, respectively), the IOR effect was significant in the detection task, $F(1,19)=62.24$, $p<.001$, but not in the discrimination task, $F(1,19)=2.26$, $p=.15$. Even though neither the interaction between expectancy and cuing nor the interaction between task, expectancy and cuing reached significance *(*$F(1,19)=1.49$, $p=.23$ and $F<1$, respectively), following previous research (Chica & Lupiáñez, 2004; Chica et al., 2006; Lupiáñez & Chica, submitted), more specific planned comparisons showed that IOR was significant at the expected location in both the detection and the discrimination task (both *p*s<.05). However, at the unexpected location, a trend towards IOR was observed in the detection task (mean cuing effect of –19 ms, $p=.14$), while a trend toward facilitation was observed in the discrimination task (mean cuing effect of 10 ms, $F<1$).

Table 8. Mean RT (in ms) in both the detection and discrimination task, and percentage of erroneous responses in the discrimination task –in parenthesis-, for each experimental condition of Expectancy and Cuing. The bottom row shows the mean cuing effect (uncued minus cued trials) for each expected and unexpected location in each task.

	Detection		Discrimination	
	Expected	Unexpected	Expected	Unexpected
Cued	309	327	473 (4.9%)	481 (3.9%)
Uncued	283	309	454 (4%)	491 (5.0%)
Mean Cuing effect	**-25**	**-19**	**-19** **(-0.9%)**	**10** **(1.1%)**

ERP results

P1, N1, and P3 components were analysed. The analysis included both the latency and the adaptive mean amplitude (20 ms before and after the higher peak for each subject in the designated time window) for electrodes ipsilateral and contralateral to the presentation of the target (central electrodes were also included in the P3 analysis) of each component. For the P1 and N1 analysis, electrodes 92 (P4) in the right hemisphere, and 59 (P3) in the left hemisphere, were used. For the P3 analysis, electrodes 53 (C3) in the left hemisphere, 87 (C4) in the right hemisphere, and 62 (Pz) in the centre, were used.

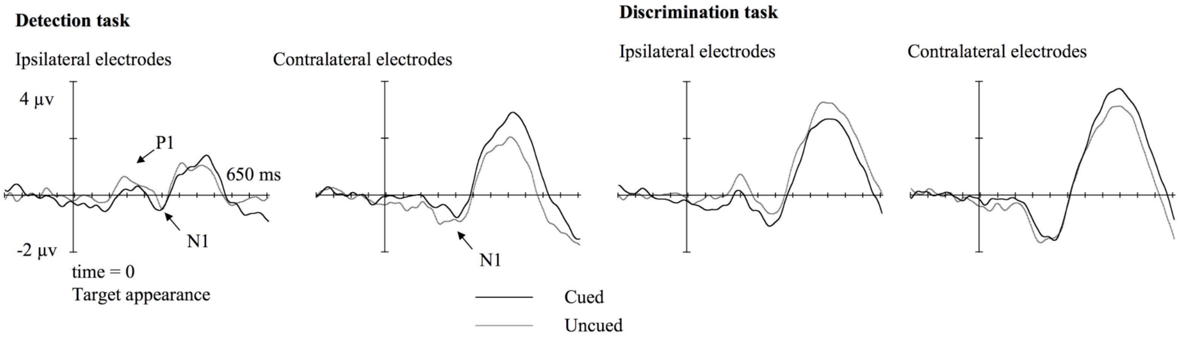
P1. The adaptive mean amplitude of P1 (150-250 ms) was submitted to a repeated-measures ANOVA with the factors of task (detection vs. discrimination), expectancy (expected vs. unexpected location trials), cuing (cued vs. uncued location trials), and laterality (ipsilateral vs. contralateral electrodes) as within participants factors. The main effect of task was significant, $F(1,19)=5.70, p=.027$, revealing an enhanced amplitude of P1 in the detection task versus the discrimination task. The main effect of laterality was also significant, $F(1,19)=17.04$, $p<.001$, and showed an enhanced amplitude of the component at ipsilateral versus contralateral electrodes. The main effect of cuing and the interaction between laterality and cuing were significant, $F(1,19)=4.68$, $p=.043$, and $F(1,19)=13.77$, $p=.001$, respectively. These results revealed a significant IOR effect (i.e., reduced P1 for cued versus uncued trials) at ipsilateral electrodes, $F(1,19)=24.08$, $p<.0001$ (see Figure 14A). However, neither the expectancy effect nor the interaction between expectancy and laterality reached significance, both *F*s<1 (see Figure 14B). Mimicking behavioural results, at ipsilateral electrodes, P1 was reduced at cued versus uncued location trials (i.e., IOR was observed) when the target appeared at an expected location in both the detection, *F*(1,19)=12.39, *p*=.002, and the discrimination task, *F*(1,19)=11.70, *p*=.003 (see Figure 15A). However, at unexpected locations no P1 modulation was observed in either task, *F*(1,19)=1.73, *p*=.20, and *F*(1,19)=1.02, *p*=.32, for the detection and the discrimination task, respectively (Figure 15B).

A similar analysis of latency effects revealed a main effect of laterality, *F*(1,19)=19.29, *p*<.001, with the peak latency of the P1 component being 12 ms delayed for ipsilateral electrodes as compared with contralateral electrodes. The main effect of task was also significant, *F*(1,19)=4.43, *p*=.049, P1 appeared 5 ms before in the discrimination task than in the detection task. None of the other main effects or interactions were significant.

In summary, these results reveal that exogenous attention (IOR) modulates the amplitude of P1 when attentional orienting is measured using an informative peripheral cue. Importantly, IOR (reduced amplitude of the P1 component for cued versus uncued location trials) is observed at endogenously attended locations, suggesting that the peripheral cue produced a decrement in perceptual sensitivity that could not be counteracted by the endogenous orienting of spatial attention. Additionally, endogenous attention seems to interact with exogenous attention in the modulation of early perceptual processes, as IOR was enhanced at expected locations as compared to unexpected locations. This interaction is consistent with the recently published paper by Hopfinger & West (2006) that would be more extensively discussed in the General Discussion.

Note that the effect on P1 was observed at ipsilateral parietal electrodes in the present study. Previous literature on P1 and IOR presents non-concluding data on the lateralization and topographical location of the effect. As can be observed in Table 9, it seems that the P1 reduction associated with IOR is more likely ipsilateral, and has been found both at occipital and parietal electrodes, although it is still unresolved whether different manipulations can give rise to a different lateralization and topographical localization of the effect.

A) Cuing effect



B) Expectancy effect

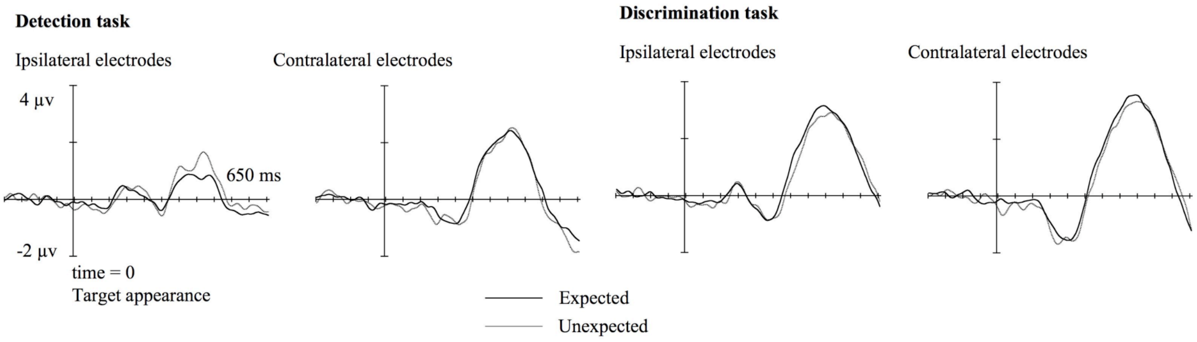
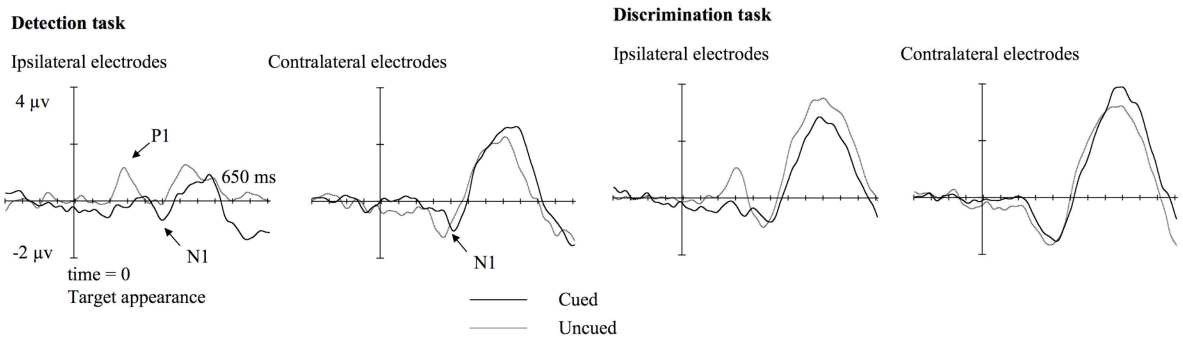


Figure 14. Mean target-locked ERPs waveforms for cued and uncued trials (A) and expected and unexpected trials (B) in the P1 and N1 analysis.

A) Cuing effect at the expected location



B) Cuing effect at the unexpected location

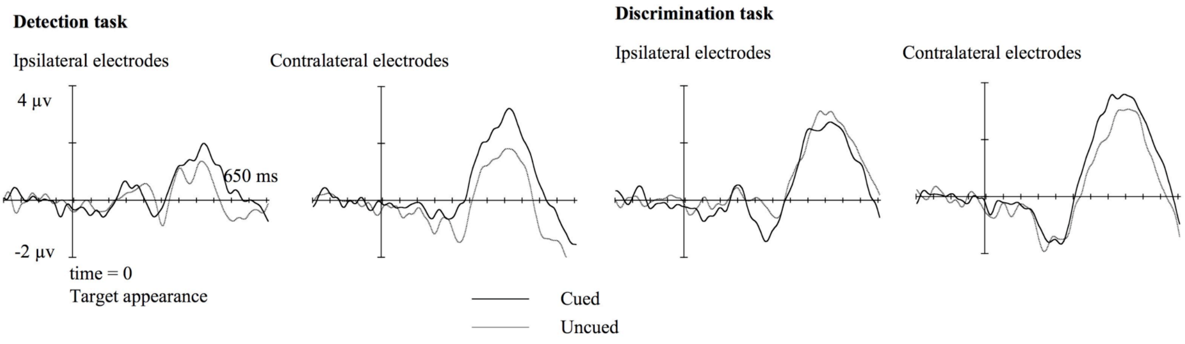


Figure 15. Mean target-locked ERPs waveforms for cued and uncued trials when the target appears at the expected location (A) and the unexpected location (B) in the P1 and N1 analysis.

Table 9. Summary of the lateralization and topographical localization of P1 effects related to IOR in the present and previous studies.

Study		**Lateralization**	**Topographical localization**
Present study		Ipsilateral	Parietal
Hopfinger & Mangum	No significant behavioural IOR	Contralateral	Occipital
McDonald et al.		Ipsilateral	Occipital & Parietal
Prime & Ward, 2004, 2006	Stimuli above and below fixation	Localization task: lateralized right hemisphere	Occipito-parietal
Wascher & Tipper		Ipsilateral	Parietal

N1. The adaptive mean amplitude data from N1 (200-300 ms) was submitted to a repeated-measures ANOVA with the factors of task (detection vs. discrimination), expectancy (expected vs. unexpected location trials), cuing (cued vs. uncued location trials), and laterality (ipsilateral vs. contralateral electrodes). The main effect of task was significant, $F(1,19)=7.98$, $p=.011$, revealing an enhanced N1 amplitude in the discrimination task as compared with the detection task, which is consistent with previous literature showing that N1 is associated with discrimination processes (Vogel & Luck, 2000). The main effect of laterality was also significant, $F(1,19)=9.41$, $p=.006$, and showed that the component was enhanced at contralateral versus ipsilateral electrodes. The interaction between cuing and laterality was significant, $F(1,19)=9.52$, $p=.006$, revealing a reduced N1 amplitude for cued versus uncued trials at contralateral electrodes, $F(1,19)=9.89$, $p=.005$ (see Figure 14A). The interaction between task, expectancy and cuing was significant, $F(1,19)=5.53$, $p=.030$, and marginally interacted with laterality, $F(1,19)=3.79$, $p=.066$. It is important to remember here that the behavioural data of this experiment showed that at expected locations, IOR was observed in both tasks, while at unexpected locations, a trend towards IOR was observed in the detection task, while a tendency to facilitation was observed in the discrimination task. Planned comparisons revealed that in expected location trials, at ipsilateral electrodes the N1 modulation was marginally different in both tasks, $F(1,19)=3.64$, $p=.071$. N1 seems to be reduced for uncued versus cued trials in the detection task but not in the discrimination task (see Figure 15A). This reduced amplitude of N1 for uncued trials in the detection task might be due to overlap from the positivity of P1. No differences were found at contralateral electrodes. At unexpected locations, the N1 modulation was significantly different in the detection and the discrimination task at ipsilateral electrodes, *F*(1,19)=5.40, *p*=.031. N1 was enhanced for cued versus uncued trials in the discrimination task (revealing a facilitatory effect) but not in the detection task. No differences between tasks were found at contralateral electrodes, *F*(1,19)=1.68, *p*=.211 (see Figure 15B).

A similar analysis of the latency effects revealed that, apart from the main effect of laterality, *F*(1,19)=39.64, *p*<.0001, the only significant effect was the interaction between expectancy and laterality, *F*(1,19)=6.41, *p*=.020, revealing that N1 was delayed in unexpected versus expected trials at ipsilateral electrodes, although the opposite was true at contralateral electrodes. However, none of the effects reached statistical significance (both *p*s=.11).

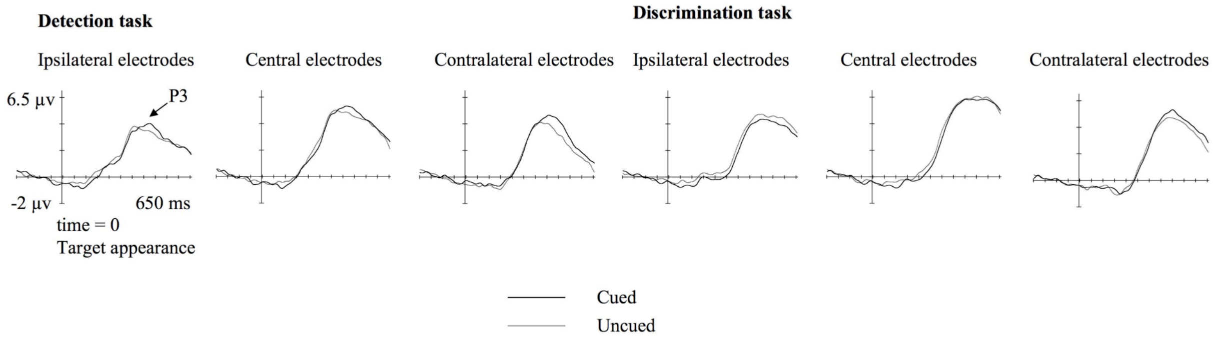
Just as the P1 results found, the results observed (reduced N1 for cued versus uncued trials at contralateral electrodes) suggest that IOR produces perceptual consequences that cannot be counteracted by the endogenous orienting of spatial attention. The N1 modulation might also be a correlate of the behavioural interaction observed between expectancy and cuing depending on the task at hand. Particularly, for unexpected targets, a trend toward IOR was observed in the detection task while a trend toward facilitation was observed in the discrimination task.

P3. The adaptive mean amplitude data from the P3 component (350-500 ms) were also submitted to a repeated-measures ANOVA, with the factors of task (detection vs. discrimination), expectancy (expected vs. unexpected location trials), cuing (cued vs. uncued location trials), and laterality (central, ipsilateral, and contralateral electrodes). The main effect of laterality was significant, *F*(2,38)=16.26, *p*<.001, and showed that the amplitude of the P3 component was enhanced at central electrodes as compared to ipsilateral and contralateral electrodes. The main effect of expectancy was also significant, *F*(1,19)=12.38, *p*=.002, revealing that the amplitude of P3 was .10 µv reduced for expected trials as compared to unexpected trials. The interaction between expectancy and laterality was significant, *F*(2,38)=5.73, *p*=.007, showing that the reduced P3 for expected versus unexpected trials was observed at ipsilateral and central electrodes (both *p*s<.001), but not at contralateral electrodes, *F*(1,19)=2.18, *p*=.156 (see Figure 16B). The interaction between task and expectancy was marginally significant, *F*(1,19)=4.10, *p*=.057, showing that the expectancy effect was larger in the detection task than in the discrimination task (see Figure 16B). The three-way interaction between expectancy, task and laterality was also marginally significant, *F*(1,19)=3.15, *p*=.054, and revealed that the expectancy effect was larger at ipsilateral and central electrodes in the detection task, while it was larger at central electrodes in the discrimination task. Importantly for the purposes of this study, the main effect of cuing was also significant, *F*(1,19)=11.11, *p*=.003, showing a .27 µv enhanced P3 amplitude for cued as compared to uncued trials. The cuing effect also interacted with laterality, *F*(2,38)=7.69, *p*=.002, with the P3 amplitude being increased for cued versus uncued location trials at central and contralateral electrodes (see Figure 16A). It is worth noting here that the cuing effect at ipsilateral and central electrodes resembles the behavioural task x cuing interaction. P3 was differentially modulated in both tasks, *F*(1,19)=5.40, *p*=.031. P3 was enhanced in cued versus uncued location trials in the detection task but not in the discrimination task.

A similar analysis of the latency of P3 revealed a significant main effect of laterality and task, *F*(2,38)=9.21, *p*<.001, and *F*(1,19)=14.03, *p*=.001, respectively. The latency of P3 was 35 ms delayed in the discrimination task as compared to the detection task. The task x laterality interaction was significant, *F*(1,19)=8.57, *p*<.001, and showed that the delayed latency of P3 in the discrimination task as compared with the detection task was larger at ipsilateral electrodes. The main effect of cuing was marginally significant, *F*(1,19)=3.90, *p*=.063, P3 latency being 6 ms delayed for cued versus uncued location trials (thus showing an IOR effect). Finally, the interaction between cuing and laterality was significant, *F*(1,19)=4.05, *p*=.026, revealing that the cuing effect was only significant at contralateral electrodes, *F*(1,19)=13.53, *p*=.002.

From the present results, it can be concluded that the P3 component was modulated by both endogenous and exogenous (IOR) attention. Additionally, the modulation of P3 at ipsilateral electrodes resembled the behavioural interaction found between cuing and task.

A) Cuing effect



B) Expectancy effect

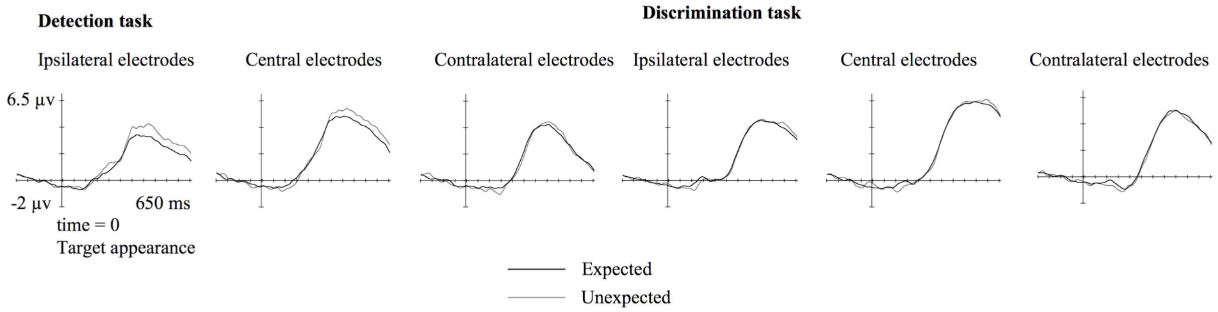


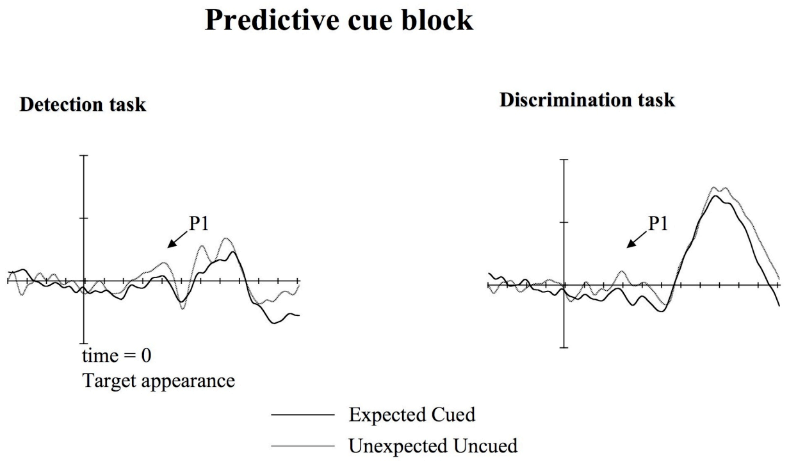
Figure 16. Mean target-locked ERPs waveforms for cued and uncued trials (A) and expected and unexpected trials (B) in the P3 analysis.

General Discussion

One of the major aims of the present research was to study the modulation of different ERP components by the endogenous and exogenous orienting of spatial attention. Attention was oriented by means of an informative peripheral cue that predicted, in different block of trials, that the target would appear at either the same or the opposite location to the cue (Chica et al., 2006; Chica et al., 2007; Lupiáñez et al., 2004). Using this paradigm, endogenous and exogenous attention can be isolated, as both expected and unexpected locations can either be cued or uncued, and both cued and uncued locations can either be expected or unexpected. This paradigm also allows us to study the possible interactions between endogenous and exogenous attention. Previous research using this or similar paradigms has shown independence between the behavioural effects produced by endogenous and exogenous attention (Lupiáñez et al., 2004; Riggio & Kirsner, 1997). Additionally, IOR has been consistently observed at endogenously attended locations (Berger et al., 2005; Berlucchi et al., 2000; Chica & Lupiáñez, 2004; Chica et al., 2006; Lupiáñez & Chica, submitted). In the present experiments, we went a step further to study the level of processing at which IOR produce its effects at both endogenously attended (expected) and unattended locations. By using ERPs, we were able to investigate the IOR effect at sensorial levels of processing (P1/N1) and later stages of processing (P3). Importantly, once this goal was achieved, we were especially interested in testing whether endogenous attention would cancel IOR (as predicted by the reorienting hypothesis), thus eliminating the previously reported reduction of P1 on cued versus uncued trials related to IOR (Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999; Prime & Ward, 2004, 2006; Wascher & Tipper, 2004), or will only mask its effects on performance by counteracting the effect at later stages of processing. If the endogenous disengagement of attention is not necessary to produce IOR, its electrophysiological marker (P1 reduction for cued versus uncued location trials) should be observed even when participants are certain about where the target would appear.

The behavioural results revealed significant expectancy and cuing effects. Participants responded more rapidly to targets appearing at the expected location than at the unexpected location, showing that endogenous attention was oriented at the 1000 ms SOA used. Regarding cuing effects, IOR (slower RTs for cued versus uncued trials) was significantly observed when the target appeared at the endogenously attended location. Crucially, the analysis of ERP components revealed that at this expected location, the amplitude of P1 was diminished for cued versus uncued trials (showing an IOR effect) in both the detection and the discrimination task. Thus, it seems clear that endogenous attention does not eliminate the effect of IOR on early perceptual stages. Knowing where the target is going to appear cannot override the perceptual impairment produced by the previous appearance of a cue at the same location as the target.

In order to further study the influence of endogenous attention on IOR, a further analysis was performed in the predictive cue block. In this block, the target appears at the same location as the cue in most of the trials. In our detection task, RTs were equally faster for cued versus uncued trials, $F<1$. This absence of an expectancy effect (faster RTs for cued-expected than for uncued-unexpected location trials) might be due to IOR producing faster responses at the uncued location, and thus counteracting the behavioural manifestation of endogenous attention. In the discrimination task, RTs were faster for cued-expected than for uncued-unexpected location trials, $F(1,19)=11.57$, $p=.003$, revealing a significant expectancy effect. These RT results are always ambiguous to interpret, as it is not possible to disentangle the contribution of expectancy and cuing to the result observed. The relevant question here is: What would happen with the physiological marker of IOR in a situation like that? Would IOR be eliminated when endogenous attention is oriented to the cued location, or would it just be masked in the RT? Interestingly, the analysis of the ERPs shows that P1 was actually diminished at ipsilateral electrodes for cued trials as compared to uncued trials in both the detection and the discrimination task, $F(1,19)=7.39$, $p=.014$, and $F(1,19)=6.55$, $p=.019$, respectively (see Figure 17). Thus, even when the cue predicted the same location of target appearance, IOR (reduced P1 amplitude for cued versus uncued trials) was observed. Note that in the discrimination task, RTs were actually faster at cued versus uncued trials. However, P1 was diminished for cued trials, revealing that IOR has emerged, and the behavioural advantage for cued vs. uncued trials was a consequence of later, decisional processes. This result is consistent with previous literature. For example, Wascher & Tipper (2004) showed that although IOR was not behaviourally observed when a cue was presented until the moment of target appearance, P1 was reduced for cued vs. uncued trials in the same manner than it was when the cue was transiently presented, and IOR was behaviourally observed. Hillyard, Luck, & Mangun (1994) also used an informative peripheral cue and found no P1 modulations at long SOAs, accompanied by a facilitation on RT. Mangun (1995) suggested that this absence of IOR on ERPs was due to two competing influences of endogenous and exogenous (IOR) attention with opposite effects. Additionally, although the authors did not give much theoretical importance to the finding, Doallo et al. (2004) used a peripheral cue predicting the same location of target appearance, and observed that P1 was reduced for cued versus uncued trials at a 500 ms SOA. Therefore, IOR (exogenous attention) seems to modulate perceptual processes more strongly than endogenous attention does. However, the present results also showed that endogenous attention modulated the effect of exogenous attention, because IOR was enhanced at endogenously attended locations. In the detection task, behavioural IOR was not significant at unexpected locations, while in the discrimination task a non-significant facilitatory effect was observed. Our previous research using this paradigm has shown significant IOR effects at both expected and unexpected locations in detection tasks (Chica & Lupiáñez, 2004; Chica et al., 2006). In our previous experiments, the task factor was always manipulated between groups of participants. The fact that IOR was reduced at the unexpected location in the detection task in the present experiment might be due to the within participants manipulation of the task factor in the present design. In fact, IOR was significantly smaller when the discrimination task was run first, $F(1,18) =7.10$, $p=.016$ (see also Squella & Ribeiro-Do-Valle, 2003). More research will be needed in order to explore how previous task sets adopted during the task at hand, influence the relationship between endogenous and exogenous attention.



<u>Figure 17</u>. Mean target-locked ERPs waveforms ipsilateral electrodes (P3 & P4) for expected-cued and unexpected-uncued trials in the detection and the discrimination task.

In a similar vein, the N1 component was also reduced in cued versus uncued location trials (this time at contralateral electrodes) in both the detection and the discrimination task. The N1 modulation at ipsilateral electrodes resembles the behavioural differences in cuing effects observed between detection and discrimination tasks. At unexpected locations, N1 was enhanced for cued versus uncued location trials in the discrimination tasks (thus showing a facilitatory effect), but not in the detection task. This result might suggest that the ongoing processing of cue produce longer lasting facilitatory effects when discrimination instead of detection tasks are required. This N1 component might index the selection of the cued location or the cued object for further perceptual processing (Lupiáñez & Chica, submitted), which is more prominent in perceptually demanding tasks.

Finally, both endogenous and exogenous orienting modulated the P3 component. The amplitude of this component was reduced when the target was presented at an expected location as compared to the unexpected location (Eimer, 1993), and it was also diminished for uncued versus cued location trials (showing an IOR effect). Therefore, in this case, both exogenous and endogenous attention seem to act similarly and in the same direction. Both exogenously cueing a location, and having an expectancy about the target not to appear there, seem to increase the P3 component of the wave. The modulation of P3 amplitude at ipsilateral electrodes seems to be another neural correlate of the different modulation of cuing effects depending on the task at hand. As can be observed in Figure 16A, P3 amplitude was enhanced in cued versus uncued location trials in the detection task (i.e., an IOR effect was observed), while it was enhanced for uncued versus cued trials in the discrimination task (revealing a facilitatory effect).

Overall, our results are consistent with a recently published study by Hopfinger & West (2006). They manipulated both endogenous and exogenous orienting of spatial attention using a different paradigm. There were two kinds of stimuli, one defined as targets (that required a response), and the other defined as non-targets (that did not required a response). ERPs were only analysed for non-targets stimuli. Endogenous attention was manipulated by a central arrow, which indicated participants to respond to targets appearing at that specific location. Exogenous attention consisted of the disappearance of one out of two peripheral markers after the presentation of the central arrow. The longer SOA used was 234 ms, so the effect of exogenous attention was a facilitatory effect (in our study, a 1000 ms SOA was used to study IOR). They reported that the late phase of P1 was enhanced for cued versus uncued location trials at both endogenously attended and non-attended locations. An interaction similar to that previously reported in our study between endogenous and exogenous attention was found in Hopfinger & West's study. They reported that the effect of exogenous attention on the late phase of P1 was enhanced at endogenously attended locations. Thus it can be concluded that although endogenous and exogenous attention has been proved to produce their effects independently (Berger et al., 2005; Berlucchi, et al., 2000; Chica, et al., 2006; Chica & Lupiáñez, 2004; Riggio & Kirsner, 1997), they can also interact or work in coordination to produce the final overt behaviour.

In summary, the present results have demonstrated that exogenous attention, in the conditions at which behavioural IOR is observed, modulates target processing at least at two stages. IOR is related to a modulation of the P1 and N1 component that is associated with early perceptual processes. Furthermore, IOR is also measured as a modulation at later stages of processing, as measured by the P3 component. However, endogenous attention (at least when measured with the present paradigm, in which endogenous and exogenous attention are elicited by the same peripheral cue, and ERPs are measured for responded-to targets) does not modulate early perceptual components as strongly as exogenous attention does, but it modulates the exogenous attentional effect, by enhancing IOR at the expected location is both tasks. On the other hand, the strongest modulation produced by endogenous attention has been observed in later stages of processing, at which the amplitude of P3 was reduced for expected versus unexpected location trials. Finally, and more important, IOR (reduced P1 amplitude for cued versus uncued location trials) was observed at endogenously attended locations, even when endogenous attention was allocated at the cued location. This result suggests that IOR produces a perceptual impairment (i.e., a detection cost) on the processing of stimuli that cannot be cancelled out by endogenously attending to that location.

Chapter IV

Endogenous attention and Illusory Line Motion depend on task set

The content of this chapter has been submitted as Chica, A. B., Charras, P., & Lupiáñez, J. (submitted-b). Endogenous attention and Illusory Line Motion depend on task set.

ABSTRACT

Task set has been shown to determine some important cognitive operations like conscious perception (Rafal, Ward, & Danziger, 2006), and the exogenous orienting of spatial attention (Folk et al., 1992; Lupiáñez, Ruz et al., 2007). In the present study we investigate whether endogenous attention would also be task-dependent. We use an illusion of movement, the Illusory Line Motion (ILM; Hikosaka et al., 1993) to explore this question. Our results revealed that endogenously attending to detect the appearance of a target produce different consequences in modulating the illusion of movement than endogenously attending to discriminate one of its features. Event related potentials to an attentional cue were also modulated differentially by endogenous attention depending on the task at hand.

Introduction

Task set, usually defined as the cognitive demands required to interact with the environment, has been shown to influence cognitive operations like the exogenous orienting of spatial attention, face recognition, resolution of conflict, and conscious perception. For instance, neglect patients are not conscious of stimuli located on their left when simultaneously presented with stimulation on their right. This phenomenon, known as extinction, is not completely stimulus-driven and can be modulated by the task at hand. Thus, when the stimulation presented on their left and right share the same response, left stimuli are more likely to be extinguished than when the same visual stimulation is associated with different responses (Rafal et al., 2006). This suggests that conscious perception depends on our aims while interacting with the environment (O'Regan, 2001).

Task set also modulates conflict resolution. In Stroop tasks (Stroop, 1935), participants have to report the colour in which a word is printed. They are encountered with congruent trials (for example, the word “red” is printed in red), or incongruent trials (for example, the word “red” printed in green). The Stroop effect consists of slower response times and lower accuracy in incongruent versus congruent trials. Interestingly, task set can modulate the magnitude of the Stroop effect (MacLeod, 1991). If the number of congruent trials is large (e.g., more than 75% of the trials), participants adopt a task set in which control processes are not very relevant. Consequently, when an incongruent trial appears, the Stroop effect is much larger. However, if the majority of trials are incongruent, control processes are more frequently needed, and the Stroop effect becomes smaller. These data indicate that task set can modulate how conflict is solved under different contextual situations.

Task set and mood have been shown to modulate whether the attentional focus is local or global, having important consequences on processes such as recognition (Gasper & Clore, 2002). Thus, for example, Mcrae and Lewis (2002) demonstrated that face recognition was enhanced after identifying the global shape of a compound Navon stimulus (e.g., a big H made out of small As), while face recognition was impaired after identification of the composing small letters.

More specifically related to attentional orienting, task set has also been proposed to determine how external stimuli attract attention (exogenous orienting). Using the Posnerian cuing paradigm, it has been demonstrated that facilitation and Inhibition of Return (IOR; a mechanism that produces slower responses at previously stimulated or explored locations when the time interval between the cue and target is long enough; see Klein, 2000; for a review) depend on the task at hand (Lupiáñez et al., 1997). Thus, when the task involves the discrimination of visual features such as shape or colour, facilitation is larger and IOR appears later than if the task only involves the detection of the target's appearance. This evidence suggests that task set, or the preparation to interact with the environment in certain manners, determines how attention is captured exogenously (see also Folk et al., 1992).

The aim of the present paper is to explore whether endogenous attention would also be implemented differently depending on the task at hand. The Posner's metaphor considered attention as a spotlight that enhanced the representation of attended locations (Posner, 1980). This theory has led researchers to assume that endogenous attention is always implemented in the same way, for example reducing external noise in the perceptual system (Lu & Dosher, 2005) or affecting the decision of where to respond (Klein & Shore, 2000). However, it could be the case that endogenous attention is not always implemented through the same process, but its implementation is task-dependent. That is, endogenously attending to discriminate a target could be different, and mobilize different processes, than endogenously attending to detect its appearance. In order to test this hypothesis, the illusion of movement known as the Illusory Line Motion will be used.

When a line is presented all at once near a previously stimulated location (where a peripheral cue was presented), the line appears to be drawn away from that location (the cue). The perception of this unreal motion is referred to as Illusory Line Motion (ILM; Hikosaka et al., 1993). The most accepted explanation about the ILM effect is based on the prior entry law (Titchener, 1908). This hypothesis suggests that the orienting of attention to the cue produces a gradient of accelerated arrival times at high levels of perceptual processing around its location. When a line is presented all at once across this gradient, the difference in arrival times across the line is interpreted by motion perception systems as a drawing of the line over time. Following this explanation, it could be hypothesized that similar ILM effects should be produced no matter whether attention is oriented exogenously by external events, o endogenously through internally generated spatial expectancies.

Nevertheless, there is still an open controversy about whether or not endogenous attention can induce the perception of ILM. Indeed, a recent series of studies have reported conflicting, or even opposite, results (Christie & Klein, 2005; Downing & Treisman, 1997; Schmidt, 2000). The experimental manipulation of the ILM is delicate because two measurements are necessary: The perception of movement and the allocation of attention. To do so, a secondary task is generally used to investigate whether or not endogenous attention was correctly allocated. In the studies cited above, ILM trials are intermixed with letter discrimination trials in which no line is presented. This secondary task allows for an objective measure of where attention is oriented. Schmidt (2000) demonstrated that endogenous attention modulated the effect of ILM using a secondary discrimination task. However, Christie & Klein (2005) have more recently demonstrated that endogenous attention did not produce the ILM effect when attention was directed to a position in space by an arrow cue, but it produced a slight modulation when endogenous attention was object-based. They concluded that ILM is very slightly produced by endogenous attention and only when attention is oriented to objects and not to space. Note that in contrast to Schmidt that reported positive results, Christie & Klein used a secondary detection task to measure the allocation of attention.

Independently on whether or not endogenous attention modulates the ILM caused by a peripheral cue, most results clearly show that the effect is not produced by only endogenous attention (Christie & Klein, 2005). To anticipate a result that we will report in this paper, ILM can be unaffected by orienting attention to the location opposite to the peripheral cue. Note that the prior entry explanation will predict the illusion to reverse in this condition. Therefore, a more plausible account for the ILM effect than the prior entry hypothesis is that the illusion is due to impletion, i.e., to the perceptual integration of the peripheral cue and the target line within the some object file representation (Downing & Treisman, 1997). Therefore, this paradigm seems to be appropriate to investigate whether tasks set (detection vs. discrimination) modulates how endogenous attention is implemented, by looking at how it interacts with perceptual integration processing, i.e., how it affects the ILM effect.

Note that in the ILM studies reviewed so far, it is implicitly assumed that endogenous attention is oriented in the same way whatever the task at hand. Some studies have used a secondary task that involved the discrimination of a single feature (Downing & Treisman, 1997; Schmidt, 2000), while in Christie & Klein's (2005) study the task involved the detection of the target's appearance. In the current study, we aim at testing the hypothesis that task set affects how endogenous attention is implemented. If endogenous attention is implemented differently depending on the task at hand, the effect of endogenous attention on ILM would depend on the secondary task used to measure whether endogenous attention was truly oriented according with the instructions.

Overview of the present experiments

In the present experiments, we use a new paradigm in which a peripheral cue is followed by a static line containing a coloured dot in one of its edges. The secondary task involved a speeded response to the dot. Task set was manipulated by requiring different groups of participants to either detect the appearance of the dot or to discriminate its colour (detection vs. discrimination tasks). In all cases, after this response, participants had to rate the perception of ILM. Endogenous attention was manipulated by making the cue predictive of the location of the dot. In Experiment 1, the cue predicted, in different blocks of trials, that the dot would appear at either the same location of the cue or at the opposite location. Thus, participants had to endogenously attend to either the cued location or to the location opposite to the cue. In Experiment 2, a non-predictive cue block was introduced and Event Related Potentials (ERPs) were recorded in some participants (also allowing for the measurement of eye movements).

Following the impletion hypothesis (Downing & Treisman, 1997), we expect the ILM effect to be almost entirely driven by the peripheral cue. That is, we expect endogenous attention not to produce the illusion, which is entirely produced the peripheral cue. Importantly, however, we expect endogenous attention to affect the ILM by modulating the perceptual integration processes between the cue and the line. Further more importantly, we expect this endogenous modulation to be dependent on tasks set.

EXPERIMENT 1

In all the previous experiments discussed in the Introduction, the secondary task to measure that endogenous attention was oriented according to the instructions was introduced in different trials to the ILM trials. That is, in some trials, the cue was presented followed by a line and participants rated the perception of motion; in other trials, a different target was presented after the cue and participants detected its appearance or discriminated one of its features. Using this method it is assumed that the orienting of attention produced by the cue is manifested equally in the two types of trials, although they use completely different targets with different task demands. In order to avoid this problem, in the current paradigm, we present a peripheral cue followed by the line, which contains the target (i.e., a colour dot in one of its edges). Participants are asked to quickly respond to the dot first, and then rate the perception of ILM without time pressure. In the same trial, this paradigm enables to measure whether endogenous attention is oriented according to the instructions (producing faster and/or more accurate responses to the dot), and whether attention modulates the perception of ILM. In one block of trials, the cue predicted the target to appear at the same location as the cue, so that endogenous attention was oriented to the cued location, while in the other block of trials the cue was counterpredictive so that endogenous attention was oriented to the opposite location to the cue. If endogenous attention modulates the perception of ILM, the magnitude of the illusion would be stronger when endogenous attention is oriented to the cued location. Additionally, in order to study whether the task set generated in a detection and discrimination task have distinct effects on the perception of ILM, some participants were asked to detect the appearance of a dot (Experiment 1A) while others had to discriminate its colour (Experiment 1B).

EXPERIMENT 1A (Detection task)

Method

Participants. Twenty naïve observers (mean age of 23 years, 3 males, 3 left-handed) participated in the experiment. All of the participants in this and the following experiments were recruited from the University of Granada, and participated in the experiment for course credit. All of them reported to have normal or corrected to normal vision and non-known neurological problems. All the experiments were conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada.

Apparatus and stimuli. The stimuli were presented on a 15-inch colour VGA monitor. An IBM compatible PC running E-Prime software (Schneider et al., 2002) controlled the presentation of stimuli, timing operations, and data collection. The participants sat at approximately 57 cm from the monitor in a dimly illuminated booth. At the beginning of each trial, a fixation point (a grey plus sign, 0.4º x 0.4º) was displayed at the centre of the screen, on a black background. Two grey circles (1.4º diameter) were displayed 1.8 º above fixation and 3.8º to the left and right. As a cue, the outline of one of the circles turned white for 50 ms and became thicker so that the circle's diameter was of 1.6º, giving the impression of a brief flash. The target was a line (6.2º in height) joining the two circles. The line contained either a red or green square (0.4º x 0.4º) in one of its edges. A 50 ms tone was used to provide response feedback.

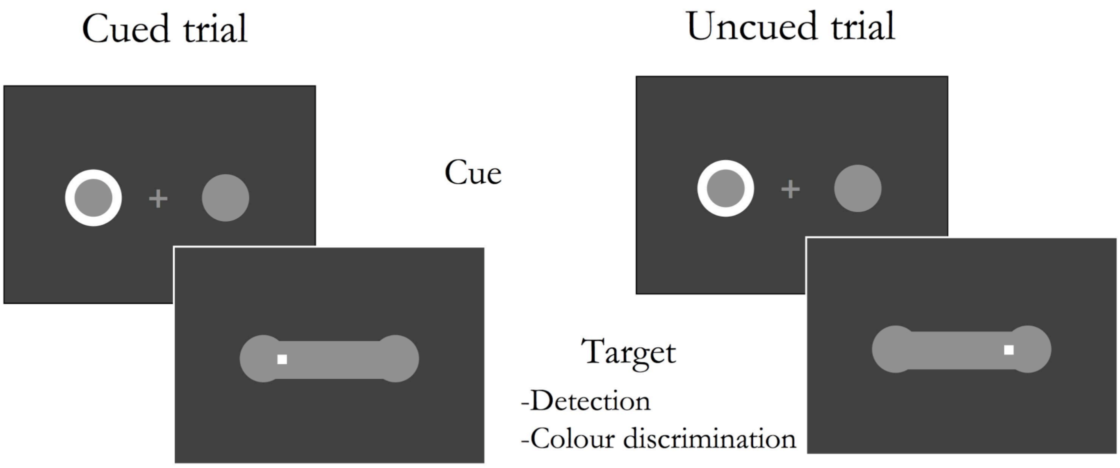


Figure 18. Example of cued and uncued trials in the experiments. In cued trials, the dot appears at the same location as the cue, while in uncued trials the dot appears at the opposite location. Half of the participants detected the appearance of the dot, while the other half discriminated its colour.

Procedure. Every trial was self-initiated by pressing the space bar. The fixation point and the two circles were then presented. After 1000 ms, the peripheral cue was randomly presented at either the left or the right marker for either 100 or 1000 ms. The target (the line plus the dot) was then displayed for 100 ms. The dot was either red or green and could appear at either the left or the right edge of the line. We use the term "cued trials" to refer to those trials in which the dot was presented at the same location as the cue, and "uncued trials" for those trials in which the dot appeared at the opposite location to the cue (see Figure 18). Catch trials, in which no dot was presented inside the line and no response was required, accounted for 16% of the trials. Participants were asked to detect the appearance of the dot as fast and accurately as possible. Half of the participants detected the target by pressing the "z" key with their left hand whereas the other half pressed the "m" key with their right hand. If no response was detected within 2000 ms of target appearance, auditory feedback was provided for 50 ms. The same auditory feedback was used for anticipatory responses. After this speeded response, the sentence "¿Has percibido movimiento?" ("*Did you perceive motion*?" in Spanish) was displayed at the centre of the screen, and participants were asked to press one out of four keys (a, s, k, l). These keys were labelled as "Collision" (motion from the two markers to the centre), "Left", "No Motion", and "Right", respectively. Participants were encouraged to take as much time as needed to respond to this question, and were informed that there was no correct or incorrect answer. After this response, they were asked to place their fingers in the "z" or the "m" key (depending on the response mapping condition) in order to get ready for the next trial.

There were two blocks of trials. In one of them, the cue predicted that the dot would appear at the same location as the cue on 75% of the trials in which the dot was presented (predictive cue block). On the remaining 25% of the trials of this block, the dot appeared at the location opposite to the cue. Thus, in this block there were 75% cued trials and 25% uncued trials. In the other block of trials, the cue predicted that the dot to appear at the opposite location on 75% of the trials (counterpredictive cue block). On the remaining 25% of the trials of this block, the dot was presented at the same location as the cue, thus leading to 75% uncued trials and 25% cued trials. Participants were informed about the predictive value of the cue and encouraged to take this information into account in order to respond fast and accurately to the dot. The order of presentation of the blocks was counterbalanced within participants.

Each block consisted of a total of 190 trials preceded by 24 practice trials. For each block, and for each cue duration condition, there were a total of 60 trials in which the target appeared at the location predicted by the cue (endogenously attended location), 20 trials in which the target appeared at the non-predicted location (endogenously unattended location). Thirty catch trials were also included.

Results

Participants that did not perceive ILM were eliminated from this and the following experiments. Participants that rated ILM toward the cue in all conditions were also eliminated assuming that they mistook the instructions to use the scale. Only one participant had to be eliminated in this experiment for rating the movement toward the cue. Misses (1.51% of trials) and false alarms (responses to catch trials, 2.88% of trials) were eliminated from the RT analyses. RTs faster than 200 and slower than 1200 ms were considered outliers and were not analysed (3.06% of trials).

RT results for the secondary task. Mean correct RTs were submitted to a repeated-measures analysis of variance (ANOVA) with the factors of cue predictivity (predictive vs. counterpredictive), cuing (cued vs. uncued location trials), and cue duration (100 and 1000 ms), all manipulated within participants. The analysis revealed a main effect of cue duration, *F*(1,17)=24.85, *MSE*=2932, *p*<.001, with RT being faster when the cue was presented for 1000 ms vs. 100 ms. The interaction between cue predictivity and cuing was significant, *F*(1,17)=10.17, *MSE*=2092, *p*=.005. This interaction revealed the fact that participants were orienting their attention endogenously according with the instructions. When the cue predicted the dot to appear at the cued location (predictive cue block), RTs were faster for cued versus uncued trials (M=544 and 575 ms, respectively), and when the cue predicted the target to appear at the opposite location (counterpredictive cue block), RTs were faster for uncued trials than for cued trials (M=572 and 590 ms, respectively; see Table 10). None of the other main effects or interactions were significant.

ILM results. Left and right responses were re-coded as either towards or away from the cue (depending on the cue location). Thus, ILM ratings were recoded in 4 values: 0 (no movement), 1 (movement away from the cue), -1 (movement towards the cue), and collision. Mean illusory rating scores (excluding “collision” responses) were submitted to a similar ANOVA with the factors of cue predictivity, cuing, and cue duration, all manipulated within participants. In this analysis, only the main effect of cuing was significant, *F*(1,17)=5.43, *MSE*=0.93, *p*=.032, revealing that ILM ratings were higher for uncued versus cued trials. Neither the main effect of cue predictivity, *F*<1, nor the interaction between cue predictivity and cuing, *F*<1, or cue predictivity and cue duration, *F*(1,17)=1.21, *MSE*=.02, *p*=.28, were significant, revealing the fact that endogenous attention did not affect the perception of ILM (see Figure 19 and Table 10). In particular, it is important to remember that the RT results revealed that endogenous attention was oriented to the cued location in the predictive cue block, and to the opposite location in the counterpredictive cue block. However, endogenous attention did not modulate the perception of the illusion.

A similar analysis of the mean collision responses showed a main effect of cuing, *F*(1,17)=4.51, *MSE*=.02, *p*=.048, with more collision responses for cued versus uncued trials. The main effect of cue duration was also significant, *F*(1,17)=9.90, *MSE*=.01, *p*=.005, with more collision responses when the cue was presented for 1000 ms vs. 100 ms.

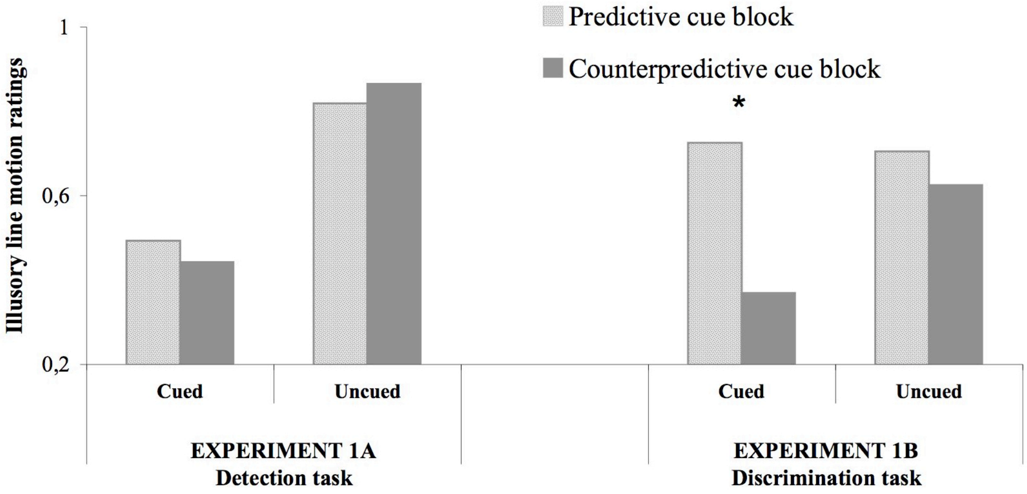


Figure 19. Mean ILM ratings for cued and uncued trials as a function of cue predictivity in Experiment 1A (detection task) and 1B (discrimination task). The asterisk represents statistically significant effects.

Table 10. Shows the mean data of the secondary task and the ILM in Experiment 1A (detection task) and 1B (discrimination task) for each experimental condition of SOA (100 and 1000 ms), cue predictivity (predictive and counterpredictive), and cuing (cued and uncued). For the secondary task, mean RT (in ms) and accuracy (ACC) –in the discrimination task, plus its standard error (in brackets), are shown. In bold, mean cuing effect for the RT (in ms). For the ILM responses, mean ILM and collision responses, plus its standard error (in brackets), are shown.

EXPERIMENT 1A: DETECTION

SOA 100 ms

	Predictive				Counterpredictive			
	Cued		Uncued		Cued		Uncued	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
RT	565	[30]	592	[38]	620	[32]	595	[32]
Cuing Effect	**27**				**-25**			
ILM	0,50	[0,162]	0,83	[0,032]	0,48	[0,154]	0,90	[0,038]
Collision	0,16	[0,069]	0,11	[0,057]	0,13	[0,059]	0,08	[0,035]

SOA 1000 ms

	Predictive				Counterpredictive			
	Cued		Uncued		Cued		Uncued	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
RT	523	[32]	559	[36]	560	[32]	551	[33]
Cuing Effect	**36**				**-9**			
ILM	0,48	[0,159]	0,81	[0,058]	0,40	[0,161]	0,83	[0,049]
Collision	0,20	[0,075]	0,16	[0,066]	0,20	[0,066]	0,13	[0,053]

EXPERIMENT 1B: DISCRIMINATION

SOA 100 ms

	Predictive				Counterpredictive			
	Cued		Uncued		Cued		Uncued	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acc	97%	[0,62]	94%	[1,00]	96%	[1,24]	95%	[0,83]
RT	893	[41]	975	[53]	885	[40]	876	[42]
Cuing Effect	**82**				**-9**			
ILM	0,80	[0,064]	0,69	[0,081]	0,47	[0,151]	0,64	[0,135]
Collision	0,14	[0,072]	0,08	[0,052]	0,10	[0,047]	0,07	[0,029]

SOA 1000 ms

	Predictive				Counterpredictive			
	Cued		Uncued		Cued		Uncued	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acc	95%	[0,95]	94%	[1,00]	94%	[1,30]	95%	[0,64]
RT	833	[46]	905	[52]	865	[51]	850	[50]
Cuing Effect	**72**				**-15**			
ILM	0,65	[0,134]	0,72	[0,062]	0,27	[0,130]	0,60	[0,139]
Collision	0,19	[0,085]	0,11	[0,068]	0,12	[0,060]	0,10	[0,053]

Discussion

The results of the present experiment have revealed that participants were faster detecting the appearance of the dot at the location predicted by the cue, indicating that endogenous attention was actually oriented according with the instructions. However, when participants were performing a secondary detection task, ILM was not modulated by endogenous attention. ILM ratings were similar when endogenously attending to the cued location vs. attending to the location opposite to the cue (see Christie & Klein, 2005; for similar results using a detection task). Importantly, as stated above, this result argue against the attentional hypothesis about ILM (Hikosaka et al., 1993), which would predict that endogenously attending to the location opposite to the cue would reverse the ILM effect caused by the presentation of the cue. In other words, if ILM is caused by accelerated arrivals times of processing at attended locations, when endogenous attention is oriented to the opposite location to the cue, the ILM effect produced by the cue should be reversed, or at least reduced. Therefore, the ILM seems more plausibly explained by impletion processes (Downing & Treisman, 1997) related to the perceptual integration between the cue and the line within the same object file.

It is important to note that endogenous attention not only did not produce the ILM (it was not reversed when the cue was counterpredictive), but not even modulated it. In Experiment 1B we run a discrimination task in order to explore whether the modulation of ILM would depend on the task at hand.

EXPERIMENT 1B (Discrimination task)

Method

Participants. Twenty naïve observers (mean age of 22 years, 2 males, all right-handed) participated in the experiment.

Apparatus, stimuli, and procedure. Everything was the same as in Experiment 1A except for the following: No catch trials we included because they were not necessary to ensure adequate performance in the discrimination task. Participants were asked to discriminate the colour of the dot by pressing the “z” key with their left hand for one of the colours, or the “m” key with their right hand for the other colour. The response mapping was counterbalanced between participants. It is well known that RTs to discriminate the colour of a target are longer than RTs to detect the target's appearance (Lupiáñez et al., 1997). For this reason and in order to equate task's difficulty, in this experiment the line and the dot were presented until response.

Results

Incorrect responses to the dot (4.69% of trials) were removed from the RT analyses. RTs faster than 200 and slower than 1700 ms were considered outliers and were not analysed (6.41% of trials).

RT and accuracy results for the secondary task. Mean correct RTs were submitted to a repeated-measures ANOVA with the factors of cue predictivity (predictive vs. counterpredictive), cuing (cued vs. uncued location trials), and cue duration (100 and 1000 ms), all being manipulated within participants. The analysis revealed a significant main effect of cue duration, *F*(1,16)=11.09, *MSE*=5905, *p*=.004, with faster RTs when the cue was presented for 1000 ms vs. 100 ms. The main effect of cuing was also significant, *F*(1,16)=4.67, *MSE*=7578, *p*=.046, with faster RTs for cued than uncued trials. Importantly, and showing that participants were endogenously attending according with the instructions, the interaction between cue predictivity and cuing was significant, *F*(1,16)=16.31, *MSE*=4133, *p*<.001. When the cue predicted the dot to appear at the cued location, RTs were faster for cued versus uncued trials (M=863 and 939 ms, respectively), and when the cue predicted the target to appear at the opposite location, RTs were faster for uncued versus cued trials (M=862 and 874 ms, respectively; see Table 10). None of the other main effects or interactions were significant.

A similar analysis of the mean erroneous responses revealed that none of the main effects or interactions reached significance. However, as can be observed in Table 10, the accuracy data revealed a similar pattern to the RT data.

ILM results. Mean illusory rating scores (excluding "collision" responses) were submitted to a similar ANOVA with the factors of cue predictivity, cuing, and cue duration, all manipulated within participants. The main effect of cue duration was significant, *F*(1,16)=5.19, *MSE*=.06, *p*=.037, with higher ILM ratings when the cue was presented for 100 ms vs. 1000 ms. The interaction between cuing and cue duration was also significant, *F*(1,16)=4.57, *MSE*=.06, *p*=.048, and showed that the perception of ILM decreased as cue duration increased for cued trials, *F*(1,16)=5.93, *MSE*=.09, *p*=.027, but did not change for uncued trials, *F*<1. Specially important for our hypotheses, the interaction between cue predictivity and cuing was significant, *F*(1,16)=10.66, *MSE*=.06, *p*=.005. This interaction revealed the fact that endogenous attention only produced an effect on cued trials. In those trials, endogenously attending to the location of the cue enhanced the perception of ILM as compared to endogenously attending to the location opposite to the cue, *F*(1,16)=8.93, *MSE*=.24, *p*=.009 (see Figure 19). Thus, endogenous attention did modulate the perception of ILM when participants were performing a secondary discrimination task.

A similar analysis of the mean collision responses revealed that none of the main effects or interactions were significant.

Discussion

Our new paradigm has been successful to produce endogenous attention effects in responding to the secondary task in both Experiment 1A (detection task) and 1B (discrimination task). Thus, endogenous attention was oriented to the location indicated by the cue. Moreover, endogenous attention did not modulate the ILM effect when participants were performing a secondary detection task, but it did when participants were performing a secondary discrimination task. This result is consistent with the previous literature, as the most recent evidence against the fact that endogenous attention affects ILM used a secondary detection task (Christie & Klein, 2005), while all the previous studies with positive results used a secondary discrimination task (Downing & Treisman, 1997, Experiment 2A; Schmidt, 2000, Experiments 1 & 2). This result is very relevant for the theoretical aim of the present paper. Endogenously attending to detect a target is implemented differentially to endogenously attending to discriminate one of its features. More specifically, endogenous attention in the context of a discrimination task seems to increase the perceptual integration between the cue and the line, thus producing a stronger perception of ILM.

EXPERIMENT 2

Experiments 2A & 2B were designed in order to replicate the results of Experiment 1, while introducing some improvements in the method. First, it could be argued that endogenous attention modulated the perception of ILM in the discrimination task but not in the detection task because the line was presented until response only in the former task. In the next experiments, the line was presented for 100 ms in both tasks. Second, a scale from –3 to +3 (left to right movement) was used to rate ILM, allowing participants to rate, not only the direction of movement, but also its strength and speed. Third, in Experiment 1, we only used a predictive and counterpredictive cue block. Thus, it could not be disentangle whether the effect of endogenous attention was due to an increased perception of the illusion when attention was oriented to the location of the cue, or a decreased perception of the illusion when attention was oriented to the opposite location to the cue. In order to facilitate the interpretation of the results, a non-predictive cue block was added, in which the cue did not predict the location of the dot-target. Finally, EEG was recorded in 16 participants. The EEG net also contained electrodes to measure horizontal and vertical eye movements, allowing us to measure whether the effects described in Experiment 1 are due to eye movements. Moreover, ERPs to the cue were analysed in order to explore the nature of the modulation of ILM.

EXPERIMENT 2A (Detection task)

Method

Participants. Twenty-eight naïve observers (mean age of 21 years, 5 males, all right-handed) participated in the experiment. The EEG was recorded in 16 of the participants.

Apparatus and stimuli. Everything was the same as in Experiment 1.

EEG recording and analysis. The EEG was recorded using a 128-channel Geodesic Sensor Net of Ag/AgCl electrodes (Tucker et al., 1994). The head-coverage included sensors lateral to and below both eyes, to monitor horizontal and vertical eye movements. The experimenter could monitor the eye movements online, and controlled that participants were not moving the eyes during the experiment, informing them if eye movements were observed in the EEG. Impedances for each channel were measured and kept below 50 KΩ before testing. All electrodes were referenced to the Cz electrode during the recording and were averaged re-referenced off-line. The EEG was amplified with a band pass of 0.1-100 Hz (elliptic filter) and digitized at a sampling rate of 250 Hz. EEG was filtered offline by using a 1-30 Hz low-pass filter, and then segmented in epochs from 100 ms before cue appearance to 335 ms after the cue. All trials containing eye movements, blinks, or artifacts, as well as trials that did not meet behavioural performance criteria were rejected. A 100 ms segment previous to the cue presentation was used to calculate the baseline.

Procedure. Everything was the same as in Experiment 1A except for the following. The fixation display varied randomly between 1000 and 1500 ms. Only a 300 ms cue duration was used. Previous research using this paradigm has demonstrated that 300 ms is a long enough interval for endogenous attention to be oriented (Chica et al., 2006). Moreover, this interval is short enough to induce an ILM effect. Trials were not self-initiated by pressing the space bar as in Experiment 1, and the inter-stimulus interval was fixed at 1000 ms. Participants detected the appearance of the dot with one hand, and rated the perception of the movement using the computer mouse with their other hand (with the hand used counterbalanced across participants). A -3 to +3 (plus a "collision" button) scale was presented on the screen. Participants were asked to use the different values of the scale to rate not only the direction of the movement but also its strength and speed, i.e., a movement to the left would take its maximum value (-3) if the perception of movement was strong and fast, and as -1 if a weak movement was perceived.

Three blocks of 160 trials each were run, all preceded by 20 practice trials. In the non-predictive cue block, the cue was not spatially predictive of the dot's location. In the predictive cue block, the cue predicted the dot to appear at its same location on 75% of the trials. In the counterpredictive cue block, the cue predicted the dot to appear at the opposite location on 75% of the trials. The order of the three blocks was counterbalanced across participants.

In the non-predictive cue block, there were 64 cued trials, 64 uncued trials, and 32 catch trials. In the remaining two blocks, there were 96 trials in which the dot appeared at the predicted location, 32 trials in which the target appeared at the non-predicted location, and 32 catch trials.

Results

Three participants were eliminated for not perceiving ILM in any condition and another 3 for rating ILM towards the cued location, probably due to misunderstanding the instructions. Misses (0.83% of trials) and false alarms (responses to catch trials, 2.18%) were eliminated from the analyses. RTs faster than 200 and slower than 1200 ms were considered as outliers and not analysed (3.56% of trials). For the participants who took part in the EEG experiment, eye movements only occurred in 3.35% of the trials.

RT results for the secondary task. Mean correct RTs were submitted to a repeated-measures ANOVA with the factors of cue predictivity (non-predictive, predictive, and counterpredictive) and cuing (cued versus uncued trials). The only effect that reached significance was the interaction between cue predictivity and cuing, *F*(2,42)=6.72, *MSE*=905, *p*=.003. When the cue was not predictive, RTs were faster for uncued versus cued trials (M=417 and 426 ms, respectively). However, when the cue was predictive, RTs were always faster at the endogenously attended location, *F*(1,42)=9.95, *MSE*=1221, *p*=.005. When the cue predicted the dot to appear at the same location, RTs were faster for cued versus uncued trials (M=423 and 437 ms, respectively). Moreover, when the cue predicted the dot to appear at the opposite location, RTs were faster for uncued versus cued trials (M=402 and 435 ms, respectively; see Table 11).

ILM results. After re-coding left-right responses into towards-away responses, ILM ratings could take a range of values from 0 (no motion) to 3 (when the movement was perceived away from the cue) or -3 (when the movement was perceived towards the cue). Collision responses were also possible. Mean illusory rating scores (excluding "collision" responses) were submitted to a repeated-measures ANOVA with the factors of cue predictivity (non-predictive, predictive, and counterpredictive), cuing (cued vs. uncued trials), and eye movement measurement (EEG vs. non-EEG). This between participants factor was included in order to explore whether eye movements measurement might modulate the observed pattern of data. The analysis revealed a main effect of cuing, *F*(1,20)=7.88, *MSE*=2.06, *p*=.011, with higher ILM ratings for uncued versus cued trials. However, the interaction between cuing and the measurement of eye movements was marginally significant, *F*(1,40)=4.27, *MSE*=2.06, *p*=.052, and showed that the stronger perception of ILM for uncued versus cued trials was only observed when eye movements were not measured, *F*(1,20)=8.71, *MSE*=2.06, *p*=.008, not being present in the group in which eye movements were monitored, *F*<1. Therefore, it seems that the stronger perception of ILM for uncued trials was due to an eye movement to the uncued target.

Regarding the endogenous orienting of attention, as in Experiment 1A, neither the main effect of cue predictivity, *p*=.26, nor the interaction between cue predictivity and cuing, *p*=.27, were significant. None of these interactions were modulated by the eye movement measurement (*F*<1, and *p*=.34, respectively). Thus, replicating the results of Experiment 1A, it can be concluded that endogenous attention was oriented according with the instructions. However, when participants were performing a secondary detection task, endogenous attention did not modulate the perception of ILM (see Figure 20). In any case, ILM was more strongly perceived when the cue was not predictive than when the cue was spatially predictive (*p*=.054). There were no differences in the perception of ILM when the cue predicted the target to appear at the same vs. the opposite location, *F*<1.

A similar analysis of the mean collision responses revealed that none of the main effects or interactions were significant.

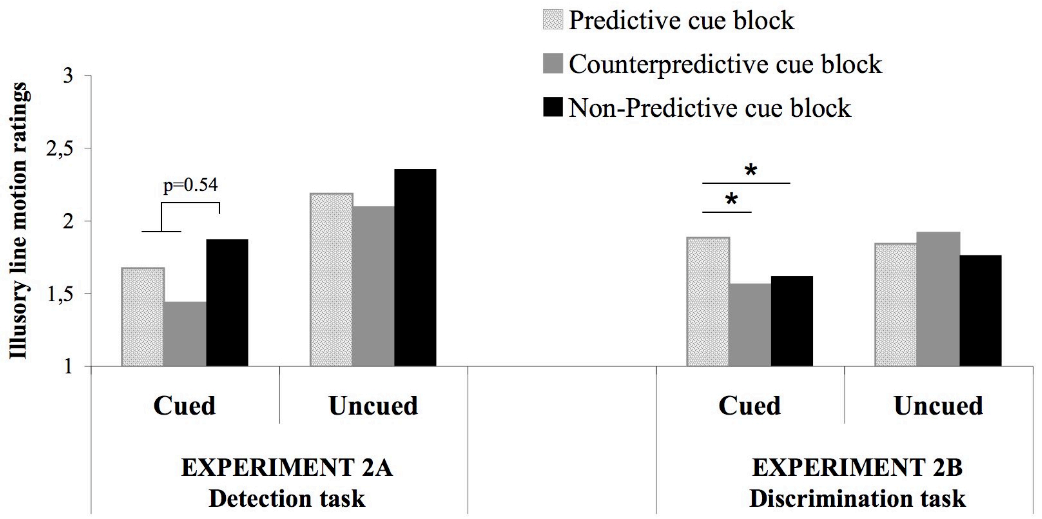


Figure 20. Mean ILM ratings for cued and uncued trials as a function of cue predictivity in Experiment 2A (detection task) and 2B (discrimination task). The asterisk represents statistically significant effects.

Table 11. Shows the mean data of the secondary task and the ILM in Experiment 2A (detection task) and 2B (discrimination task) for each experimental condition of cue predictivity (predictive, counterpredictive, and non-predictive), and cuing (cued and uncued). For the secondary task, mean RT (in ms) and accuracy (ACC) –in the discrimination task, plus its standard error (in brackets), are shown. In bold, mean cuing effect for the RT (in ms). For the ILM responses, mean ILM and collision responses, plus its standard error (in brackets), are shown.

		Predictive				**Counterpredictive**				**Non-Predictive**			
		Cued		Uncued		Cued		Uncued		Cued		Uncued	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
EXPERIMENT 2A: DETECTION	RT	423	[22]	437	[28]	435	[22]	403	[19]	426	[21]	418	[23]
	Cuing Effect	**14**				**-32**				**-8**			
	ILM	1,53	[0,33]	2,27	[0,19]	1,31	[0,32]	2,19	[0,24]	1,79	[0,31]	2,43	[0,15]
	Collision	0,00	[0,002]	0,01	[0,005]	0,02	[0,011]	0,01	[0,004]	0,01	[0,012]	0,01	[0,004]

		Predictive				**Counterpredictive**				**Non-Predictive**			
		Cued		Uncued		Cued		Uncued		Cued		Uncued	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
EXPERIMENT 2B: DISCRIMINATION	Acc	93%	[1,24]	91%	[1,11]	89%	[1,67]	92%	[1,23]	91%	[1,43]	89%	[1,94]
	RT	671	[24]	695	[26]	694	[26]	680	[24]	679	[25]	689	[26]
	Cuing Effect	**25**				**-14**				**9**			
	ILM	1,85	[0,14]	1,81	[0,18]	1,52	[0,17]	1,89	[0,14]	1,59	[0,19]	1,74	[0,19]
	Collision	0,01	[0,003]	0,01	[0,008]	0,00	[0,002]	0,01	[0,004]	0,00	[0,001]	0,00	[0,000]

Discussion

Experiment 2A has replicated the main finding of Experiment 1A: When participants adopt a detection set, even though RTs to the dot are faster at the endogenously attended location, endogenous attention does not modulates the perception of ILM. In any case when the cue was made spatially predictive (of either the same or the opposite location to the cue) the perception of ILM decreased as compared with the non-predictive cue block. In the next experiment we will try to replicate the result of Experiment 1B in which endogenous attention to the cued location did enhance the perception of ILM when participants were performing a secondary discrimination task.

EXPERIMENT 2B (Discrimination task)

Method

Participants. Twenty-eight naïve observers (mean age of 21 years, 1 male, 4 left-handed) participated in the experiment. The EEG was recorded in 16 of the participants.

Apparatus, stimuli and procedure. Everything was the same as in Experiment 2A except that participants were asked to discriminate the colour of the dot using their middle and index finger of either their left or their right hand. The response mapping was counterbalanced across participants.

Results

One participant was eliminated for not perceiving the illusion in any of the conditions. Misses (1.90% of trials) and false alarms (responses to catch trials, 0.96%) were eliminated from the analyses. Incorrect responses (8.23% of trials) were also excluded from the RT analysis. RTs faster than 200 and slower than 1200 ms were considered outliers and not analysed (3.26% of trials). For the participants that took part in the EEG experiment, eye movements only occurred in 1.95% of trials.

RT and accuracy results for the secondary task. Mean correct RTs were submitted to a repeated-measures ANOVA with the factors of cue predictivity (non-predictive,

predictive and counterpredictive cue block) and cuing (cued versus uncued trials). The interaction between cue predictivity and cuing was significant, $F(2,52)=8.54$, $MSE=608$, $p<.001$. This interaction revealed the fact that when the cue was not predictive, RTs were faster for cued versus uncued trials (M=679 and 688 ms). However, when the cue was predictive, RTs were faster at the endogenously attended location, $F(1,26)=13.04$, $MSE=785$, $p<.001$. Thus, when the cue predicted the dot to appear at the same location, RTs were faster for cued versus uncued trials (M=671 and 695 ms), whereas when the cue predicted the dot to appear at the opposite location, RTs were faster for uncued versus cued trials (M=680 and 694 ms; see Table 11).

A similar analysis of the mean accuracy responses revealed a similar cue predictivity by cuing interaction, $F(2,52)=3.45$, $MSE=.002$, $p=.039$. Responses were more accurate for cued versus uncued trials when the cue was not predictive. When the cue was predictive, responses were more accurate at the endogenously attended location (cued trials when the cue predicted the same location and uncued trials when the cue predicted the opposite location, see Table 11).

ILM results. Mean illusory rating scores (excluding “collision” responses) were submitted to a repeated-measures ANOVA with the factors of cue predictivity, cuing, and eye movement measurement (EEG vs. non-EEG). This analysis revealed a significant main effect of cue predictivity, $F(1,25)=3.30$, $MSE=.12$, $p=.045$. Participants rated the perception of ILM more strongly when attending to the cued location versus the opposite location ($p=.007$) or when the cue was not predictive ($p=.046$). No differences were found between the opposite and the non-predictive cue block ($F<1$). Moreover, as in Experiment 1A, cue predictivity interacted with cuing, $F(2,50)=3.23$, $MSE=.17$, $p=.048$, revealing that the effect just described was only observed in cued trials (see Figure 20). None of the other main effects or interactions were significant.

The analysis of the mean collision responses could not be performed due to a lack of variance.

Discussion

Replicating the results of Experiment 1B, the present experiment has shown that when participants are performing a secondary discrimination task, endogenous attention does modulate the perception of ILM. RTs to discriminate the dot revealed that endogenous attention was oriented to the location indicated by the cue. Additionally, when participants were endogenously attending to the location of the cue ILM ratings were higher than when endogenous attention was oriented to the opposite location or when the cue was not predictive.

ERP results of Experiments 2A (detection task) & 2B (discrimination task)

As can be observed in Figure 21, the cue reliably elicited a negative component starting between 100 and 200 ms after its presentation. This component was clearly observed at contralateral electrodes P3 & P4 in both tasks. The first step in our analysis was to determine when the component started and finished. As the component was only elicited at contralateral electrodes, we compared the waveform at ipsilateral electrodes versus contralateral electrodes. The component was considered to start when the waveform at contralateral electrodes was significantly more negative than the waveform at ipsilateral electrodes, and to finish when the differences were not significant anymore. Multiple one-tailed paired t-tests were performed every 4 ms, from the moment of cue presentation until after 335 ms. This analysis was performed for each condition in each task. Table 12 shows the values at which the waveform at contralateral electrodes was significantly more negative than that at ipsilateral electrodes in each condition and task. This time window was used to perform the following analyses in the amplitude and latency of the component.

Table 12. Time-window, in ms from the moment of cue presentation, at which the waveform at contralateral electrodes was more negative than that at ipsilateral electrodes. This time-window was considered the start and end of the ERP component in each condition of cue predictivity in both the detection and the discrimination task.

Task	Cue predictivity condition	Time-window
Detection	Predictive cue block	180-296
	Counterpredictive cue block	192-284
	Non-predictive cue block	176-312
Discrimination	Predictive cue block	208-288
	Counterpredictive cue block	132-284
	Non-predictive cue block	96-240

The minimum amplitude and latency of this negative component was analysed using a one-way ANOVA with the factor of cue predictivity in each task. In the detection task, the main effect of cue predictivity did not reach significance in either the amplitude or the latency analysis, both *F*s <1. In the discrimination task, the analysis of the minimum amplitude revealed that the differences in amplitude were not significant, *F*<1. However, the latency of the component showed a significant main effect of cue predictivity, *F*(2,28)=18.93, *MSE*=699, *p*<.001. Planned comparisons revealed that the latency of the component was marginally delayed when the cue predicted the same location vs. the opposite location, p=.062. The latency of the component was significantly delayed when the cue predicted the same location vs. the non-predictive block, *p*< .001, and when the cue predicted the opposite location as compared with the non-predictive block, *p*< .001 (see Figure 21).

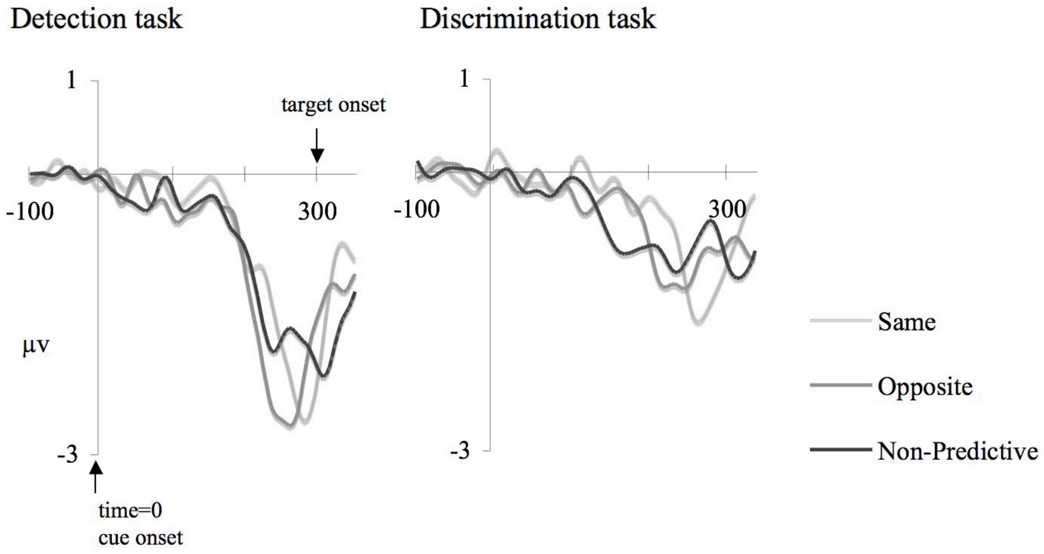


Figure 21. Mean cue-locked ERP waveforms for each condition of cue predictivity in Experiment 2A (detection task) and 2B (discrimination task). The vertical axis crosses the horizontal axis at the moment of cue presentation. The target was always presented at 300 ms.

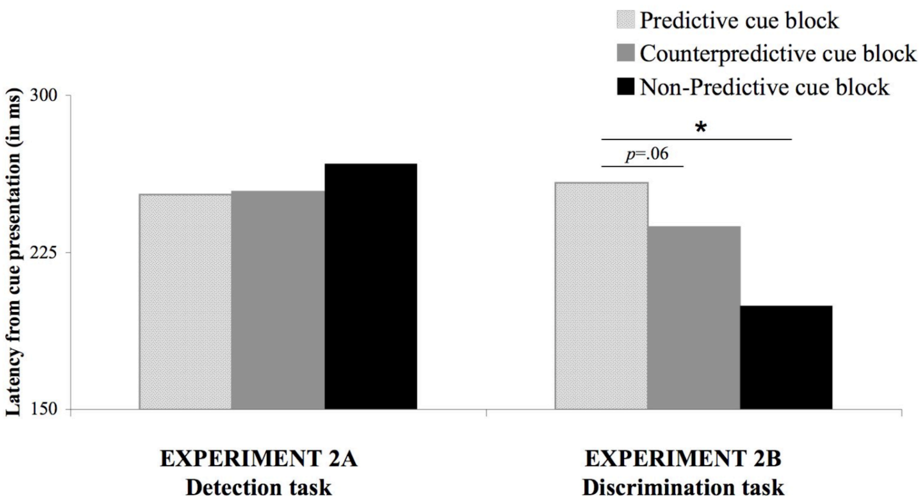


Figure 22. Mean latency (in ms) of the parietal negative component for each condition of cue predictivity in Experiment 2A (detection task) and 2B (discrimination task). The asterisk represents statistically significant effects.

Discussion

The analyses of the ERPs elicited by the cue revealed a negative component starting 100-200 ms after its presentation. In the discrimination task, the latency of the component seemed to be related with the behavioural results. The later the component reached its peak, the more illusion would be perceived. Thus, the latency of the negative component was delayed when endogenous attention was oriented to the cued location, in which more ILM was perceived. In the detection task there were no significant effects in amplitude or latency of the component (note that the behavioural results also showed non-significant effects), but the component was 13-14 ms delayed in the non-predictive block (as compared with the countepredictive and predictive cue block, respectively; see Figure 22), in which more illusion was perceived.

General Discussion

In the present paper, we aimed at exploring the role of task set on the implementation of endogenous attention. We investigated whether endogenous attention is oriented in the same way when preparing to detect the appearance of a target versus preparing to discriminate one of its features. The results of the two experiments reported seem to indicate that different processes were mobilized by endogenous attention depending on whether participants were attending to detect or discriminate the target, modulating perceptual integration differently.

ILM was used to explore the role of task set in the implementation of endogenous attention. This illusion is created after the presentation of a peripheral cue followed by a line, which is perceived as moving away from the cue. We manipulated independently the location of the peripheral cue inducing the illusion and the allocation of endogenous attention. Results clearly showed that the illusion is entirely produced by the peripheral cue, ILM being therefore due to an apparent motion or impletion effect (Downing & Treisman, 1997). Importantly, although endogenous attention did not produce the illusion, it did modulate it, indicating a role of endogenous attention on perceptual integration or impletion processes. Further more importantly for our goals, the attentional modulation clearly depended on task set, i.e., on what were participants attending for. Endogenously attending to the location of the cue enhanced the ILM effect but only when participants were performing a secondary discrimination task. Our results have shown that endogenously attending to detect the appearance of the target does not facilitate the integration between the cue and the target that causes the perception of ILM. In fact, making the cue spatially informative (of either the same or the opposite location) reduces the perception of the illusion, as compared with a non-predictive cue block (Experiment 2). Attending to detect the appearance of a target seems to prepare the system not to integrate information, as to be able to detect new events. Attending to discriminate target's features, however, seems to prepare the system to integrate information at the attended location or object, until enough information is accumulated to perform the task. Lupiáñez, Milliken & colleagues (Lupiáñez, Ruz et al., 2007; Milliken et al., 2000) have proposed that in attentional orienting procedures with detection tasks, the most important process might be to segregate the onset of the target from that of the peripheral cue. The system needs to be ready to make a fast response when a stimulus is detected, and the only confusion might arise from the onset of the cue. In our paradigm, this segregation process might interfere with the integration of the cue and the line, especially when the cue carries a meaning and participants are trying to apply it.

Additionally, the analysis of the ERPs to the cue revealed that the cue was processed differently in the different attentional conditions depending on the task at hand. In particular, the endogenous attentional effect was only observed in the discrimination task. The latency of a parietal N200 component is in line with the ILM results. The latency of this component was delayed when the cue predicted the appearance of the target at the same location (in which more illusion was perceived). We hypothesized that the latency of the N200 component might be reflecting the time the cue is being analyzed by the perceptual system in order to be integrated with the line. The more time the better integration. In the detection task, although not significant, the latency of the component was maximally delayed in the non-predictive cue block, in which more ILM was also perceived.

In summary, the results of the present experiments lead us to conclude that endogenous attention is differentially implemented depending on the task at hand. Although ILM is not produced by endogenous attention, it can be modulated if the task set of the participant favours the integration between the cue and the line. And the integration between the cue and the line might be related to the latency of a N200 parietal component elicited by the cue.

Chapter V

Comparing intramodal and crossmodal cuing in the endogenous orienting of spatial attention

The content of this chapter has been published as Chica, A. B., Sanabria, D., Lupiáñez, J., & Spence, C. (2007). Comparing intramodal and crossmodal cuing in the endogenous orienting of spatial attention. Experimental Brain Research, 179(3), 353-364.

ABSTRACT

The endogenous orienting of spatial attention has been studied with both informative central cues and informative peripheral cues. Central cues studies are difficult to compare with studies that have used uninformative peripheral cues due to the differences in stimulus presentation. Moreover, informative peripheral cues attract both endogenous and exogenous attention, thus making it difficult to disentangle the contribution of each process to any behavioural results observed. In the present study, we used an informative peripheral cue (either tactile or visual) that predicted that the target would appear (in different blocks of trials) on either the same or opposite side as the cue. By using this manipulation, both expected and unexpected trials could either be exogenously cued or uncued, thus making it possible to isolate expectancy effects from cuing effects. Our aim was to compare the endogenous orienting of spatial attention to tactile (Experiment 1) and to visual targets (Experiment 2) under conditions of intramodal and crossmodal spatial cuing. The results suggested that the endogenous orienting of spatial attention should not be considered as being a purely supramodal phenomenon, given that significantly larger expectancy effects were observed in the intramodal cuing conditions than in the crossmodal cuing conditions in both experiments.

Introduction

Attention can be oriented to a position in space either endogenously (e.g., following an instruction to attend to that location), or exogenously (e.g., following the presentation of a stimulus at that location). The “Posnerian” cuing paradigm has been widely used to study the orienting of spatial attention over the last three decades or so (e.g., Posner, 1980). Research has shown that attention can be oriented to a location in space by means of either central or peripheral cues. Central cues typically consist of stimuli presented at fixation (e.g., an arrow pointing to the left or right), with participants having to orient their attention voluntarily according to the informational content of the cue. Peripheral cues consist of stimuli presented at peripheral locations, which are thought to capture spatial attention exogenously (automatically) at that spatial location (e.g., Yantis & Jonides, 1990). Both types of cues can be either spatially-informative or spatially-uninformative concerning the likely location of a subsequently-presented target stimulus. Researchers have typically used informative central or peripheral cues to elicit endogenous attentional orienting, while spatially non-predictive peripheral cues have been used to investigate exogenous spatial attention.

A number of researchers have attempted to compare the effects of the endogenous and exogenous orienting of spatial attention using informative central cues versus spatially non-predictive peripheral cues (Funes et al., 2005; Klein, 2004, for recent reviews). These researchers have shown that longer intervals are needed in order for participants to orient their attention endogenously by means of a central informative cue, than to orient their attention exogenously by means of a spatially non-predictive peripheral cue (e.g., Eimer, 2000; Müller & Findlay, 1988). This difference may be due to endogenous attentional orienting taking place more slowly than exogenous orienting, or to the extra time needed to interpret the central cue as compared to the more immediate response elicited by the peripheral cue (e.g., Eimer, 2000). Qualitative differences between the effects of the two types of cues have also been observed in several studies (e.g., Spence & Driver, 1994). For example, while peripheral cues (either spatially non-predictive, Briand, 1998; or predictive, Briand & Klein, 1987) produce larger effects in visual conjunction search tasks than in feature search tasks, non-informative central arrow cues have been shown to produce similar effects in both tasks (see Klein & Shore, 2000). More recently, Funes, Lupiáñez, and Milliken (Funes et al., 2007) highlighted a double dissociation between the effects of central and peripheral cues on a spatial version of the Stroop task.

Note, however, that the differences between the consequences of the exogenous versus endogenous orienting of spatial attention observed in the above-mentioned studies could either be due to the mechanism orienting spatial attention (i.e., endogenous or exogenous), and/or to the informative value of the cue (spatially predictive vs. non-predictive), and/or to other perceptual factors related to the fact that in exogenous orienting studies an object (the cue) is presented at approximately the same position as the target on a proportion of trials (i.e., on cued trials), while under conditions of central cuing, there is absolutely no spatial correspondence between the cue and target stimuli.

The use of informative peripheral cues provides one means of avoiding these problems. In many previous studies, the cue predicted the target location on the majority (e.g., 80%) of trials. Note that expected trials are always cued under such conditions, whereas unexpected trials are always uncued[5]. Typically, RTs are faster for cued than uncued trials even at longer cue-target SOAs, where inhibition of return (IOR, slower RTs for cued than for uncued trials, see Klein, 2000, for a review) is observed when attention is oriented by spatially non-predictive peripheral cues (e.g., Posner et al., 1982; Spence & Driver, 1994, Experiment 4; 1996). Using such *predictive cues* (as expected trials are always cued), expectancy effects can be enhanced by a facilitatory effect attributable to the automatic capture of attention by the cue. At longer SOAs, IOR is not observed, and it has been argued that it may be masked by the endogenous orienting of spatial attention to the expected location (Cohen et al., 2005; Posner et al., 1982). In other studies, the cue has predicted the target's appearance on the opposite side on the majority of trials (e.g., 20% cued). Using such *counterpredictive cues*, an initial facilitatory effect is normally observed at the cued location (showing that the capture of attention by the peripheral cue cannot be automatically overridden at short SOAs, Warner et al., 1990), followed by faster RTs in uncued than in cued trials (i.e., an expectancy effect, Posner et al., 1982; Spence & Driver, 1994, Experiment 5). However, as expected trials are always uncued, this expectancy effect can also be enhanced by any IOR effects that may be present (Posner et al., 1982). Therefore, by using only predictive or counterpredictive peripheral cues, it is simply not possible to separate the effects of the endogenous versus exogenous (facilitation and IOR) orienting of spatial attention.

Researchers studying crossmodal attention have also investigated the nature of the attentional links between sensory modalities under conditions of endogenous spatial orienting (see Spence & Driver, 2004, for a recent review). As in the intramodal studies mentioned earlier, informative peripheral cues have been used, predicting either the same (e.g., Buchtel & Butter, 1988; Butter, Buchtel, & Santucci, 1989; Cohen et al., 2005; Mondor & Amirault, 1998) or opposite side of target appearance (Klein, Brennan, D'Aloisio, D'Entremont, & Gilani, 1987). For example, Mondor and Amirault compared the cuing effects elicited by visual and auditory cues on the subsequent discrimination of visual and auditory targets. When informative cues were used (predicting the same position of target appearance),

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[5] In the present paper, cued and uncued locations refer to target locations preceded or not by a stimulus (the cue) at that spatial location, while expected and unexpected locations refer to locations where the participants endogenously expect the target to occur (due to verbal instructions and target probability manipulations).

significantly larger cuing (and/or expectancy) effects were reported in the intramodal than in the crossmodal conditions. By contrast, Butter et al. (1989) compared the cuing effects elicited by informative visual and tactile peripheral cues (predicting the same position of target appearance) in the detection of either visual or tactile targets. They reported larger cuing-expectancy effects when tactile cues were used than when visual cues were used, in both visual and tactile detection tasks (see also Tassinari & Campara, 1996). This result might, however, reflect differences in cue salience rather than expectancy differences. Note that in both studies cues predicting the same position were used, thus making it impossible to isolate the endogenous and exogenous orienting of spatial attention, as expected trials were always cued while unexpected trials were always uncued (Spence, Nicholls, Gillespie, & Driver, 1998).

In the experiments reported here, we attempted to isolate the endogenous orienting of spatial attention from cuing effects (see Chica, et al., 2006; Chica & Lupiáñez, 2004; Lupiáñez et al., 2004), thus being able to compare the endogenous orienting of attention in intramodal (visual-visual, tactile-tactile) and crossmodal (visual-tactile and tactile-visual) conditions. An informative peripheral cue was used (either tactile or visual), which predicted that the target would appear, in different blocks of experimental trials, on either the same or opposite side as the cue. Crucially, by using this experimental manipulation, expected and unexpected location trials could be either cued or uncued (see the Methods of Experiment 1 for further details), thus avoiding the confounds caused by the use of only predictive or only counterpredictive cues that were present in previous research (e.g., Buchtel & Butter, 1988; Butter et al., 1989; Cohen et al., 2005; Klein et al., 1987; Mondor & Amirault, 1998). The same visual and tactile cues were presented in both experiments, with tactile targets being presented in Experiment 1, while visual targets were presented in Experiment 2.

EXPERIMENT 1. Tactile targets

The principal aim of Experiment 1 was to compare the endogenous orienting of spatial attention to tactile targets under conditions of intramodal versus crossmodal spatial cuing. To this end, a predictive peripheral cue was used, that predicted in different blocks of trials, that the target would either appear on the same or opposite side as the cue. As noted in the Introduction, by using this manipulation, expected and unexpected trials could be either cued or uncued (see the Procedure for details). This aspect of the design enabled us to avoid possible confounds attributable to the use of only predictive or only counterpredictive cues, in which endogenous orienting cannot be disentangled from cuing effects (i.e., those effects due to the correspondence between the location of the cue and the target).

Methods

Participants. Thirty-six participants (17 men and 19 women) took part in this study. Their mean age was 26 years, with a range from 19 to 35 years. Thirty-two of the participants were right-handed, and the remaining 4 were left-handed, by self-report. All of the participants in this and the following experiments reported having normal or corrected to normal vision and normal tactile perception. They were naïve as to the purpose of the experiment and all received a 5 UK sterling gift voucher in return for their participation. The experiment comprised two experimental sessions, each lasting for approximately 60 minutes. The experiments were conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, Oxford University.

Apparatus and materials. The participants were seated in a dimly-illuminated booth. The fixation point consisted of an orange LED placed 30 cm directly in front of the participant. Two red LEDs and two tactile stimulators (bone conduction vibrators, Oticon-A, 100 Ohm; Hamilton, Scotland), situated 15 cm to the left and right of fixation, were used to present the cue (visual or tactile) and target (tactile) stimuli. Both the visual and tactile stimuli were presented at a clearly suprathreshold level. The red LEDs and the tactile stimulators were embedded in two blocks of foam. The distance between the LED and the tactile stimulator in each foam block was 2 cm vertically. The participants placed their index fingers on the tactile stimulators (see Figure 23). Two footpedals were situated under the table, one under the toes, and the other under the heel of the participant's right foot. White noise was presented over headphones at 70 dB(A) throughout each block of experimental trials, in order to mask any noises caused by the participants when they made their responses or by the operation of the LEDs or the vibrotactile stimulators. The LEDs, vibrotactile stimulators, and footpedals were all controlled via the parallel port of a computer using the E-prime software (Schneider et al., 2002), and a bespoke relay box.

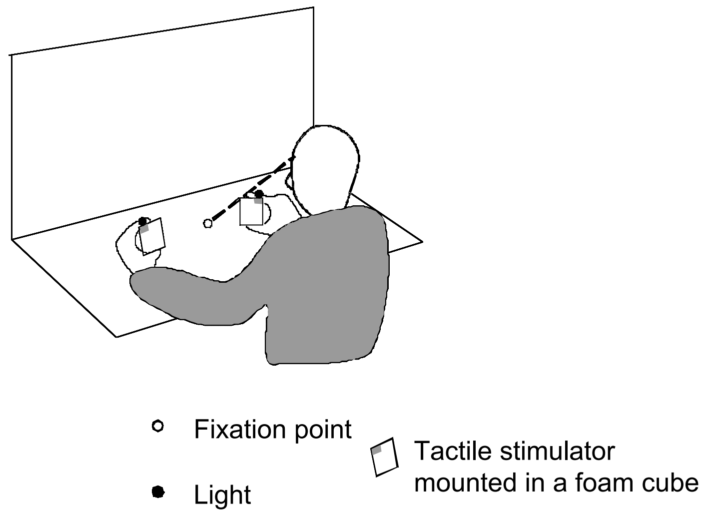


Figure 23. Schematic view of the experimental set-up. The dashed line indicates the direction of fixation.

Procedure. The orange fixation LED was illuminated at the beginning of each trial. This LED remained illuminated until the offset of the target. One second after the onset of the fixation light, a cue was presented to either the left or right side. In the intramodal cuing condition, the cue consisted of a 40 ms vibration of one of the two vibrators, while in the crossmodal condition, the cue instead consisted of the illumination of one of the two peripheral LEDs for 40 ms. The target was presented after a variable SOA of either 200 or 1000 ms. The target consisted of either a pulsed (four 40 ms vibrations separated by 10 ms gaps) or continuous (a single continuous vibration lasting for 200 ms) vibrotactile stimulus. The participants were required to discriminate between the pulsed and continuous vibrotactile targets with their right foot, lifting their toes in response to one type of vibration and their heel in response to the other (with the response mapping counterbalanced across participants). If no response was made within 2000 ms of target onset, or if the participants made the wrong response, the fixation light was flashed twice for 50 ms, with a 50 ms interstimulus interval. The same feedback was provided when participants made an anticipatory response. The next trial started after an intertrial interval of 1000 ms.

On 20% of the trials, no target was presented and no response was required (catch trials). On the remaining 80% of trials, a target was presented, and the cue correctly predicted the location of the target on 75% of those trials. In different blocks of trials the cue was either predictive or counterpredictive with regard to the target location. Thus, in one block of trials, the position of the cue predicted the position of the target. Thus, when the target appeared at the location predicted by the cue, these were classified as expected location trials (because the participants were presumably expecting the target to appear at that location) and also cued location trials (because the cue and target appeared at the same position). In contrast, those trials from the block in which the target appeared at the opposite location to the cue were both unexpected and uncued (see Figure 24). In the other block of trials, the cue predicted that the target would appear on the opposite side to the cue. In this case, if the target did indeed appear on the opposite side to the cue, these were expected but uncued location trials. However, if the target appeared at the same position as the cue, these were classified as unexpected but cued location trials. Thus, both expected and unexpected trials could be either cued or uncued. The participants were verbally instructed as to whether the cue would predict the same or opposite position as the target in the majority of trials at the start of each block of trials (although they were not informed of the exact cue validities that would be used), and the participants were encouraged to take this information into account. The order of presentation of the predictive and counterpredictive cue blocks was also counterbalanced across participants.

The experiment consisted of two sessions, one intramodal (tactile cues and tactile targets) and the other crossmodal (visual cues and tactile targets), with the order of presentation of the sessions counterbalanced across participants.

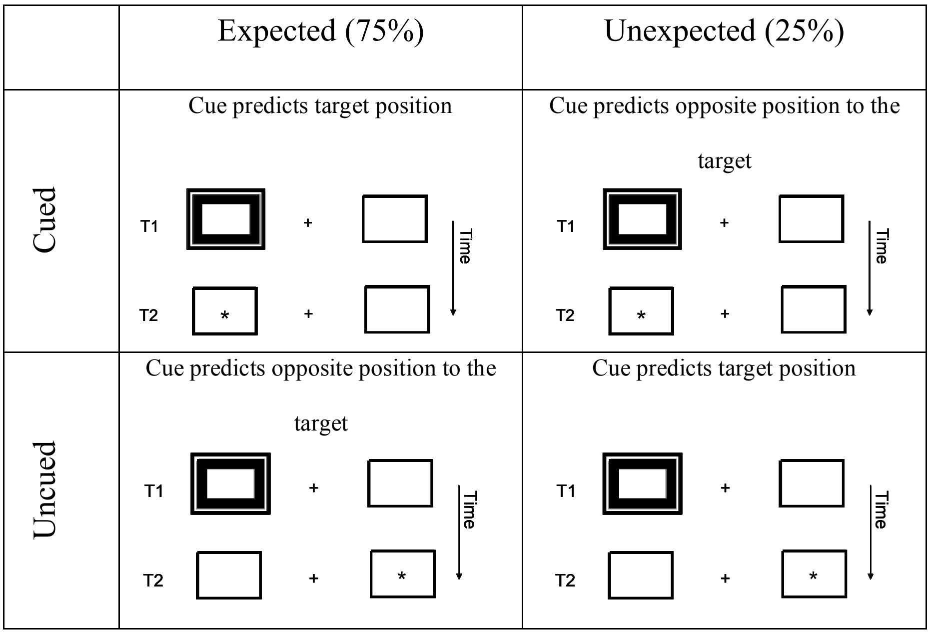


Figure 24. Examples of four of the trial types used in Experiments 1 and 2. The cue is represented symbolically by a box of thicker outline, while the target is represented symbolically by an asterisk. The cue either predicted the same or opposite position as the target (75% validity on trials on which a target was presented), in different blocks of trials. Therefore, in the block with predictive cues, the

data from the expected-cued (top left panel) and unexpected-uncued (bottom-right panel) conditions were collected for the analysis. In the block with counterpredictive cues, data from the expected-uncued (bottom-left panel) and the unexpected-cued (top-right panel) conditions were collected for the analysis.

Design. The 4 factors in the experimental design were Trial Type (Intramodal vs. Crossmodal), Expectancy (Expected location trials vs. Unexpected location trials), Cuing (Cued location trials vs. Uncued location trials), and SOA (200 vs. 1000 ms), with all of the variables manipulated on a within-participants basis. Each session involved two experimental blocks of 240 trials, each preceded by 20 practice trials. Thus, each participant completed 480 experimental trials per session (384 of them being target trials, and the remainder being catch trials). Thus, for each experimental condition resulting from the crossing of the Trial Type (intramodal and crossmodal), Cuing (cued and uncued trials), and SOA (200 or 1000 ms) factors, there were 48 observations for unexpected location trials, and 144 for expected location trials. The participants were encouraged to take a break after every 60 trials.

Results and discussion

Trials on which no response was made (misses; 1.0% of trials overall) and false alarms (i.e., erroneous responses on catch trials; 0.5%) were eliminated from the data analysis. Trials on which a wrong key press was made (2.7%) were discarded from the RT analysis. Finally, RTs above and below 2.5 standard deviations from the mean RT by experimental condition (Trial Type, Expectancy, Cuing, and SOA) and participant were eliminated as outliers (3.0% of trials in total). In this and the subsequent experiment reported in this study, participants were excluded from the analysis if their accuracy fell below 70% correct in either of the experimental sessions. No participants had to be eliminated from the analysis of Experiment 1.

The mean RT data (see Miller, 1988) were submitted to a repeated-measures analysis of variance (ANOVA), with the factors of Trial Type (2), Expectancy (2), Cuing (2), and SOA (2), see Table 13. The analysis revealed a borderline-significant main effect of Trial Type, $F(1,35)=4.03$, $MSE=12065$, $p=.05$, showing that participants responded more rapidly on crossmodal trials (M=702 ms) than on intramodal trials (M=721 ms) overall. The main effect of Expectancy was also significant, $F(1,35)=56.26$, $MSE=807$, $p<.0001$, with participants responding more rapidly when the target was presented at the expected location

(M=703 ms) than when it was presented at the unexpected location (M=721 ms). Trial Type interacted with both Expectancy, *F*(1,35)=14.42, *MSE*=482, *p*<.001, and SOA, *F*(1,35)=11.68, *MSE*=849, *p*<.01. The three-way interaction between Trial Type, Expectancy, and SOA was also significant, *F*(1,35)=9.2, *MSE*=466, *p*<.01. Two further ANOVAs for each SOA revealed that at the shorter SOA (200 ms), the interaction between Trial Type and Expectancy was significant, *F*(1,35)=26.79, *MSE*=414, *p*<.001, showing that, although the expectancy effect was statistically significant in both intramodal, *F*(1,35)=103.9, *MSE*=380, *p*<.001, and crossmodal conditions, *F*(1,35)=7.1, *MSE*=350, *p*<.05, it was significantly larger in the intramodal condition (mean expectancy effect=mean RT difference between unexpected and expected trials, of 33 ms) than in the crossmodal condition (expectancy effect of 8 ms). However, at the longer SOA, the expectancy effect was similar in magnitude for both the intramodal and crossmodal conditions (mean expectancy effects of 16 ms and 14 ms, respectively), *F*<1 (see Figure 25A).

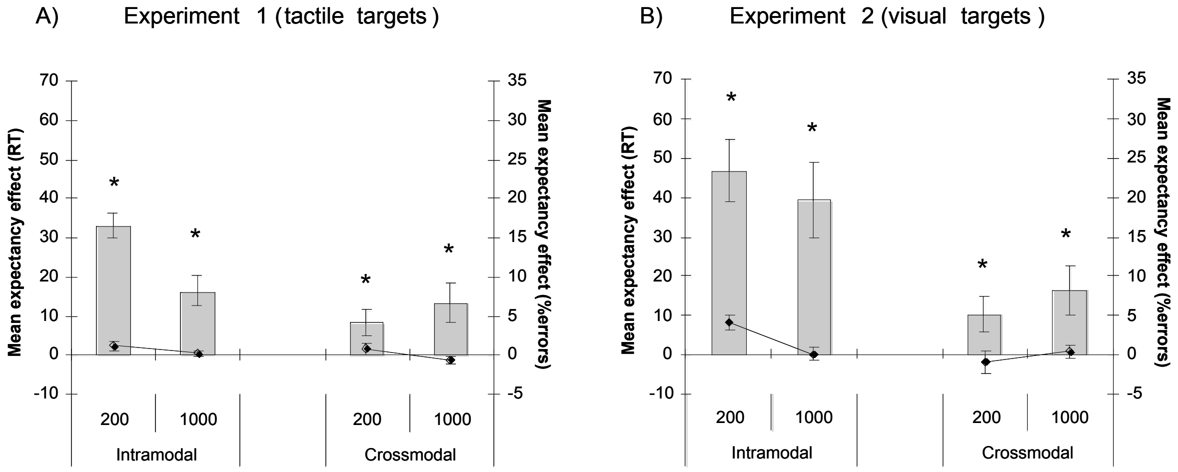


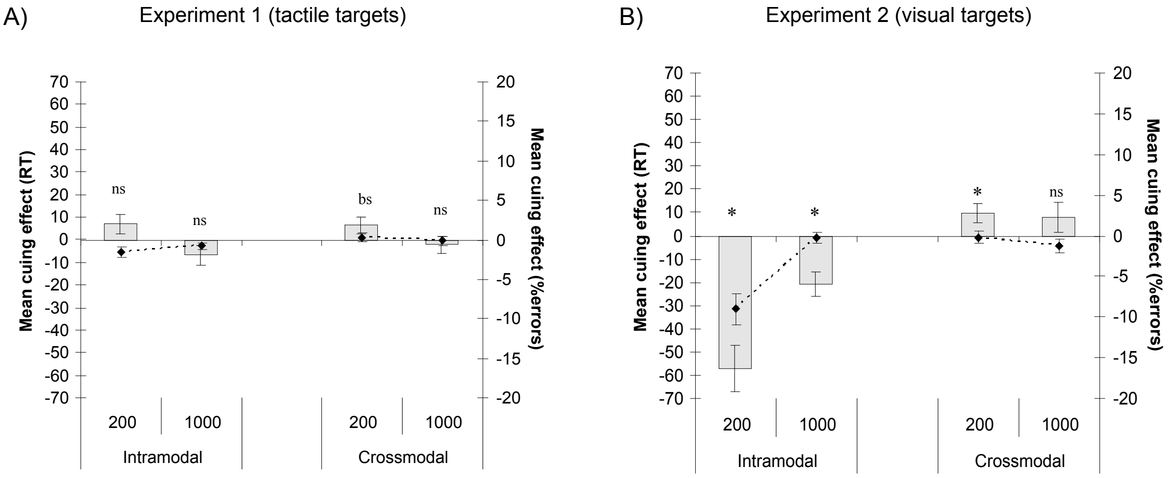
Figure 25. Mean expectancy effect, ±SE, for the RT (bars) and error data (lines), in Experiment 1, tactile targets (A), and Experiment 2, visual targets (B), in both the intramodal and crossmodal conditions. Asterisks represent significant effects: p *< .05.*

Table 13. Mean reaction times (+ SE), in ms, and mean error rates, as a function of the Trial Type, Expectancy, Cuing, and SOA factors in Experiments 1 (tactile targets) and 2 (visual targets). The bottom row shows the mean cuing effect (mean RT in uncued minus cued trials) for each experimental condition.

	Experiment 1 (tactile targets)															
	Intramodal								Crossmodal							
	Expected				Unexpected				Expected				Unexpected			
SOA (ms)	200		1000		200		1000		200		1000		200		1000	
	Cued	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**
RT (ms)	707	710	712	706	736	748	729	722	695	694	702	698	695	710	714	714
SE	14.1	14.0	14.0	14.3	14.7	15.6	14.2	14.0	16.6	15.5	16.0	16.0	16.4	15.7	16.3	15.5
Errors (%)	4.6	3.0	3.5	2.7	5.2	3.1	4.7	3.4	3.1	2.9	3.9	3.7	4.3	4.8	4.1	3.7
Mean RT cuing effect	3 ms		-6 ms		12 ms		-7 ms		-1 ms		-4 ms		15 ms		-0 ms	

	Experiment 2 (visual targets)															
	Intramodal								Crossmodal							
	Expected				Unexpected				Expected				Unexpected			
SOA (ms)	200		1000		200		1000		200		1000		200		1000	
	Cued	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**	**Cued**	**Uncued**
RT (ms)	792	733	728	705	837	781	765	746	702	707	711	715	707	722	723	735
SE	26.0	21.1	18.3	16.3	27.8	26.3	24.9	22.0	18.6	17.1	20.7	17.2	17.3	19.2	15.6	18.6
Errors (%)	15.9	6.2	5.1	5.0	19.3	10.9	5.4	4.9	7.5	6.0	6.3	5.7	5.3	6.4	7.2	5.4
Mean RT cuing effect	-59 ms		-23 ms		-56 ms		-19 ms		5 ms		4 ms		15 ms		12 ms	

The interaction between Cuing and SOA was significant, *F*(1,35)=5.96, *MSE*= 767, *p*<.05, and can be attributed to the borderline-significant facilitatory effect (i.e., faster responses on cued than on uncued trials) observed at the shorter SOA (mean cuing effect, RT difference between uncued and cued trials of 6 ms), *F*(1,35)=3.93, *MSE*=819, *p*=.05, while the cuing effect was negative at the longer SOA (mean cuing effect of - 4 ms), *F*(1,35)=1.77, *MSE*=849, *p*=.19. The Cuing x SOA interaction did not depend on Trial Type, *F*<1 (see Figure 26A).



<u>Figure 26</u>. Mean cuing effect, ±SE, for the RT (bars) and error data (lines), in Experiment 1, tactile targets (A), and Experiment 2, visual targets (B), in both the intramodal and crossmodal conditions. Asterisks represent significant effects: p *< .05.*

Importantly, there was no interaction between Expectancy and Cuing, F<1, nor between Expectancy x Cuing x SOA, *F*(1,35)=1.19, *MSE*=8.71, *p*=.28. This absence of any interaction suggests that the differences found in expectancy effects between intramodal and crossmodal conditions were not due to differences in cuing effects. None of the other terms in the overall analysis of the RT data reached significance.

A similar analysis of the error data revealed a significant main effect of Expectancy, *F*(1,35)=10.02, *MSE*=8.37, *p*<.01, with participants making fewer errors when the target appeared on the expected side (M=3.4%) than when it appeared on the unexpected side (M=4.1%). Thus, participants responded more rapidly to targets at the expected location than at the unexpected location and also made fewer errors, ruling out any criterion shifting account for the expectancy effect observed. The interaction between Trial Type and SOA was also significant, *F*(1,35)=4.68, *MSE*=1.7, *p*<.05; in the intramodal condition, lower error rates were observed at the longer SOA (M=3.2%) as compared to the shorter SOA (M=4.4%), *F*(1,35)=7.97, *MSE*=12.72, *p*<.01. However, in the crossmodal condition, the accuracy of participants' responses was similar at both intervals (both Ms=3.8%), *F*<1. None of the other main effects or interactions reached significance.

The results of Experiment 1 revealed that participants were able to voluntarily (i.e., endogenously) attend to the position predicted by the cue. When expectancy effects are isolated from cuing effects, the endogenous orienting of spatial attention was larger in the intramodal than in the crossmodal condition, this difference was primarily seen at the shorter SOA. The absence of any interaction between expectancy and cuing effects suggests that this result cannot be explained by differences in cuing effects in the two conditions. This result can, however, be interpreted in terms of the intramodal condition giving rise to larger expectancy effects than the crossmodal condition, and/or in terms of participants orienting their endogenous attention more rapidly in the intramodal condition than in the crossmodal condition. When performing a tactile discrimination task, the 1000 ms SOA used might provide sufficient time to completely orient endogenous attention (reaching a ceiling effect) in both the intramodal and crossmodal conditions.

It could also be argued that the larger expectancy effect reported in the intramodal as compared to the crossmodal condition at the short SOA was due to the slower processing of the visual cue, which did not allow endogenous orienting to be completed in the crossmodal condition. The fact that the expectancy effect observed at the short SOA was also significant in the crossmodal condition makes this hypothesis unlikely. Nevertheless, Experiment 2 was carried out in order to test this hypothesis. The same visual and tactile cues were used, but visual (rather than tactile) targets were now presented. If the differences found in Experiment 1 between the intramodal and the crossmodal endogenous orienting of spatial attention were due to differences in the amount of time required to process the cue stimuli, larger expectancy effects should be observed in the crossmodal than in the intramodal condition in this experiment.

EXPERIMENT 2. Visual targets

In Experiment 2, the same visual and tactile cues were presented, but a visual discrimination task was now used. This enabled us to evaluate an explanation of the results of Experiment 1 that was based on the specific properties of the cuing stimuli used.

Methods

Participants. Twenty-four participants (6 men and 18 women) took part in this study. They had a mean age of 23 years, with a range from 18 to 30 years. Twenty-two of the participants were right-handed, and 2 were left-handed, by self-report.

Apparatus, materials, design, and procedure. These were identical to Experiment 1 with the following exceptions: White noise was presented by means of a loudspeaker cone placed directly above the table. Visual targets were presented instead of tactile targets. The target stimuli consisted of either the pulsed or continuous illumination of one of the red LEDs presented to either side (i.e., the task was once again non-spatial in nature). The pulsed target consisted of four 40 ms onsets of one of the LEDs, separated by 10 ms gaps, while the continuous target consisted of the continuous illumination of one of the LEDs for 200 ms.

Results and discussion

Four of the participants were eliminated from the analysis of the data because their accuracy fell below 70% in one of the sessions (the intramodal session in all cases). Misses (1.9% of trials) and false alarms (1.8% of trials) were also eliminated from the analysis. Trials on which a wrong key-press was made (6.6% of trials) were discarded from the RT analysis. Finally, RTs above and below 2.5 standard deviations from the mean RT by experimental condition (Trial Type, Expectancy, Cuing, and SOA) and participant were eliminated as outliers (leading to the removal of 3.1% of trials overall).

The mean RT data were submitted to an ANOVA with the factors of Trial Type (2), Expectancy (2), Cuing (2), and SOA (2) (see Table 13). The analysis revealed a significant main effect of Trial Type, $F(1,19)=14.55$, $MSE=11510$, $p<.01$, with participants responding significantly more rapidly on the crossmodal trials than on intramodal trials (M=715 vs. 761 ms, respectively). The main effect of Expectancy was also significant, $F(1,19)=31.83$, $MSE=1994$, $p<.001$, with participants responding more rapidly when the targets were presented at the expected location (M=724 ms) than when they were presented at the unexpected location (M=752 ms). Just as for Experiment 1, Expectancy interacted with Trial Type, $F(1,19)=19.67$, $MSE=903$, $p<.001$: Although the effect of Expectancy was significant in both the intramodal and crossmodal conditions, $F(1,19)=34.90$, $MSE=2126$, $p<.001$, and

F(1,19)=9.12, *MSE*=771, *p*<.01, respectively, it was significantly larger (by 30 ms) in the former case (see Figure 25B).

The main effects of Cuing, *F*(1,19)=13.34, *MSE*=1371, *p*<.01, and SOA, *F*(1,19)=29.68, *MSE*=984, *p*<.001, were significant, as were the interactions between SOA and Trial Type, *F*(1,19)=49.40, *MSE*=1486, *p*<.001, Trial Type and Cuing, *F*(1,19)=36.76, *MSE*=1248, *p*<.001, and between Trial Type, Cuing, and SOA, *F*(1,19)=24.01, *MSE*=306, *p*<.001 (see Figure 26B). The latter interaction can be attributed to participants responding more slowly to cued versus uncued trials in the intramodal condition, at both the short and long SOAs, *F*(1,19)=34.98, *MSE*=1877, *p*<.001, and *F*(1,19)=11.77, *MSE*=735, *p*<.01, respectively. In the crossmodal condition, by contrast, a significant facilitatory effect was observed at the short SOA, *F*(1,19)=6.47, *MSE*=293, *p*<.05, while no cuing effect was observed at the longer SOA, *F*(1,19)=2.37, *MSE*=528, *p*=.13 (see Figure 26B). As in the previous experiment, there was no interaction between Expectancy and Cuing, F<1, or between Expectancy, Cuing, and SOA, F<1. Thus, the larger expectancy effect found for intramodal than crossmodal conditions in this experiment cannot be accounted for by any differences in cuing effects.

A similar analysis of the error data revealed a significant main effect of Trial Type, *F*(1,19)=4.66, *MSE*=140.58, *p*<.05, with participants making fewer errors in the crossmodal condition than in the intramodal condition (M=6.2% and 9.0%, respectively). There was also a significant interaction between Trial Type and SOA, *F*(1,19)=20.33, *MSE*=60.22, *p*<.001, with participants making significantly more errors in the intramodal condition than in the crossmodal condition at the short SOA (M=6.3% and M=13.0%, respectively), *F*(1,19)=11.64, *MSE*=157.78, *p*<.01, but not at the long SOA (M=6.1% and M=5.1%, respectively), *F*(1,19)=1.03, *MSE*=43.04, *p*=.13. Trial Type interacted with Expectancy, *F*(1,19)=4.68, *MSE*=24.08, *p*<.05, and the three-way interaction between Trial Type, Expectancy, and SOA was also significant, *F*(1,19)=7.16, *MSE*=19.23, *p*<.05: That is, participants responded more accurately in the expected than in the unexpected location trials at the short SOA, in the intramodal (M=11.0% and 15.1%, respectively), but not in the crossmodal condition (M=6.7% and 5.8%, respectively). The main effects of Cuing, SOA, and the interaction between Cuing and SOA were all significant, *F*(1,19)=16.89, *MSE*=33.89, *p*<.001, *F*(1,19)=19.71, *MSE*=66.13, *p*<.001, and *F*(1,19)=8.17, *MSE*=36.25, *p*<.05, respectively. Finally, the interaction between Trial Type, Cuing, and SOA also reached significance, *F*(1,19)=18.07, *MSE*=26.56, *p*<.001. This latter interaction presumably reflects the fact that participants made more errors in cued than uncued trials in the intramodal condition at the short SOA, *F*(1,19)=18.59, *MSE*=7.59, *p*<.001, but not at the long SOA, *F*<1. However, in the crossmodal condition no significant cuing effects were observed at either interval, *F*<1, and *F*(1,19)=1.96, *MSE*=15.24, *p*=.17, respectively.

The results of Experiment 2 again showed that the main effect of Expectancy was larger in the intramodal condition than in the crossmodal condition when participants had to perform a visual discrimination task. Responses were slower and less accurate in the intramodal condition than in the crossmodal condition. This effect might be due to the similarity between the cue and target stimuli (which was greater in the intramodal condition than in the crossmodal condition) thus meaning that the target was less distinct (note that, in general, the effect of trial type was greater at the short SOA, where similarity might play a greater role). A similar explanation might be extended to cuing effects (mainly at the short SOA): The participants responded more slowly to targets appearing at the same location as the cue versus at the opposite location. This effect was larger in the intramodal than in the crossmodal condition. We speculate that, due to the similarity between the cue and target (specially in the intramodal condition), the effect observed could be caused by the increased difficulty associated with discriminating the presence of two events presented on the same side (the cue and the target in cued trials) as compared to discriminating two events presented on different sides (uncued trials; Lupiáñez & Weaver, 1998). This effect was mainly observed for visual targets rather than for tactile targets. This result is consistent with previous results showing that tactile stimuli access consciousness faster than visual stimuli (Spence, Shore, & Klein, 2001). Therefore, the difficulty in discriminating the stimuli at the same location would be smaller in the intramodal tactile condition. Given the rapid access to consciousness of tactile stimuli, at the 200 ms SOA, participants may have had little problem in segregating the cue from the target as constituting separate events, thus reducing the perceptual difficulty and therefore leading to better performance on cued trials. We do not have any evidence as to whether the negative cuing effect observed at the longer SOA is (or is not) similar in nature to the one observed at the short SOA. The negative cuing effect observed at the longer SOA might be explained by a similar difficulty in discriminating two events presented at the same location versus opposite locations (although the effect would be expected to be smaller given the longer time interval between the cue and target), or else it might be due to other processes such as the exogenous disengagement of spatial attention (although researchers would need to invest more of an effort in order to understand what it means to exogenously disengage one's attention from the cued location; Berlucchi, 2006). Moreover, it is important to highlight the fact that the expectancy effect did not interact with cuing in either of the experiments reported here, thus indicating that the larger expectancy effect found for intramodal versus crossmodal conditions cannot simply be explained by any differences in cuing effects.

In order to test for the presence of any effect of target modality in the present study, the mean RT data from Experiments 1 and 2 were submitted to a mixed ANOVA with the additional between-participants factor of Target Modality (Tactile vs. Visual). This analysis revealed a significant Trial Type x Expectancy x Target Modality interaction, $F(1,54)=5.16$, $MSE=630$, $p<.05$. Although the expectancy effect was larger in the intramodal than in the crossmodal condition for both visual and tactile targets, significantly larger expectancy effects were found for visual than for tactile targets in the intramodal (43 ms and 24 ms, respectively) but not in the crossmodal condition (14 ms and 11 ms, respectively). The larger intramodal expectancy effect for visual conditions versus tactile conditions might be a consequence of the increased difficulty of the visual discrimination task as discussed above.

General Discussion

The experiments reported in the present study were designed to compare the endogenous orienting of spatial attention under conditions of intramodal and crossmodal cuing. As highlighted in the Introduction, several previous studies have attempted to compare the endogenous and exogenous orienting of spatial attention using central cues versus spatially non-predictive peripheral cues (Funes et al., 2007; Klein & Shore, 2000; Müller & Rabbitt, 1989). However, central informative cues differ from spatially non-predictive peripheral cues in terms of the attentional system that is supposed to be oriented, and/or in the informative value of the cue itself, and also in the spatial correspondence between the cue and target that occurs with peripheral but not with central cues. Endogenous orienting effects have also been studied using peripheral informative cues that predict either the same (Butter et al., 1989; Cohen et al., 2005; Mondor & Amirault, 1998; Posner et al., 1982; Spence & Driver, 1994) or opposite (Klein et al., 1987; Posner et al., 1982; Spence & Driver, 1994) location as that of the target. However, informative peripheral cues will typically elicit both endogenous and exogenous shifts of spatial attention, thus making it difficult to isolate the contribution of each of these processes to any behavioural result observed.

Moreover, several researchers have argued that one cannot infer a great deal about the nature of any crossmodal links in endogenous spatial attention using peripheral informative cues as the informative value of the cue about the spatial location of the target is independent of the cue modality (Driver & Spence, 1994; Pashler, 1998; Spence & Driver, 1996; Spence, Nicholls, & Driver, 2001). The results of a study by Mondor and Amirault (1998), however, provide empirical evidence that is seemingly inconsistent with this view. In particular, they observed larger expectancy effects in intramodal than crossmodal audiovisual conditions. However, as their cues predicted that the target would appear at the same location, one cannot determine whether the larger effect found in intramodal versus crossmodal conditions was due to expectancy or to cuing effects. In the present study, we used informative peripheral cues that predicted that the target would appear at either the same or opposite location to the cue (in different blocks of experimental trials). By using this experimental manipulation, both expected and unexpected trials can be either cued or uncued, thus making it possible to isolate the endogenous orienting of spatial attention from cuing effects, and to compare this endogenous orienting under conditions of intramodal versus crossmodal cuing.

The results of the two visuotactile experiments reported in the present study, are similar to those reported by Mondor and Amirault (1998) in their study of audiovisual links in spatial attention: Although participants were able to attend endogenously to stimuli from either the same or different modality as the cue, the endogenous orienting of spatial attention was larger when the cue and target were presented in the same sensory modality than when they were presented in different sensory modalities (see Chambers, Stokes, & Mattingley, 2004; Spence, Pavani, & Driver, 2000, Experiment 1, for similar results). In the two experiments reported here, we were able to separate the endogenous orienting of spatial attention from cuing effects, and still found larger endogenous orienting effects in the intramodal condition than in the crossmodal condition. Therefore, we can conclude that, even when the expectancy and cuing effects elicited by peripheral cues are isolated, the magnitude of the effect of the endogenous orienting of spatial attention is greater when the cue and target are presented in the same modality than when they are presented in different sensory modalities.

Previous research has shown that non-spatial attention can be exogenously oriented to a specific sensory modality, producing a cost (at short SOAs) for responding to stimuli presented in a different sensory modality (e.g., Harvey, 1980; Spence, Nicholls et al., 2001; Turatto, Benso, Galfano, & Umiltà, 2002; Turatto, Galfano, Bridgeman, & Umiltà, 2004). In the experiments reported here, we observed that a cost in the endogenous orienting of spatial attention is also observed when the target stimulus is presented in a sensory modality different to that of the cue. This cost in the endogenous orienting to stimuli from different sensory modalities occurs in both visual and tactile discrimination tasks, thus showing that endogenous attention does not depend, at least in the present experiments, on the type of target presented (however, larger expectancy effects were found in the intramodal condition when visual targets were presented, as compared with tactile targets). The time-course of endogenous attentional orienting also seems to depend on the modality of the target involved. In the tactile discrimination task, expectancy effects were larger for intramodal than for crossmodal conditions only at the short SOA. We speculate that the 1000 ms SOA might provide sufficient time for participants to fully orient their endogenous attention in both intramodal and crossmodal conditions.

In conclusion, the results of the present study suggest that although attention can be oriented to stimuli from different sensory modalities, and that crossmodal endogenous orienting is similar when visual and tactile targets are presented, spatial attention is not controlled in an entirely supramodal manner (Spence, Nicholls, et al., 2001), since the effects of the endogenous orienting of spatial attention were more pronounced under intramodal than under crossmodal cuing conditions.

Chapter VI

General Discussion

Summary of the empirical evidence presented in the thesis

The principal aim of this thesis was to study the independence of endogenous and exogenous attention. We approached this topic by creating a paradigm in which endogenous and exogenous attention are manipulated orthogonally while presenting the same visual stimulation. In Chapter II.I. (Chica & Lupiáñez, 2004; Chica et al., 2006), the paradigm is presented. An informative peripheral cue predicts, in different blocks of trials, that the target would appear at either the same or the opposite location to the cue. Using this manipulation, both endogenously attended (expected) and endogenously unattended (unexpected) locations can be exogenously cued or uncued. If endogenous and exogenous attention consist of two separate attentional systems, they should produce their effects independently, without interacting with each other. The results revealed that in a simple detection task, IOR (a marker of exogenous attention) was independent of the endogenous orienting of spatial attention. That is, comparable IOR was observed at endogenously attended and unattended locations. In a discrimination task, however, IOR interacted with endogenous attention, with the effect being observed at the expected location, but not at the unexpected location.

A second aim of the thesis was to study the nature of IOR. In particular, the more extended hypothesis about the effect postulates that IOR consists of the inhibition of the return of attention to a previously attended location (Klein, 2000). Therefore, this hypothesis would predict that IOR would not be observed until attention is disengaged from the cued location. However, we have consistently demonstrated that IOR is observed at endogenously attended locations, from where attention has not been disengaged (Chica & Lupiáñez, 2004, under review; Chica et al., 2006). In Chapter II.II., we further explored the relation between IOR and attentional disengagement. In Experiments 1 & 2, endogenous attention was “disengaged” from the cued location using a central flash (exogenously) or given the high probability of the target to be presented at the central location (endogenously). It was shown that IOR was observed when attention was “disengaged” from the cued location exogenously by presenting a cue at fixation, but facilitation instead of IOR was observed when attention was disengaged from the cued location endogenously. Furthermore, in Experiment 3, using the same paradigm as in Chapter II.I., it was demonstrated that even after the endogenous disengagement of attention, facilitation instead of IOR can be observed in a discrimination tasks. Thus, the results of Chapter II lead us to conclude that 1) under certain circumstances, endogenous and exogenous attention can produce their effects independently of each other, supporting the idea that endogenous and exogenous attention are in fact two different attentional systems; 2) IOR can be completely dissociated from the endogenous disengagement of spatial attention, as the IOR effect can be observed at endogenously attended locations, and facilitation instead of IOR can be observed even after the endogenous disengagement of spatial attention from the cued location. In other words, attentional disengagement seems to be neither necessary nor sufficient for IOR to be observed.

Once we demonstrated the independence of the attentional systems, a further aim of our research was to study the differential effects of endogenous and exogenous attention at different stages of visual processing. In order to do that, we used a psychophysical and an electroencephalographic approach. In Chapter III.I. (Chica et al., submitted-a), we approached this topic using the Signal Detection Theory. We found that both endogenous and exogenous attention modulated perceptual sensitivity (as measured by d'). However, endogenous and exogenous attention produced their effects on d' independently of each other and with a different time-course. Exogenous attention produced its effects early in time, while endogenous attention produced its effects at longer SOAs. Additionally, only endogenous but not exogenous attention produced changes in response criterion. The criterion to detect information was more lenient when participants knew where the target would appear. We also observed an interaction between endogenous and exogenous attention in criterion measures. The criterion became more conservative at expected-cued trials, maybe due to the emergence of IOR. It seems that at long SOAs, IOR produces changes in response criterion mainly at expected locations. This result is consistent with the results observed in Chapter II: When participants were performing a discrimination task, IOR was only observed at expected locations. The results suggested that both exogenous facilitation and endogenous attention affect early stages of processing, while only endogenous attention produces further effects on later stages of processing. IOR, however, seems to affect response criterion, although the data of this chapter do not provide any information about the effect of IOR on perceptual processes.

In Chapter III.II. (Chica & Lupiáñez, under review), we further explored the effects of endogenous and exogenous attention on visual perception, but this time using ERPs. We studied the different modulations of endogenous and exogenous attention (in this experiment we used a long SOA to measure IOR) on early (P1-N1) and late (P3) stages of processing.

The results revealed that exogenous attention modulated early components more strongly than endogenous attention. IOR modulated P1 and N1 components of the wave, while endogenous attention did not produce a significant main effect on these components. Additionally, the electrophysiological marker of IOR (P1 reduction for cued versus uncued trials) was not eliminated when endogenous attention was oriented to the target location. Endogenous attention, however, modulated the effect of exogenous attention on P1, enhancing IOR at the endogenously attended location. Finally, both endogenous and exogenous attention modulated later stages of processing (P3), reducing its amplitude when the target was presented at the endogenously attended location, and at the location exogenously prioritized by IOR (i.e., the uncued location). Taking together the results of Chapter III, we can conclude that endogenous and exogenous attention produce different effects on the processing of visual information. Using the present paradigm, endogenous attention produced changes in perceptual sensitivity (d') but it did not produce significant main effects on P1 or N1. However, endogenous attention can modulate the exogenous attentional effect on P1, producing an enhancement of the IOR effect at the expected location (it also enhances the P1 modulation produced by exogenous facilitation, see Hopfinger & West, 2006). Regarding exogenous attention, we found that the facilitatory effect observed at short SOAs produced changes in perceptual sensitivity (d') but did not affect response criterion measures. IOR, however, modulated both early (P1 and N1) and late stages of processing (P3 & response criterion).

The final aim of the thesis was to explore whether the implementation of endogenous attention would depend on factors such as task set or the sensory modality in which the information is presented. In Chapter IV (Chica et al., submitted-b), we studied whether endogenous attention would be implemented differently depending on the task at hand. In order to do that, we used the Illusory Line Motion effect (ILM), which is caused by the presence of a peripheral cue near one of the edges of a static line. We wondered whether the effect of endogenous attention on the perception of ILM would depend on the task set of the participant while performing the task. The results revealed that endogenous attention modulates the ILM caused by the peripheral cue. Importantly, this modulation depended on the task at hand. ILM was only modulated by endogenous attention when participants were performing a secondary discrimination task as compared to a detection task. These results imply that endogenously attending to discriminate a target produces different consequences than endogenously attending to detect its appearance. Furthermore, the results shed some light on the current controversy about whether or not endogenous attention modulates the perception of ILM (Christie & Klein, 2005; Schmidt, 2000). Endogenous attention does not produce ILM, although it can modulate the effect caused by the peripheral cue if the conditions of the task favour the perceptual integration between the cue and the line (if participants adopt a set to discriminate target's features, or if attention is directed to objects versus space; Christie & Klein, 2005). The modulation of ILM was related to the latency of a parietal N2 component, which might reflex how long the cue is processed by the perceptual system in order to be integrated with the line.

Finally, in Chapter V (Chica et al., 2007), the effect of endogenous cuing on intramodal and crossmodal displays was explored. The intramodal displays consisted of either a visual cue and a visual target or a tactile cue and a tactile target. The crossmodal displays consisted of either a visual or a tactile cue, followed by a target from a different modality (also visual or tactile). The results showed that the endogenous orienting of spatial attention was larger when the stimuli were presented intramodally vs. crossmodally, leading us to conclude that although attention can be oriented to stimuli from different sensory modalities, spatial attention is not controlled in an entirely supramodal manner.

Endogenous and exogenous orienting mechanisms independently contributing to performance

The interest in the study of endogenous and exogenous attention has produced a rich literature that supports our findings. The following table (modified with permission from Klein, 2004) shows a summary of all the differential effects of endogenous and exogenous attention on the processing of information that we know so far (including the evidence presented in this thesis).

Table 14. Dissociations between endogenous and exogenous attention.

Behaviour	**Endogenous**	**Exogenous**
Speed (1)	Slow	Fast
Disruption by memory load (1)	YES	NO
Cue predictability (1)	YES	NO
Spread on objects (2)	Not necessarily	YES
Meridian Crossing effect (3)	YES	NO
Disengage deficit after parietal injury (4)	NO	YES
IOR (5)	NO	YES
Stimulus enhancement (6)	NO	YES
Interaction with visual search tasks (7)	NO	YES
Interaction with non-spatial expectancies (7)	YES	NO
Modulation of Spatial Stroop (8)	Increase	Decrease
Effects on early perceptual processes (9)	Smaller	Larger
Effects on later decisional stages (9)	YES	Facilitation: NO IOR: YES
Produces ILM (10)	NO	YES

Note: 1) Jonides (1981) and Müller & Rabbitt (1989). 2) Egly, Driver, & Rafal (1994) and Macquistan (1997), but see Abrams & Law (2000), and Goldsmith & Yeari (2003). 3) Reuter-Lorenz & Fendrich (1992). 4) Bartolomeo & Chokron (2002a), see also Losier & Klein (2001) for a review. 5) Posner & Cohen (1984). 6) Lu & Dosher (1998), but see Chapter III.I. of this manuscript for the discussion of the recent controversy on this data (Chica et al., submitted-a; Prinzmetal et al., 2005). 7) For a review see Klein & Shore (2000). 8) Funes et al. (2007). 9) See Chapter III of the present thesis (Chica et al., submitted-a; Chica & Lupiáñez, under review), see also Hopfinger & West (2006). 10) See Chapter IV of the present manuscript (Chica et al., submitted-b).

Some of the data presented in Table 14 can easily be explained by a single system orienting attention. Endogenous orienting is slower and more susceptible to interruption than exogenous orienting (Jonides, 1981). Endogenous attention is affected by the frequency with which the cues are given (Jonides, 1981), and does not produce IOR. In fact, it was proposed that endogenous attention to the location of a peripheral cue would mask the appearance of

IOR (Posner et al., 1982). However, most of the data are more easily explained assuming the independence of the two systems. Particularly, exogenous attention to a part of an object spreads to the whole object automatically, although endogenous attention only spreads to objects when specific instructions are given or when the attentional focus is controlled to be broad (Goldsmith & Yeari, 2003). The fact that exogenous attention is more object-based than endogenous attention, can also explain the differences found on the meridian crossing effect. In these experimental paradigms, stimuli locations are manipulated so that the objects can appear on either the same location of a vertical meridian or on different meridians. The effect consists of slower RTs when the cue and target are presented on opposite sides of the vertical meridian as compared to the same side, once distance is equated. The meridian effect is only observed with endogenous cues, but not with exogenous cues (Reuter-Lorenz & Fendrich, 1992). We reckon that if exogenous attention is object-based, the space in which the cue and target are presented would not have any effect. However, if endogenous attention is more space based, the location were stimuli are presented would produce the meridian effect. The effects of endogenous and exogenous attention on the ILM could also be interpreted on this object-space based frame. ILM is observed when attention is attracted exogenously to one of the edges of a line (by presenting a peripheral cue). Endogenous attention only produces the effect when attention is object-based, but not space-based (Christie & Klein, 2005). Moreover, we demonstrated that endogenous attention to the location of a peripheral cue only modulated the ILM effect when the task set favoured the integration between the cue and the line.

Exogenous and endogenous attention also differ on the stages of processing at which they produce their effects. Exogenous attention has been shown to produce signal enhancement and external noise reduction, while endogenous attention only affects external noise reduction (Lu & Dosher, 2005). We have also shown that both endogenous and exogenous attention (facilitatory effects) modulate perceptual sensitivity (d'), while only endogenous attention affected response criterion (Chica et al., submitted-a). IOR affected both early and late stages of processing as measured by P1-N1 and P3 modulations respectively (Chica & Lupiáñez, under review).

From all this evidence, two dissociations deserve special attention. The first reported dissociation by Klein & Shore (2000) has already been discussed in the Introduction. Brian and Klein (Briand, 1998; Briand & Klein, 1987) observed that the effect of exogenous attention on feature and conjunction tasks interacted, while the effect of endogenous attention on these tasks was additive. On the other hand, Klein (1994) observed that when non-spatial expectancies such as target frequency were manipulated, the manipulation affected mainly to endogenous attention, but not to exogenous attention. When these two pieces of data are taken together they constitute a double dissociation between exogenous and endogenous attention, which strongly support the independence of the two attentional systems. Klein & Shore concluded that exogenous attention affected early perceptual processes related with feature binding while endogenous attention affected later decisional processes. But perhaps the clearest evidence in this sense is the one observed by Funes et al. (2007), who have recently reported the first double dissociation[6], within the same experiment, on the qualitative effects of endogenous and exogenous attention. They studied the effects of endogenous attention (using spatially informative central cues), and exogenous attention (using spatially non-informative peripheral cues), in the spatial Stroop task. In this task, an arrow is presented either to the left or to the right of fixation. The arrow can also be pointing either left or right, and participants are required to respond to the location the arrow is pointing at. Note that when the arrow is presented on the left, pointing left, the location where the arrow is presented is congruent with the location the arrow is pointing at. However, when the arrow is presented on the left, pointing right, the location of the arrow is incongruent with the location the arrow is pointing at. Generally, RTs are faster on congruent trials than on incongruent trials (i.e., the spatial Stroop effect). Interestingly, Funes at el. showed that the spatial Stroop effect was differentially modulated by endogenous and exogenous attention: While exogenous attention decreased the spatial Stroop effect (smaller effect at the cued location, mostly at short SOAs), endogenous attention increased the spatial Stroop effect (larger effect at the

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[6] Hein, Rolke, & Ulrich (2006) have also reported a dissociation on the effects of endogenous and exogenous attention on temporal resolution tasks. Yeshurun & Levy (2003) were the first to report that exogenous attention impaired temporal resolution tasks such as detecting a gap within two sequentially presented stimuli. Hein, et al. (2006) extended this finding reporting that while exogenous attention (triggered by either non-informative or informative peripheral cues) impaired temporal resolution tasks, endogenous attention (triggered by a central informative cue) enhanced performance on those tasks. However, Chica & Christie (under review; see Appendix II) controlled for speed-accuracy trade-offs using an exogenous cuing paradigm, and found that when response time was constricted, exogenous attention enhanced performance in temporal resolution tasks. Therefore, both endogenous and exogenous attention seem to enhance temporal resolution, although exogenous cuing paradigms (using peripheral cues) are likely to produce speed-accuracy trade-offs in these kind of tasks.

endogenously attended location mostly at longer SOAs). In line with the object versus space-based characteristics of endogenous and exogenous attention discussed above, Luo, Fu, & Lupiáñez (under review) have found that the reduction of the spatial Stroop effect induced by peripheral cues is object based, and not space based. They found that the reduction of the spatial Stroop does not only occur on the location of the peripheral cue but it spreads to the entire object where the cue has been presented (Egly et al., 1994).

Endogenous and exogenous attention are implemented in different neural circuits

So far, we have demonstrated that endogenous and exogenous attention can produce their effects independently from each other, and produce qualitatively different effects on the processing of stimuli. A further strategy to prove their independence is to study whether they are implemented in different neural circuits in the brain. Neuroimaging studies have suggested that the brain contains two partially segregated systems for visual orienting; a dorsal network (including parts of the intra-parietal sulcus and frontal eye field), bilaterally represented, and concerned with endogenous orienting, and a more ventral, right-lateralized network (temporo-parietal junction and inferior frontal gyrus) subserving exogenous orienting (Corbetta & Shulman, 2002). Kincade et al. explored the brain areas involved in exogenous and endogenous orienting using functional magnetic resonance imaging (fMRI; Kincade et al., 2005). In their experiment, a central marker was surrounded by eight boxes during the cue period. In the exogenous orienting condition, either the left or the right box had a different colour than the surrounding boxes, which were displayed in the same colour (for example, a red box on the left hand side of fixation was surrounded by seven green boxes). In the neutral orienting condition, the colour of the boxes was distributed randomly, with some constrains so that no perceptual grouping occurred. And finally, the central cue condition was identical to the neutral condition but a central arrow indicated the most likely location of target appearance (75% validity). The results demonstrated that endogenous attention produced greater preparatory activity than exogenous attention in the frontal eye field (FEF) and intraparietal sulcus (the dorsal frontoparietal attention network). Exogenous attention recruited occipitotemporal regions, sensitive to colour information and part of the dorsal network, including the FEF, suggesting a partly overlapping circuit for endogenous and exogenous orienting. The right temporoparietal junction (TPJ; ventral frontoparietal attention network) was strongly modulated by exogenous attention to behaviourally relevant stimuli, such as targets at unattended locations. However, the TPJ did not respond to salient, task-irrelevant colour singletons, indicating that behavioural relevance is critical for TPJ modulation during exogenous attention. However, given the low temporal resolution of fMRI, it is not possible to determine whether task-irrelevant colour singletons do in fact produce a transient capture of attention, which is them overridden by the endogenous control set (only attending to task-relevant features), or do not produce any attentional capture at all.

Compelling neuropsychological evidence also indicates dissociations between exogenous and endogenous attention. Some patients suffering from right parietal injury present a syndrome known as left unilateral neglect. In this patients, exogenous orienting is heavily biased rightward (Bartolomeo & Chokron, 2001, 2002a). They may also show a lack of IOR for right, ipsilesional stimuli (Bartolomeo et al., 1999; Bartolomeo et al., 2001; Lupiáñez et al., 2004), consistent with their rightward exogenous bias. However, endogenous attention is largely spared although slowed (Bartolomeo et al., 2001).

Endogenous and exogenous interactions on the control of the final response

We have proved and reviewed evidence about the fact that the two attentional systems are independent and mainly exert their modulation at different stages of processing. However, they surely work not in isolation but in a coordinate way, in order to provide coherent behaviour. Further research should differentiate between the different way the two mechanisms are triggered (endogenous generations of expectancies vs. automatic activations of location and/or object representations), the different effects that the two mechanisms might have on information processing, and the way the two mechanisms might interact.

In relation to how the mechanisms are triggered, exogenous attention is normally driven by peripheral objects or luminance changes that are supposed to attract attention automatically (Ruz & Lupiáñez, 2002). More recently, it was demonstrated that gaze cuing (faces looking left or right, presented at the centre of the screen) can also attract attention even when the face carries no information about the target (Friesen & Kingstone, 1998). It was proposed that gaze attracted attention exogenously. However, it was soon discover that the effects produced by gaze cuing were not exactly the same to those produced by peripheral objects. For example, IOR was not observed under gaze cuing conditions. Only very recently, Frischen, Tipper, and cols have shown that IOR can be observed with this type of cues, provided that a cue is presented at fixation (a long SOA is also necessary but not sufficient).

Importantly, the effect is not observed if no fixation cue is presented, even if the face looks strait ahead (after the peripheral looking cue) in order to disengage attention (Frischen et al., 2007; Frischen & Tipper, 2004). Thus, triggering exogenous attention by peripheral cues or by gaze cuing does not seem to produce the same effects on information processing.

Also related with the exogenous orienting of spatial attention, IOR has been consistently proved to occur after the presentation of a peripheral cue both under conditions of covert orienting (when the eyes are kept at fixation; Posner & Cohen, 1984) and under overt orienting situations (Klein, 1988). When the eyes move to a peripheral location and back to the centre, RTs to detect a target presented at the previously inspected location are slowed (Rafal, Calabresi, Brennan, & Sciolto, 1989). We have recently explored whether these two forms of IOR (generated by peripheral cues and eye movements) produce similar effects on information processing. We observed that when the task involves the discrimination of features, IOR is observed under conditions of covert but not overt orienting (Chica, Taylor, Lupiáñez, & Klein, in preparation). We interpreted these results in the context of the recent literature indicating that IOR is generated by at least two mechanisms, one perceptual and the other rather motoric (Sumner, 2006; Sumner et al., 2004; Taylor & Klein, 2000). When IOR is generated by eye movements, the effect might be related with the superior colliculi and might not produce an effect at perceptual levels of processing, thus not producing an effect on discrimination tasks. However, when IOR is triggered by peripheral cues under covert orienting conditions, it might not be implemented in the superior colliculi, and produces an effect on perceptual processing, affecting discriminations tasks (Chica & Lupiáñez, under review; Handy et al., 1999). In fact, IOR has been elicited by cues only visible by short-wave-sensitive cones. Given that the superior colliculi are blind to these stimuli, the evidence clearly demonstrate that at least some IOR is not mediated by the superior colliculi (Sumner, 2006; Sumner et al., 2004).

Even more complicated is the case of endogenous attention. As it has been largely discussed in this manuscript, endogenous attention is normally driven either by informative central or peripheral cues. Usually, researchers have used these types of cues (many times as exchangeable), assuming that endogenous attention would produce the same effect with either type of cue. However, some results have proved this assumption to be wrong. For example, Briand (1998) studied the effect of endogenous and exogenous attention on feature and conjunction search tasks. He found that the when attention was manipulated using non-informative peripheral cues (exogenous attention), the effect of attention interacted on these tasks, while it produced additive effects when using informative central cues (endogenous attention). Importantly, when the peripheral cue was made spatially informative (thus producing both endogenous and exogenous shifts of attention), it produced the same effect that non-informative peripheral cues. Therefore, the reported dissociation between the effects of endogenous and exogenous attention on visual search is better explained as a dissociation between the effects of peripheral versus central cues. When a peripheral cue is presented (no matter whether it is spatially informative or not) cuing effects are larger on conjunction than in feature search tasks. However, when a central cue drives attention, cuing effects are similar in both tasks.

In a similar vein, Funes et al. (2007) reported a double dissociation between the effects of endogenous and exogenous attention on a spatial version of the Stroop task. As described before, they found that exogenous attention triggered by non-informative peripheral cues reduced the spatial Stroop effect. However, endogenous attention, triggered by an informative central cue enhanced the spatial Stroop effect. Thus, endogenous and exogenous attention produce completely opposite effects on the spatial Stroop task. Moreover, when peripheral cues are made predictive, one would expect endogenous and exogenous attentional effects to cancel each other out, and maybe produce a null effect. Surprisingly, when the peripheral cue was made spatially informative, the modulation of the spatial Stroop was identical to the one caused by non-informative peripheral cues (Funes et al. 2007; Experiment 2B). In a further experiment (unpublished data), in which the peripheral cue was made predictive, again the same reduction in the Spatial Stroop effect was observed at the cued location, although the reduction was not restricted to the shortest SOA, but sustained at longer SOAs (Luo et al., under review). Similarly, when we used our paradigm to manipulate endogenous and exogenous attention (making the cue predictive and counterpredictive of the target appearance), we did not find an increase of the spatial Stroop effect at the endogenously attended location (Chica, Funes, & Lupiáñez, 2005).We can therefore conclude that the increase on the spatial Stroop effect produce by endogenous attention is not a consequence of endogenous orienting per se or the informative value of the cue. Instead, it is only observed when attention is endogenously oriented to locations non-previously cued by the presence of an object.

We reckon that the use of informative peripheral cues creates a situation in which endogenous and exogenous attention might interact for the control of behaviour. For example, it is well known that endogenous attention elicited by central cues does not produce the IOR effect (Posner & Cohen, 1984). However, we have reported that endogenous attention elicited by informative peripheral cues enhances the behavioural IOR, as well as its electrophysiological marker (enhanced P1 for cued versus uncued trials; Chica & Lupiáñez, under review; see Chapter III.II.). Additionally, we have also reported that endogenous attention on itself does not produce the ILM effect. However, endogenous attention to the location of a peripheral cue can enhance the ILM effect caused by the cue when the task set favours the integration between the cue and the line (Chica et al., submitted-b; see Chapter IV). Therefore, we propose that at least under the situation of an informative peripheral cue, the effects of endogenous and exogenous attention might not be additive. Endogenous attention seems to enhance the effect of exogenous attention, even if endogenous attention would never produce this effect in isolation.

In this vein, Prinzmetal et al. (2005) have recently reported a result that argues against a broad part of the previous literature (see Chapter III.I.). They showed that endogenous attention affected both accuracy and RT experiments, while exogenous attention only affected RT experiments. These results led them to conclude that endogenous attention produced signal enhancement, while exogenous attention affected the decision of where to respond. In their studies, exogenous attention was manipulated using a non-informative peripheral cue, while endogenous attention was manipulated by making the cue spatially informative. Therefore, in line with the results exposed above, we believe that Prinzmetal dissociation is not a dissociation between endogenous and exogenous attention, but is related with the informative value of the cue. We propose that endogenous attention to the peripheral cue might enhance the effect of the peripheral cue, producing effects on accuracy.

In general, it can be concluded that endogenous and exogenous attention are two separate attentional systems that can work independently. As discussed in the Introduction, the endogenous system maintains goal-directed behaviour in spite of distracting events, while the exogenous system allows the processing of novel, unexpected events, sometimes prioritizing the inspection of novel, non-previously attended events through IOR. Endogenous and exogenous attention affect visual perception differentially, produce qualitatively different effects on the processing of stimuli and are implemented in different neural substrates in the brain. There are many open questions, and further research is necessary to understand the effects of endogenous and exogenous attention when they are triggered differently, and how they interact or work in coordination for the control of behaviour. This knowledge would lead to an integrated theory about the neural circuits and function of endogenous and exogenous attention.

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Appendix I

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Inhibición de retorno sin retorno de la atención

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La Inhibición de Retorno (IR) consiste en mayores tiempos de reacción para responder a lugares a los que se ha orientado la atención de manera involuntaria previamente. Posner y Cohen (1984) propusieron que este efecto se debe a un mecanismo que impide que la atención se reoriente hacia lugares previamente atendidos. Por tanto, la IR debería ser cancelada si voluntariamente se mantiene la atención en el lugar en el que el estímulo objetivo aparecerá. En este trabajo manipulamos que el estímulo objetivo (señalado o no por una señal exógena) apareciera en un lugar esperado o no esperado por el participante. En contra de la hipótesis propuesta por Posner y Cohen (1984), los resultados mostraron IR tanto en la posición esperada como en la posición no esperada. Efectos similares fueron obtenidos con tarea de detección y discriminación, aunque el curso temporal fue diferente, replicando los resultados obtenidos por Lupiáñez, Milán, Tornay, Madrid y Tudela (1997).

Inhibition of return without return of attention. Inhibition of Return (IOR) is an effect that consists of faster reaction time (RT) in responding to locations where we have previously attended involuntarily. Posner & Cohen (1984) postulated that this effect is due to a mechanism that prevents reorienting attention to previously attended locations. Thus, IOR should be cancelled if the person voluntarily maintains attention at the location where the target will appear. In this experiment we manipulated the target (which could be either cued or un-cued exogenously) to appear either in an expected or unexpected location. The results showed, opposed to Posner and Cohen's hypothesis, significant IOR in both expected and unexpected positions. Similar effects were observed with detection and discrimination tasks, but the temporal course was different, thus replicating the pattern of results observed by Lupiáñez, Milán, Tornay, Madrid y Tudela (1997).

Los estímulos novedosos, no esperados, o potencialmente peligrosos, tienen la capacidad de capturar nuestra atención de manera automática (véase Ruz y Lupiáñez, 2002, para una revisión sobre el fenómeno de captura atencional). Esta captura atencional producida por las características de los estímulos es conocida como orientación atencional *exógena o involuntaria*. Sin embargo, la atención también puede dirigirse a los estímulos de acuerdo con las metas e intenciones de la persona. Este tipo de orientación atencional dirigida por las metas, intenciones y expectativas es conocida como orientación atencional *endógena o voluntaria*.

El paradigma de costes y beneficios (Posner y Cohen, 1984), usando diferentes tipos de señales atencionales, nos permite estudiar estas dos formas de orientación atencional y la interacción entre ellas. En este paradigma suele presentarse un punto de fijación, y a cada lado de éste una cajita o marcador. Posteriormente aparece una señal que dirige la atención del participante a una de las dos posiciones. Finalmente aparece un estímulo al que los participantes tienen que responder. En este paradigma se pueden usar señales centrales o periféricas. Mediante el uso de señales periféricas no predictivas de la futura localización del estímulo objetivo podemos medir los efectos de la orientación atencional exógena, y mediante el uso de señales centrales predictivas podemos medir los efectos de la orientación atencional endógena. Cuando usamos señales exógenas (por ejemplo, un flash en una de las cajitas) y la tarea consiste en detectar el estímulo objetivo, si el SOA (tiempo transcurrido desde que aparece la señal hasta que aparece el objetivo, del inglés: S*timulus Onset Asynchrony)* es menor de 300 ms, los participantes son más rápidos en responder al estímulo objetivo cuando éste se presenta en el mismo lugar en que se presentó la señal (facilitación). Sin embargo, si el SOA es mayor de 300 ms el efecto se invierte, de forma que los participantes son más rápidos en responder si el estímulo objetivo se presenta en un lugar diferente al lugar en que se presentó la señal. Esta inversión del efecto que se produce con las señales exógenas fue observada por primera vez por Posner y Cohen (1984), y desde entonces es conocida como efecto de *Inhibición de Retorno* (IR; véase Lupiáñez, Rueda y Tudela, 1999, para una revisión). Es decir, la IR es un efecto atencional consistente en mayores tiempos de reacción para responder a los lugares ya atendidos con anterioridad. Algunos autores han propuesto que la IR maximiza la eficacia de la búsqueda visual, ya que previene que la atención retorne a los lugares u objetos que ya han sido examinados (Klein, 2000; Posner y Cohen, 1984; Tipper, Driver y Weaver, 1991).

El efecto de IR se ha encontrado de manera consistente en tareas de detección. Aunque los primeros estudios no encontraron IR en tareas de discriminación (Egly, Rafal y Henik, 1992; Terry, Valdes y Neill, 1994; Tanaka y Shimojo, 1996), Lupiáñez, Milán,

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Tornay, Madrid y Tudela (1997) sí encontraron IR usando una tarea de discriminación, aunque con este tipo de tareas el efecto sigue un curso temporal diferente, presentándose la IR más tardíamente con SOAs de 700 y 1000 ms.

En relación con el mecanismo que subyace al efecto de IR, Posner y Cohen (1984) solamente encontraron IR usando señales periféricas, pero no con señales centrales. Además, sólo encontraron el efecto si la atención se desenganchaba de la posición atendida y volvía al punto de fijación. A la luz de estos resultados, y en línea con la metáfora del foco de linterna (Posner, Snyder y Davison, 1980), los autores propusieron que la IR consistía en un efecto de orientación-reorientación de la atención, que se debe a un mecanismo que inhibe que la atención retorne a lugares recientemente atendidos, lo que reflejaría un mecanismo con valor adaptativo en situaciones que requieren búsqueda visual.

Por tanto, esta *hipótesis de la reorientación* predeciría que si la atención se mantiene en la posición señalada por una señal exógena, de forma que no deba volver a ese lugar cuando se presenta el estímulo objetivo, el efecto de IR no debiera aparecer. En otras palabras, si el efecto de IR consiste realmente en la inhibición del *retorno* de la atención, el efecto no debiera producirse si no es necesario tal *retorno*.

Sin embargo, en un estudio de Berlucchi, Di Stefano, Marzi, Morelli y Tassinari (1981) se demostró que aunque los participantes supiesen dónde iba a aparecer el estímulo objetivo, eran más lentos en responder a los ensayos en los que el estímulo objetivo se presentaba en la misma posición que la señal exógena previa, en comparación con los ensayos en los que el estímulo objetivo se presentaba en el lugar contrario. En este estudio el estímulo objetivo se presentaba siempre en la misma posición durante un bloque de ensayos. No obstante, la evidencia no fue concluyente, ya que al presentarse el estímulo objetivo siempre en el mismo lugar, el mantenimiento voluntario de la atención en esa localización pudo ser obstaculizado por un proceso de habituación. Posteriormente, Berlucchi, Chelazzi y Tassinari (2000) usaron un procedimiento en el que el estímulo objetivo aparecía en una de cuatro posibles posiciones, y era precedido por una señal no predictiva en una de esas localizaciones. En cada bloque de ensayos los participantes tenían que atender voluntariamente a una posición concreta en relación con la posición de la señal. Los resultados mostraron menores tiempos de reacción (TR) en la posición atendida voluntariamente y mayores TR en la posición atendida exógenamente (es decir, IR con respecto al lugar de la señal). Pero el resultado más importante en este estudio fue que los efectos que acabamos de describir fueron independientes: en todos los SOAs se encontró IR tanto en la posición atendida endógenamente como en la posición no atendida. Nótese que estos resultados contradicen la hipótesis de la orientación-reorientación de la atención, ya que si los participantes estaban manteniendo la atención de manera endógena en una determinada posición deberían ser más rápidos en responder cuando el estímulo objetivo se presentase en ese lugar, con independencia del lugar de la señal exógena. Esto no siempre ocurría, ya que si la señal exógena se había presentado en esa localización, se seguía presentando IR aunque los participantes mantuviesen la atención en ese lugar. Por tanto, la hipótesis de la reorientación queda en cierta medida refutada por los datos anteriores.

Sin embargo, en el procedimiento utilizado por Berlucchi et al. (2000) la orientación endógena no se realizó en función de la predictividad de la señal, como es habitual en la literatura.

El objetivo principal de nuestro trabajo fue poner de nuevo a prueba las explicaciones del efecto de IR basadas en la hipótesis de la reorientación, pero utilizando un procedimiento diferente al de Berlucchi et al. (2000), en el que la orientación voluntaria sí se produce en función de señales predictivas que inducen a los participantes a generar, en cada ensayo, una expectativa de aparición del objetivo en un lugar determinado. Para ello hemos utilizado una variación del paradigma de costes y beneficios, en el que manipulamos la orientación atencional tanto endógena como exógena mediante una *señal periférica predictiva*. En una condición, la señal periférica predecía la aparición del estímulo objetivo en el mismo lugar de la señal, mientras que en otra condición la señal predecía su aparición en el lugar contrario a la señal. Tomando en consideración todas las condiciones, el estímulo objetivo podía aparecer en el lugar predicho por la señal, o en el lugar contrario, lo que nos permitirá medir la orientación endógena. Además, en cada uno de los casos anteriores, el objetivo podía aparecer en el lugar de la señal o en el lugar contrario, lo que nos permitirá medir la orientación exógena, y la interacción entre los dos tipos de orientación. De acuerdo a nuestra exposición anterior sobre la hipótesis de la reorientación, si los resultados, en lugar de mostrar interacción, muestran independencia (aditividad) entre la señalización exógena y la orientación endógena, el efecto de IR debería ser explicado por otra hipótesis diferente.

Además, en el presente estudio manipulamos el tipo de tarea, lo que permite abordar, como segundo objetivo, las diferencias en el curso temporal de los efectos encontrados en tareas de detección y discriminación. Lupiáñez et al. (1997) encontraron que la IR aparecía más tarde en tareas de discriminación. Esto podría deberse a que la atención se desengancha más tarde en la tarea de discriminación (esta hipótesis del «desenganche tardío» *–late disengaging–* es la que propone Klein, 2000). Pero esta diferencia en el curso temporal podría también deberse a que otros efectos de señalización (efectos perceptuales independientes de la orientación-reorientación) son facilitatorios durante un intervalo mayor, o en mayor medida, en la tarea de discriminación (Lupiáñez, Milliken, Solano, Weaver, y Tipper, 2001). Ya que con nuestro procedimiento hemos disociado los efectos de señalización de los de orientación de la atención, el uso de ambas tareas nos permitirá analizar si las diferencias en el curso temporal de los efectos de señalización en la tarea de detección y discriminación se deben a la orientación de la atención o a efectos perceptuales de la correspondencia señal-objetivo.

Método

Participantes

En este experimento participaron 60 estudiantes universitarios (30 para la tarea de detección y 30 para la de discriminación), 44 mujeres y 16 hombres, de los cuales 53 eran diestros y 7 zurdos. La edad media de los participantes era de 20,6 años. Todos ellos informaron tener visión normal o corregida, no eran informados del propósito del experimento hasta la finalización del mismo y participaban en él voluntariamente para la obtención de créditos.

Aparatos y estímulos

Los estímulos eran presentados en un monitor de 15 pulgadas. Para la programación del experimento, la presentación de los estímulos y el registro de las respuestas se utilizó el programa E-prime (Schneider, Eschman, Zuccolotto, 2002). Los participantes realizaban el experimento en una sala con luz tenue, sentados a unos 57 cm del monitor, y con la barbilla apoyada sobre una mentonera. Al comienzo de cada ensayo se presentaba un punto de fijación, que podía ser un signo «+» (5 mm de ancho y alto) o un signo «-» (5 mm de ancho) y dos cajitas (17 × 17 mm) de color blanco sobre fondo negro, cada una a 70 mm del punto de fijación. Como señal de orientación una de las cajitas emitía un flash (aumentando ligeramente su grosor durante 50 ms). Cuando los sujetos cometían un error aparecía un sonido de 50 ms de duración y 1.997 Hz.

Procedimiento

Al comienzo de cada ensayo aparecía el punto de fijación y las cajitas, que permanecían en la pantalla durante todo el ensayo. Tras 1.000 ms se presentaba la señal de orientación con una probabilidad del 50% en cada una de las cajitas. Trascurrido un intervalo variable (50, 350, 650 o 950 ms) se presentaba el estímulo objetivo (un asterisco de color rojo en la mitad de los ensayos y de color amarillo en la otra mitad) en una de las dos cajitas durante 33 ms, el 50% de las ocasiones en la cajita de la izquierda y el 50% restante en la de la derecha. Tras la desaparición del asterisco permanecían en la pantalla el punto de fijación y las cajitas hasta que el sujeto respondía o hasta pasados 2000 ms. Después de 1.000 ms, en los que la pantalla permanecía de color negro comenzaba el siguiente ensayo.

En el 20% de los ensayos no se presentaba ningún asterisco (catch trials), y los sujetos eran informados de que en estos ensayos no debían emitir ninguna respuesta. De los restantes ensayos, en los que sí se presentaba el estímulo objetivo, si el punto de fijación era un signo «+» se informaba a los participantes de que el asterisco se presentaría casi siempre en la misma posición en que se presentó la señal. Efectivamente, en el 75% de los ensayos el asterisco se presentaba en la misma posición en la que se había presentado la señal. Éstos eran ensayos esperados (el asterisco se presentaba donde el participante esperaba) y señalados (la señal y asterisco se presentaban en la misma posición). En el 25% de ensayos restantes, el asterisco se presentaba en el lugar contrario al de la señal. Éstos eran ensayos no esperados (porque el asterisco se presentaba en un lugar no esperado por el participante) y no señalados (porque la señal y el asterisco se presentaban en posiciones distintas). Sin embargo, cuando el punto de fijación era un signo «-» se informaba a los participantes de que en la mayoría de las ocasiones el asterisco se presentaría en el lugar contrario al de la señal. Así, en el 75% de las ocasiones el asterisco se presentaba en el lugar contrario a la señal (ensayos esperados-no señalados), y en el 25% restante el asterisco se presentaba en el mismo lugar en que se había presentado la señal (ensayos no esperados-señalados).

La tarea de los participantes consistía en responder al asterisco lo más rápidamente posible e intentando no cometer errores. En la tarea de detección, debían pulsar una tecla (la tecla «m» para la mitad de los participantes, y la tecla «z» para la otra mitad), tan pronto como viesen el asterisco. En la tarea de discriminación los participantes debían pulsar una tecla si el asterisco era de color rojo y otra tecla diferente si era de color amarillo (la mitad de los participantes pulsaban la tecla «m» si el asterisco era de color rojo y la tecla «z» si era amarillo, siendo al contrario para la otra mitad de los participantes). La tarea duraba aproximadamente 45 minutos. Entre bloques de ensayos se instaba a los sujetos a descansar unos segundos. Al principio del experimento los sujetos eran informados del significado del punto de fijación, y se insistía en que lo tuviesen en cuenta para intentar responder más rápidamente. También se hacía especial hincapié en que no realizasen movimientos oculares y mantuviesen siempre los ojos en el punto de fijación.

Diseño

El diseño experimental consistía en una variable manipulada entregrupos, Tarea, y 3 variables manipuladas intraparticipantes: Expectativa Espacial, Señalización y SOA. La variable Expectativa Espacial podía tomar dos valores: ensayos de lugar esperado vs. lugar no esperado. La variable Señalización podía tomar igualmente dos valores: ensayos señalados vs. ensayos no señalados. Por último, la variable SOA podía tomar cuatro valores: 100, 400, 700 y 1.000 ms. Los participantes realizaban un bloque de práctica (24 ensayos) seguido de 4 bloques experimentales. Cada bloque experimental consistía en 160 ensayos, por lo que el total de ensayos en la tarea era de 640. De estos ensayos, 128 eran catch trials y los 512 restantes eran ensayos con objetivo. Así, por condición experimental de Señalización y SOA, había 16 ensayos de lugar no esperado y 48 ensayos de lugar esperado.

Resultados y discusión

El porcentaje de falsas alarmas (respuestas a catch trials) fue de 7,10% para la tarea de detección y 2,03% para la de discriminación. El porcentaje de ensayos de no respuesta (en inglés *misses*) fue tan sólo de 2% y 1,2%, respectivamente, para las tareas de detección y discriminación, por lo que no fue analizado en mayor detalle. En la tarea de discriminación el porcentaje de respuestas incorrectas fue del 6,8%, que fueron eliminadas de los análisis de TR. Los ensayos con respuesta correcta con latencia menor de 100 ms o mayor de 1.200 fueron igualmente excluidos del análisis de TR, lo que dejaba fuera a un 1% de los ensayos en la tarea de detección y un 1,39% en la de discriminación. En la tabla I se muestran los datos para cada condición experimental.

Para el análisis de los resultados, los TR medios por condición experimental se introdujeron en un ANOVA mixto 2 × 2 × 4 × 2 con las variables Expectativa Espacial (2; Lugar Esperado vs. No Esperado), Señalización (2; Lugar Señalado vs. No Señalado) y SOA (4; 100, 400, 700, 1.000 ms) como variables intraparticipantes y la variable Tarea (2; Detección vs. Discriminación) manipulada entregrupos. El porcentaje de errores de la tarea de discriminación se analizó mediante un ANOVA de medidas repetidas de Expectativa Espacial (2) × Señalización (2) × SOA (4). No obstante, en este análisis ningún efecto principal ni interacción resultó estadísticamente significativo. Por otra parte, se realizó un análisis del balance velocidad-precisión (*trade off*), correlacionando el TR y el porcentaje de errores por sujeto y condición experimental, cuyo resultado fue 0.40, lo que indica que los sujetos no respondieron más rápidamente a costa de la imprecisión de sus respuestas.

El análisis del TR mostró un efecto principal de Tarea, F (1,58)= 150.64, p<.0001, de forma que, como esperábamos, los participantes eran más rápidos en la tarea de detección que en la de discriminación. Obtuvimos igualmente los efectos típicos de preparación, como se muestra en el efecto principal de SOA, que fue igualmente significativo, F (3,174)= 38.25, p<.0001. La interacción SOA × Tarea resultó también significativa, F (3,174)= 4.37, p<.01; en ambas tareas, el TR era menor para los SOAs de 400 y 700 ms que para los otros dos SOAs, siendo menor en el

SOA de 1.000 ms que en el de 100 ms, aunque sólo en la tarea de detección.

Más interesante fue la obtención de un efecto significativo de Expectativa Espacial, F (1,58)= 23.80, p<.0001, que consistía en menores TR en los ensayos esperados que en los ensayos no esperados, lo que mostraba la efectividad de nuestra manipulación. Así mismo, se observó un efecto principal de Señalización, F (1,58)= 39.29, p<.0001, siendo los participantes más rápidos en responder a los ensayos no señalados que a los ensayos señalados (es decir, IR). No obstante, este efecto dependía del SOA, como se deduce de la interacción Señalización × SOA, que resultó también significativa, F (3,174)= 20.15, p<.0001. Además, la interacción Tarea × Señalización fue significativa, F (1,58)= 10.90, p<.01. Así, en concordancia con la literatura previa, el efecto de IR sólo aparece a partir del SOA de 400 ms para la tarea de detección, y del SOA de 700 ms para la tarea de discriminación (véase el panel A de la figura 1).

De gran relevancia para nuestras hipótesis, el efecto de Señalización dependía de la Expectativa Espacial, como se deduce de la interacción entre las dos variables, que fue significativa, F (1,58)= 7.41, p<.01. La interacción era debida a la existencia de un mayor efecto de IR en los ensayos de lugar no esperado, como se deduciría la hipótesis de la orientación-reorientación atencional. Sin embargo, contrariamente a lo predicho por esta hipótesis, la IR en el lugar esperado se mostró altamente significativa en la correspondiente comparación planeada, F (1,58)= 17.87, p<.0001. Es decir, aunque la IR fuera mayor en el lugar no esperado, en el lugar esperado (donde se mantiene orientada voluntariamente la atención) también se observó un robusto efecto de IR.

Tabla 1

Tiempos de reacción medios, porcentajes de errores de no respuesta [entre corchetes] y de respuesta incorrecta (entre paréntesis) para cada condición experimental

		SOA de 100 ms		**SOA de 400 ms**		**SOA de 700 ms**		**SOA de 1000 ms**	
Tarea	**Señalización**	**Esperados**	**No esperados**	**Esperados**	**No esperados**	**Esperados**	**No esperados**	**Esperados**	**No esperados**
Detección	**Señalados**	398 [2.0]	396 [1.0]	370 [1.8]	380 [1.9]	368 [2.0]	389 [1.5]	374 [2.6]	392 [2.5]
	No señalados	397 [1.9]	389 [0.8]	352 [2.2]	362 [1.7]	346 [2.4]	346 [2.7]	364 [2.1]	370 [1.7]
	Efecto de señalización	-1	-7	-18	-18	-22	-43	-10	-22
Discriminación	**Señalados**	583 (7.2) [1.0]	596 (7.6) [1.5]	572 (6.6) [0.5]	578 (6.5) [0.4]	576 (7.1) [0.9]	605 (6.8) [1.3]	596 (6.5) [1.0]	607 (7.0) [1.9]
	No señalados	595 (6.5) [0.9]	613 (6.3) [1.3]	568 (7.2) [1.3]	583 (7.6) [1.5]	566 (7.0) [1.0]	562 (7.6) [1.9]	588 (6.8) [1.2]	601 (7.0) [1.9]
	Efecto de señalización	12	17	-4	5	-10	-43	-8	-6

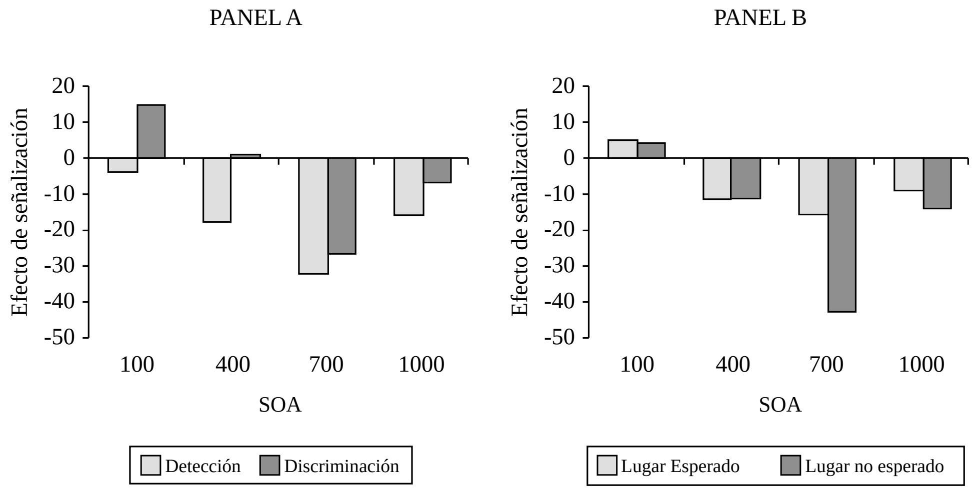

Figura 1. *En el panel A podemos observar el efecto de señalización (TR en los ensayos no señalados menos TR en los ensayos señalados) en los diferentes SOAs en función de la tarea. Los ensayos señalados son aquellos en los que la señal y el estímulo objetivo se presentan en la misma posición, mientras que los ensayos no señalados son aquellos en los que se presentan en posiciones diferentes.*
En el panel B podemos observar el efecto de señalización en los diferentes SOAs en función de la Expectativa Espacial (Lugar Esperado vs. No Esperado). En los ensayos esperados el estímulo objetivo se presenta en el lugar donde el participante espera (por la información del punto de fijación), mientras que en los no esperados el estímulo objetivo se presenta en el lugar no esperado por el participante

Por último, las interacciones Expectativa Espacial × Señalización y Señalización × SOA eran moduladas por la interacción Expectativa Espacial × Señalización × SOA, F (3,174)= 4.50, p<.005. Para analizar más detalladamente esta interacción, y dada la importancia para nuestras hipótesis de la interacción Expectativa Espacial × Señalización, en función de la tarea, realizamos un ANOVA mixto de 2(Expectativa Espacial) × 2(Señalización) × 2(Tarea) en cada uno de los SOAs, cuyos resultados más relevantes se representan en la figura 1 (panel B).

SOA 100: Además de la variable Tarea, que resultó significativa en todos los SOAs, el análisis mostró que ni el efecto de Expectativa Espacial ni el efecto de señalización fueron significativos, F (1,58)= 2.53, p= .1171 y F (1,58)= 2.26, p= .1384, respectivamente. Las interacciones Expectativa Espacial × Tarea y Señalización × Tarea fueron significativas, F(1,58)= 11.38, p<.005, y F(1,58)= 7.89, p<.01, respectivamente, mostrando que los efectos de ambas variables sólo se produjeron en la tarea de discriminación F(1,29)= 10.19, p<.005 y F(1,29)= 7.58, p<.02.

La interacción Expectativa Espacial × Señalización no resultó significativa, F<1. Estos resultados nos indican que transcurridos 100 ms desde la aparición de la señal, no ha habido tiempo suficiente para que el participante desarrolle la expectativa de lugar y se oriente voluntariamente hacia el lugar donde cree que aparecerá el objetivo. Además, en SOAs tan cortos aún no se manifiesta el efecto de IR ni en tareas de detección ni de discriminación. La ausencia de facilitación en la tarea de detección con un SOA tan corto replica resultados previos obtenidos por otros investigadores (Lupiáñez et al, 2001). En cualquier caso, en la tarea de discriminación, con la única que se obtuvo un efecto de Señalización, aunque no de IR sino de facilitación, el efecto era independiente de la Expectativa Espacial (F<1).

SOA 400: Los efectos de Expectativa Espacial y Señalización fueron significativos, F (1,58)= 12.98, p<.001, F (1,58)= 4.20, p<.05, respectivamente. Sin embargo, la interacción Expectativa Espacial × Señalización no resultó significativa, F<1. De acuerdo con la literatura previa, la interacción Señalización × Tarea fue significativa, F(1,58)= 4.93, p<.05, mostrando un efecto significativo de IR exclusivamente para la tarea de detección, F(1,29)= 8.05, p<.01, el cual fue independiente de la Expectativa Espacial, mostrándose especialmente significativo en el lugar esperado, F(1,29)= 19.49, p<.0005. Es decir, aunque la ejecución de los sujetos mostraba que ya se había desarrollado la expectativa del lugar en que aparecería el estímulo objetivo, en la tarea de detección se observaba IR en el lugar en que los participantes esperaban que se presentase el objetivo.

SOA 700: Tanto el efecto de Expectativa Espacial, F (1,29)= 9.50, p<.005, como el efecto de Señalización, F (1,29)= 83.50, p<.0001, fueron significativos, mostrando los efectos respectivos de orientación endógena e IR. En este caso, la interacción Expectativa Espacial × Señalización también resultó significativa, F (1,29)= 25.32, p<.0001. Este dato podría estar, en principio, a favor a de la hipótesis de la orientación-reorientación de la atención. Sin embargo, hemos de destacar que, a pesar de la interacción significativa, el efecto de IR fue altamente significativo tanto en el lugar esperado como en el no esperado (p<.00001 en ambos casos).

SOA 1000: De nuevo, tanto el efecto de Expectativa Espacial, F (1,29)= 12.80, p<.001, como el efecto de Señalización, F (1,29)= 18.17, p<.0001, resultaron significativos. Sin embargo, la interacción Expectativa Espacial × Señalización no fue significativa, F<1. Al igual que en el SOA de 400 ms, los participantes manifestaban en su ejecución que habían desarrollado la expectativa de lugar, pero aún orientando su atención al lugar en que se iba a presentar el objetivo con una alta probabilidad, sigue presentándose IR en el lugar en que los participantes esperan que se presente el objetivo.

En resumen, podemos observar que al menos en algunas condiciones (SOA de 400 para la tarea de detección y SOA de 1.000 ms con ambas tareas) se observa IR con independencia de la orientación endógena de la atención en función de la expectativa espacial. Además, en el SOA de 700 ms, en el que se observa una interacción entre los efectos de Señalización y Expectativa Espacial, el efecto de IR se produce de forma altamente significativa incluso en el lugar en que los participantes esperan que se presente el objetivo. Es decir, aunque los participantes sepan que el estímulo objetivo se presentará en un lugar determinado con una alta probabilidad y estén orientados hacia esa posición (lo que podemos objetivar mediante el efecto de Expectativa Espacial), el TR es mayor para los ensayos señalados que para los ensayos no señalados (se presenta IR), tanto en el lugar esperado como en el lugar no esperado.

Por otra parte, estos resultados replican los obtenidos por Lupiáñez et al (1997) en los que encontraron que el curso temporal de los efectos de señalización era diferente para las tareas de detección y discriminación. En concreto, en este experimento observamos que en el SOA de 100 ms no se manifiestan efectos significativos de señalización para la tarea de detección, aunque en la tarea de discriminación sí aparece una facilitación significativa. En el SOA de 400 ms, se manifiesta la IR en la tarea de detección, pero no en la de discriminación. Y por último, en los SOAs de 700 y 1.000 ms, sí aparece el efecto de IR en ambas tareas.

Discusión general

Los resultados obtenidos en este experimento contradicen las explicaciones del efecto de IR basadas en la hipótesis de la reorientación, según la cual no deberíamos encontrar IR si la atención se mantiene de forma endógena en una posición, siempre y cuando se entienda la atención como un «foco de linterna» que se orienta en el espacio en base a factores endógenos y exógenos, o una combinación de ambos. Al contrario, los resultados apoyarían la existencia de 2 sistemas atencionales independientes, que se sustentarían en sistemas cerebrales diferentes. De hecho, tanto estudios comportamentales como neuroanatómicos han demostrado que la atención endógena y exógena pueden disociarse (Gitelman, Nobre, Parrish, LaBar, Kim, Meyer y Mesulam, 1999; Jonides, 1981; Müller y Rabbitt, 1989; Posner, Cohen, Choate, Maylor y Hockey, 1984). Así, por ejemplo, en el síndrome de heminegligencia, que ocurre tras lesiones parietales (normalmente derechas), se produce una alteración de la orientación atencional exógena hacia el hemicampo contralateral al lugar de la lesión, mientras que la orientación atencional endógena se encuentra relativamente preservada (Bartolomeo y Chokron, 2002). En la orientación atencional endógena están implicados el surco intraparietal inferior (IPs) (Corbetta, Kincade, Ollinger, McAvoy y Shulman, 2000) y el campo del ojo frontal (FEF) (Henik, Rafal y Rhodes, 1994), mientras que en la orientación atencional exógena están implicados la unión temporoparietal (TPJ) (Corbetta et al, 2000) y los colículos superiores (Sapir, Soroker, Berger y Henik, 1999; Dorris, Klein, Everling y Muñoz, 2002).

Ambos sistemas atencionales pueden funcionar de forma paralela. El sistema de orientación exógena está muy relacionado con la detección de estímulos novedosos. Según Lupiáñez, Decaix, Siéroff, Milliken y Bartolomeo (en revisión) la aparición de un objeto nuevo (la señal o el estímulo objetivo) siempre provoca un cierto grado de captura atencional, independientemente de la expectativa endógena del participante. En SOAs cortos, tanto la señal como el estímulo objetivo se benefician de esta captura atencional, quizás porque ambos son tratados como un único objeto nuevo (Lupiáñez et al, 2001). En SOAs largos, el tiempo transcurrido entre la señal y el estímulo objetivo da lugar a que ambos se segmenten perceptualmente, y por tanto si el estímulo objetivo se presenta en la posición señalada, no es considerado por el sistema como un nuevo objeto. Sin embargo, cuando el estímulo objetivo se presente en una posición no señalada, el sistema sí lo procesará como un objeto nuevo y se beneficiará de una más rápida captura atencional. Es decir, el efecto de IR se podría deber a una pérdida de la facilitación que se produce en las posiciones en las que se presente un estímulo nuevo (ver Milliken, 2002, Milliken, Tipper, Houghton y Lupiáñez, 2000). Es decir, la IR se podría conceptuar como una pérdida de novedad, esto es, ausencia de captura atencional por parte de estímulos que aparecen en posiciones previamente señaladas con señales exógenas.

En nuestro paradigma, cuando el estímulo objetivo se presenta en una posición esperada se beneficia de la orientación atencional endógena. Pero si esta posición ha sido a su vez señalada exógenamente, se producirá un perjuicio, ya que deja de ser un objeto nuevo. Por eso aparece IR aunque el participante espere que el estímulo se presente en esa posición. Sin embargo, cuando el estímulo se presenta en una posición no esperada y señalada, el tiempo de reacción se enlentecerá aún más, debido a que los participantes no esperan que el estímulo objetivo se presente en esa posición y además no se trata de un objeto nuevo.

Por último, ya que nuestros datos parecen mostrar que el efecto de IR no se debe necesariamente a un mecanismo de enganche-desenganche u orientación-reorientación de la atención, los diferentes cursos temporales encontrados en tareas de detección y discriminación no pueden deberse, como propone Klein (2000) a que la atención se desenganche más tarde en tareas de discriminación, ni tampoco a que se desenganche antes en tareas de detección. Parece, por tanto, que el que la IR aparezca más tarde en tareas de discriminación se debe a que los efectos perceptuales que produce la señal facilitan el procesamiento del estímulo objetivo durante un intervalo mayor en estas tareas (Lupiáñez et al, 2001). Sería necesario más esfuerzo investigador para dilucidar los efectos perceptuales diferenciales que produce la señal en ambos tipos de tareas. Por ejemplo, sería apropiado el uso de índices de procesamiento entre la aparición del estimulo y la emisión de la respuesta, que complementen las medidas unidimensionales como el TR y la exactitud. Entre estos índices, los asociados a la electroencefalografía, por su alta resolución temporal, están especialmente indicados. Específicamente, en nuestro paradigma, estos índices permitirían obtener información sobre el procesamiento que la señal recibe. A la luz de los resultados actuales, nosotros predeciríamos que el procesamiento de la señal sería diferente en función de la tarea o del *set* mental que los participantes adopten para llevarla a cabo.

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Appendix II

Spatial attention does improve temporal discrimination

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Abstract

It has recently been stated that exogenous attention impairs temporal resolution tasks (Hein, Rolke, & Ulrich, 2006; Rolke, Dinkelbach, Hein, & Ulrich, 2006; Yeshurun, 2004; Yeshurun & Levy, 2003). In the present experiments we aimed at studying the effect of spatial attention in temporal resolution while constraining reaction time such that variance was substantially reduced and the response decision was made within comparable time windows in all conditions. The results revealed that, when speed stress was controlled, performance was impaired for cued trials as compared with neutral trials, although it was actually improved for cued trials as compared to uncued trials. These results suggest that speed-accuracy trade-off effects may have played an important role in the previous studies, because when it was controlled, the results completely reversed, revealing that exogenous attention does improve performance on temporal resolution tasks.

Attention to a location in space has been found to improve visual spatial tasks such as contrast sensitivity (Cameron, Tai, & Carrasco, 2002), spatial resolution (Yeshurun & Carrasco, 1998) and acuity (Baldassi & Burr, 2000). However, a relatively recent finding suggests that attention is not beneficial for all tasks. In particular, spatial attention seems to degrade visual temporal resolution tasks. Temporal resolution refers to the ability to follow rapid changes in light intensity over time, or to resolve temporal details (Levine, 2000). Yeshurun & Levy (2003, Experiment 1) provided the first demonstration that spatial attention degrades temporal resolution. In their task, participants were asked to judge if either one or two disks were presented (both at the same spatial location). That is, the task was to detect a temporal gap within the stimulus. This target was preceded by either a spatially informative cue or a neutral cue. The spatial cue consisted of a small green line situated above the disk. This cue was always presented at the same location as the target (e.g., 100% valid cue). The authors postulated that this cue captured attention in a "stimulus-driven, automatic manner" (page 226, lines 23-25), however, as it was 100% predictive about the target location, it is not possible to disentangle the contribution of endogenous and exogenous attention to the effect observed (Chica, Lupiáñez, & Bartolomeo, 2006). The neutral cue consisted of two green lines (each of them 17 times larger than the spatially informative cue) presented above and below the entire display. Their results clearly showed that perceptual sensitivity (as measured by d') was impaired for spatially-cued trials as compared to neutral cue trials. Response bias effects were also observed. Participants adopted a more conservative criterion (reluctance respond that a gap was present) to spatially-cued trials than to neutral cue trials. In order to control for an alternative explanation of the finding related to local interference (the neural activity of the spatial cue could be integrated with that of the target, leading to a worse performance in spatially-cued trials), Yeshurun (2004, Experiment 1) replicated her previous finding using the same spatial cue and a different neutral cue. Each neutral cue (above and below the display) was composed of nine horizontal bars (each one identical to the valid cue). Again, spatially-cued trials showed a decreased perceptual sensitivity and a more conservative criterion than neutral cue trials.

It is important to note that the neutral cues used in both experiments were bigger and much more salient than the spatial cue. Back on 1984, when the cost and benefit paradigm started to be used regularly, Jonides & Mack (1984) noted that in order to compare spatial cues with neutral cues, both cues had to be matched in physical appearance, potential alerting and ease of encoding. It can easily be noticed that in the experiments just described, the neutral cues were not matched in size and alertness, which can explain the better performance in neutral trials as compared with spatially-cued trials. Moreover, the fact that the cues were different could have led to different preparatory states in the participant. We reckon that a way of solving this problem could be the use of the same cue that can appear at either the same location of the target (cued trials) or at the opposite location (uncued trials). It is also important, from the participant point of view, that it is not possible to know whether the trial will be cued or uncued until the target appears, thus allowing equating the cognitive processes related with the processing of the cue.

In this vein, Rolke and colleagues (Rolke, Dinkelbach, Hein, & Ulrich, 2006, Experiment 1) first replicated Yeshurun & Levy (2003) experiment, finding that d’ was larger for neutral cue trials than spatially-cued trials, and response criterion was more conservative for spatially-cued trials versus neutral cue trials. In this experiment, RT was also faster for neutral trials. Rolke et al. noted that the difference in luminance and size between the cues might explain the better performance in neutral cue trials, which may be more alerting than spatially-cued trials. To deal with this issue, Rolke et al. (2006, Experiment 2) used the same spatial cue that could appear at either the same location of the target (on 75% of the trials) or at the opposite location (on 25% of the trials). Again they found that d' was impaired in cued as compared to uncued trials, and a more conservative criterion was adopted to respond to cued trials. Moreover, a speed-accuracy trade-off (SAT) was also present, with RT being faster for cued versus uncued trials (this RT effect was larger in size than the accuracy effect). In summary, accuracy was impaired for cued versus uncued trials, although responses were faster and a more conservative criterion was used to respond to cued than uncued trials. Conscious of the problem of finding a SAT effect, the authors ran a third experiment in which they asked participants to withhold their response until an imperative signal was presented after a second. Under this conditions, d' was again lower for cued versus uncued trials, although no evidence of SAT was found (see General Discussion for an extended comment on this SAT analysis). Hein, Rolke & Ulrich (2006, Experiment 1) extended the findings to a temporal order judgment task (TOJ). In this case, the typical Posnerian paradigm was used (a fixation cross surrounded by two markers, in which the peripheral cue consisted of the brightening of one of the markers). In their TOJ task, two dots were successively presented at different spatial locations, at either the left or right marker. The participants' task was to judge which dot came first. The results again showed an impaired accuracy for cued trials versus uncued trials. However, a SAT was found, with

RTs being faster for cued trials versus uncued trials. Furthermore, three unpublished experiments with exogenous and endogenous cues have been run by the second author of this paper that have confirmed the RT effect, cued faster than uncued, while also showing accuracy effects that were equivocal or in the opposite direction.

As pointed out above, the experiments conducted by Yeshurun and colleagues do not provide strong empirical support to the conclusion that exogenous attentional orienting impairs temporal resolution because: 1) The neutral cue was much bigger and brighter than the spatial cue, which might have exogenously produced probably different alerting effects. 2) The use of different cues might produce different expectations and preparatory states in the participant, thus leading to different cuing effects produced, not by the orienting of attention, but by other mechanisms (Jonides & Mack, 1984). Moreover, when cued versus uncued trials have been compared (Hein et al., 2006; Rolke et al., 2006), SAT effects were also found, making responses faster but less accurate in cued trials.

The aim of the present experiments was to study the effect of spatial attention in temporal resolution while constraining RT for the response decision to be made within comparable time windows for both cued and uncued trials. We did this by examining points along the SAT curve. This will allow us to estimate the effect of attention on temporal processing at different speed rates, when the available information for responding is accumulating. RT was constrained by the deadline method, in which participants were asked to respond within a specified time window. The deadline was manipulated between blocks of trials in order to produce speed-accuracy shifts (see e.g., Ivanoff & Klein, 2006; McCormick & Francis, 2005). In the first experiment we used the same cue that could randomly appeared at either the target location (cued trials), or at the opposite location (uncued trials) (Hein et al., 2006; Rolke et al., 2006), while in the second experiment we compared spatially-cued trials versus neutral cue trials in a replication of Yeshurun and Levy (2003). The results showed that, when speed stress is controlled, perceptual sensitivity was still impaired in spatially-cued trials as compared to neutral cue trials. However, perceptual sensitivity was in fact enhanced for cued versus uncued trials, revealing that exogenous attention improves temporal resolution.

EXPERIMENT 1 (Cued v. Uncued)

As highlighted in the Introduction, the results of Yeshurun & Levy (2003) are difficult to interpret because the neutral and the spatial cue were physically very different. The use of this specific neutral cue might have produced different preparatory states, and probably larger alerting effects, than the spatial cue. In order to rule out this possibility, cued versus uncued trials were compared. In this case, the same cue is used in both conditions. More importantly, the participant cannot know in advance if the trial is cued or uncued until the target appears, making it possible to equate all the cognitive processes involved in the processing of the cue. In the present experiment the cue was not predictive, i.e., cued and uncued trials were equally likely. Speed stress was controlled by a signal tone indicating when to respond.

Method

Participants

Sixteen naïve participants (3 males and 13 females, mean age of 21 years) from Dalhousie University took part in the experiment for course credits. All of them had normal or corrected to normal vision and normal hearing.

Apparatus and stimuli

A PC running E-prime software (Schneider, Eschman, & Zuccolotto, 2002) controlled the presentation of stimuli, timing operations, and data collection. The stimuli used in the experiment were presented in a black background. Participants seated at approximately 45 cm from the monitor. The fixation point consisted of a grey 1º x 1º plus sign. The target consisted of a white circle, 2º in diameter, presented at either 5.8º to the left or right of fixation. The cue consisted of a green horizontal line subtending 1.5º x 0.4º of visual angle, and situated 0.6º above the target.

Procedure

The sequence of events in a given trial is represented in Figure 1. Every trial started with a fixation cross that remained on the screen for the whole trial. After 1000 ms, the spatial cue was randomly presented to either the left or right of fixation. The target was then randomly displayed at either the same or the opposite location of the cue. In the no-gap condition, a white disk appeared for 118 ms. In the gap condition, the white disk appeared for 47 ms, disappeared for 24 ms, and then appeared again for 47 ms. After a variable interval (stimulus-to-tone-interval, STI), a 94 ms tone was presented that opened a further window of 212 ms to respond. The STI (defined as the time between the appearance of the gap, or the same moment in the no gap condition, until the appearance of the tone) had four levels manipulated between blocks: 191, 263, 335, and 407 ms. Half of the participants experienced the 4 blocks in an ascendant order, while the other half experienced the blocks in a descendent order. If participants did not respond on time, the words "NO RESPONSE" were presented in red for 482 ms. Anticipatory responses were also indicated by the words "TOO SOON" for 482 ms. No feedback for correct or incorrect responses was provided in the experimental trials. The inter-stimulus-interval (ITI), in which the fixation point was removed, and the screen remained black, was 482 ms duration.

Each of the 4 blocks consisted of 200 trials preceded by 24 practice trials. Practice trials were similar to the experimental trials except that no tone for response was presented, participants could respond for 2470 ms after target disappearance, and incorrect response feedback was provided. There were a total of 44 trials for each experimental condition of cuing (cued versus uncued trials), gap condition (gap and no-gap trials), and STI (191, 263, 335, and 407 ms). The task lasted for approximately 50 minutes, and participants were allowed to take a rest every after 50 trials.

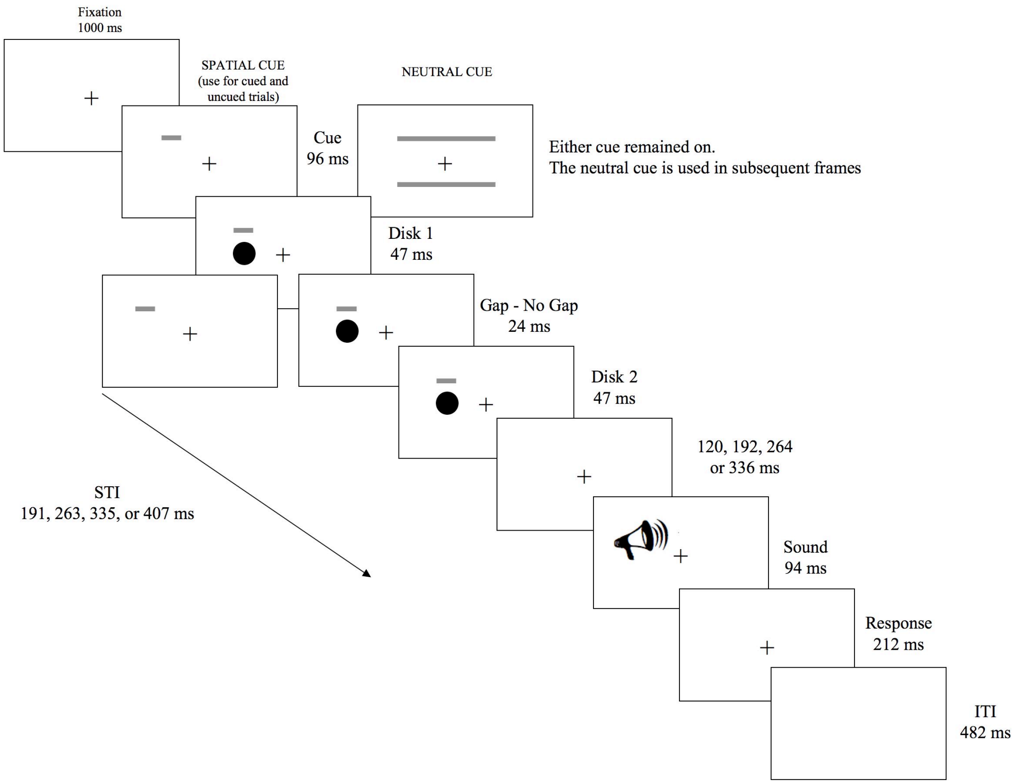

Figure 1. Sequence of events in a given trial. Spatially-cued trials (from Experiment 1 and 2), and neutral trials (from Experiment 2) are represented.

Results

Misses (8.7% of trials), late responses (responses during the 482 ms ITI; 0.57% of the trials), and early responses (8.1% of the trials), were removed from the analysis.

Mean RT data were submitted to a repeated measures ANOVA, with the factor of cuing (cued and uncued trials) and STI (191, 263, 335, and 407 ms). Apart from the main effect of STI, the main effect of gap condition was significant, *F*(1,15)=5.62, *MSE*=1390, *p*=.032. RT was faster in the gap condition as compared with the no gap condition. The interaction between STI and cuing was significant, *F*(1,15)=3.17, *MSE*=205, *p*=.034, revealing faster RT for cued versus uncued trials, but only at the shorter STI.

A similar analysis of mean d' values revealed significant main effects of STI, *F*(3,45)=10.85, *MSE*=.622, *p*<.001, and cuing, *F*(1,15)=42.32, *MSE*=.079, *p*<.001, and no interaction between them, *F*<1. Participants' perceptual sensitivity (as measured by d') was better as STI increased, and was larger for cued versus uncued trials (see Figure 2). In the criterion analysis, none of the main effects or the interaction between them approached significance (see Table 1).

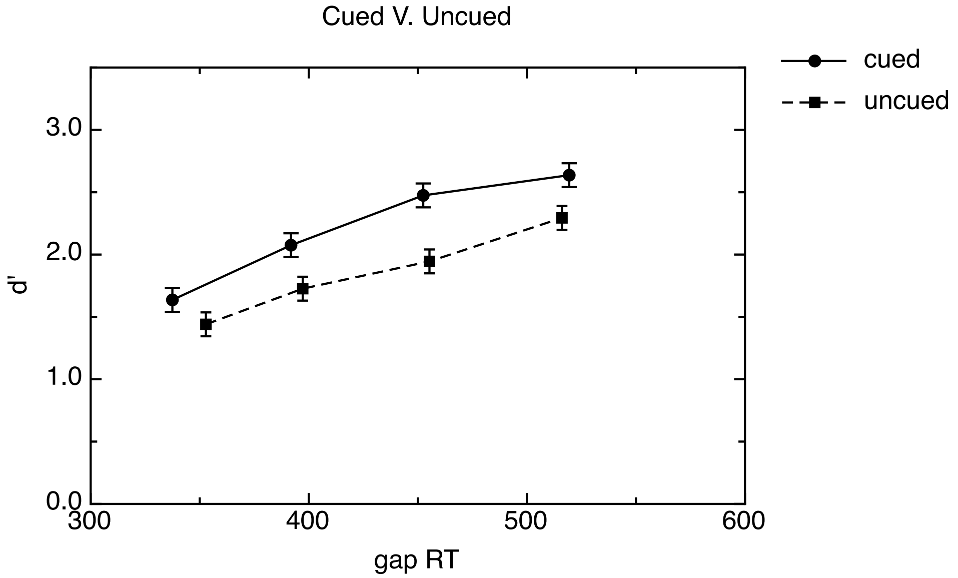

Figure 2. Mean d' values for cued versus uncued trials, in Experiment 1, as a function of the gap condition RT. Error bars only represent the main effect in accuracy and are 95% confidence intervals (Loftus & Masson, 1994).

Table 1. Mean RT data for the gap and no gap condition (in ms), mean d' and response criterion (c), as a function of cuing and STI, in Experiments 1 (Cued v. Uncued) and 2 (Cued v. Neutral).

	Experiment 1					**Experiment 2**			
	STI					**STI**			
Gap RT (ms)	**120**	**192**	**264**	**336**		**120**	**192**	**264**	**336**
Cued	337	392	452	519	**Cued**	355	404	472	551
Uncued	353	397	455	516	**Neutral**	340	386	451	525
No Gap RT (ms)									
Cued	349	408	460	542	**Cued**	370	418	475	553
Uncued	350	406	465	531	**Neutral**	367	420	475	544
Perceptual sensitivity (d')									
Cued	1.60	1.95	2.51	2.60	**Cued**	1.82	1.90	2.32	2.42
Uncued	1.34	1.63	1.98	2.40	**Neutral**	1.80	2.36	2.95	2.90
Response criterion (c)									
Cued	0.02	0.18	0.17	0.23	**Cued**	-0.01	0.21	0.28	0.09
Uncued	0.20	0.20	0.18	0.16	**Neutral**	-0.05	-0.05	0.15	0.09

Therefore, the results of Experiment 1 were straightforward, when speed stress was controlled, perceptual sensitivity was in fact improved by the exogenous orienting of spatial attention (i.e., in cued trials as compared with uncued trials). Moreover, no evidence of a SAT was found in this experiment, RT being even faster in cued than uncued trials at the shorter STI. It is possible that this SAT manipulation was responsible for the results being the opposite of that in the literature. Therefore, a replication of the original finding from Yeshurun an Levy (2003) was undertaken.

EXPERIMENT 2 (Cued v. Neutral)

Given that the results of Experiment 1 were so dramatically different from the extant literature, and most importantly, lead to different conclusions than Yeshurun & Levy (2003), a replication was undertaken. Our Experiment 2 experiment was a replication of Yeshurun & Levy's (2003) Experiment 1, in which spatially-cued trials and neutral cue trials were compared. The spatial cue always appeared at the target location. In order to control for SAT effects, a tone signaled (at four different intervals, manipulated between blocks) when to respond.

It is worth noting that Experiment 1 was designed from the outset in anticipation of such a replication. Careful examination of Yeshurun & Levy (2003) will show that this is method is a very close replication.

Method

Participants

Twenty naïve participants (3 males and 9 females, mean age of 21 years) from Dalhousie University took part in the experiment for course credits. All of them had normal or corrected to normal vision and normal hearing.

Apparatus and stimuli

Everything was exactly the same as in Experiment 1 except for the cues used. In Experiment 2, the cue from Experiment 1 was also used for cued trials. But, in neutral cue trials, the cue consisted in a 25.5º x 0,4º horizontal line presented centrally above and below fixation. Because only these trials were run, in a replication, then the spatial cue was 100% predictive.

Procedure

The procedure was also exactly the same as Experiment 1 except that uncued trials were replaced with neutral cue trials.

Results

Misses (11.1% of trials), late responses (0.34% of the trials), and early responses (4.8% of the trials), were removed from the analysis.

Mean RT data were submitted to a repeated-measures analysis of variance (ANOVA), with the factors of cueing (spatially-cued trials and neutral cue trials), gap condition (gap and no gap), and STI (191, 263, 335, and 407 ms). Apart from the main effect of STI, the main effect of cuing was significant, $F(1,11) = 20.25$, $MSE = 309$, $p < 0.001$. RTs were faster for neutral cue trials than spatially-cued trials, which may indicate that the neutral cue was in fact more alerting than the spatial cue. Gap condition was also significant, RT was faster in the gap condition than in the no gap condition, $F(1,11)=9.75$, $MSE=1526$, $p= 0.010$. The interaction between gap and cuing was also significant, $F(1,11)=10.53$, $MSE=354$, $p = 0.008$, revealing that the cueing effect was only observed in the gap condition. RT never interacted with STI.

Mean accuracy data, as d' values, were submitted to a repeated measures ANOVA, with the factors of cuing and STI. This analysis revealed that both of the main effects were significant. As expected, the STI effect, $F(1,11)=8.33$, $MSE=.49$, $p<.001$, showed an increase in perceptual sensitivity as the STI became longer. The main effect of cuing, $F(1,11)=31.96$, $MSE=.11$, $p<.001$, revealed higher perceptual sensitivity to neutral cue trials (M=2.50) versus spatially-cued trials (M=2.11). The interaction between STI and cuing was also significant, *F*(1,11)=2.99, *MSE*=.16, *p=.045,* and showed that the cuing effect was not present at the short STI (see Figure 3). Criterion was also examined but there were no significant effects (see Table 1).

In summary, the present experiment showed that, even when speed stress was controlled, the results replicated Yeshurun & Levy (2003). Therefore, it was not the SAT manipulation that caused the reversal of the cueing effect in Experiment 1.

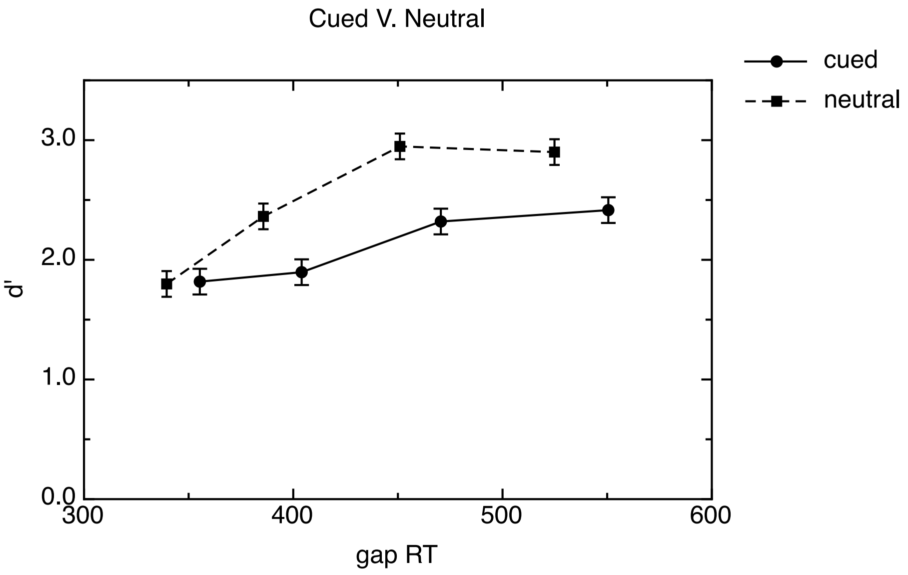

Figure 3. Mean d' values for cued versus neutral trials, in Experiment 2, as a function of the gap condition RT. Error bars only represent the main effect in accuracy and are 95% confidence intervals.

General Discussion

A recent line of research (Hein et al., 2006; Rolke et al., 2006; Yeshurun, 2004; Yeshurun & Levy, 2003) suggests that exogenous attention might impair perception in tasks involving temporal resolution. However, the empirical evidence so far is not convincing for varying reasons. In the first demonstration of the effect (Yeshurun & Levy, 2003), 100%

spatial cues were compared with neutral cues. This design was problematic for two main reasons: 1) The neutral cue was much bigger and brighter than the spatial cue, which might have exogenously produced probably different alerting effects. 2) The neutral cue and spatial cue set up different expectations and preparatory states on the part of the observer and not the best possible comparisons (Jonides & Mack, 1984). Moreover, when cued and uncued trials have been compared (Hein et al., 2006; Rolke et al., 2006), performance results were disputable because SATs were also found, and analysis of the effects sizes in the RT and accuracy show stronger effects in RT, the measure that contradicted Yeshurun & Levy (2003) accuracy results.

On the one had, in relation to the comparison of neutral versus spatial cues, evidence in Yeshurun (2004) suggests that perhaps there is something to the alerting hypothesis with respect to their neutral cue. She essentially replicated the Yeshurun & Levy (2003) findings but used a far less salient neutral cue than in the earlier studies. While the findings supported Yeshurun & Levy (2003), they also suggest that it may be the differential intensity of the neutral and spatial cues that generates the effect because it is much smaller in Yeshurun (2004). And, it may well be that temporal attention, or attention to a specific time period that is rallied by warning signals is more sensitive to temporal discriminations than spatial (and vice versa).

On the other hand, Rolke et al. (2006), Experiment 3, intended to control for the possibility of an SAT. However, instead of attempting to control the window wherein the decision is made at an early time, they chose simply to allow the participant to delay the response until at least 1 second after the possible gap. This manipulation can potentially mask the SAT problem rather than solving it because the actual time the decision is made is unknown and likely at some time far before the time that the response is made. It appears to be the nature of these cueing manipulations that they provoke an SAT in the temporal gap discrimination task. This SAT usually manifests itself in 400-500 msec. Therefore, a response made to a tone 1 second later may simply render invisible an SAT that has already occurred. The present method presents no such problem because the response is required to be made at a time when the participant is typically not prepared and the decision has not yet been made. Therefore, we believe that in all of the prior experiments mentioned here with a cued versus uncued manipulation testing the effects of attention on temporal stimuli, there has been an SAT and, at best, equivocal results.

In the present experiments we compared performance in cued trials as compared with uncued trials (Experiment 1), and spatially-cued trials as compared with neutral cue trials (Experiment 2). Speed stress was controlled using a deadline method in which a tone signaled when to respond at different time intervals. RT and accuracy were improved in neutral cue trials as compared with spatially-cued trials, which is ambiguous because the cues are dramatically different stimuli that set up different expectation and automatically activate systems in different manners. Clarifying the matter, RT was comparable in cued versus uncued trials at all but the shorter SOA, in which RT was faster for cued versus uncued trials. The accuracy data showed that sensitivity was indeed enhanced in cued trials as compared to uncued trials, a much more fair comparison because the system is in the same state prior to target onset for both kinds of trial (Jonides & Mack, 1984). As SAT effects were controlled and no criterion bias modulations were found, it can be concluded that exogenous attention enhances temporal resolution by modulating early perceptual processes. Prior conclusions to the contrary may have been based on a confounded method in early experiments coupled by the unfortunate situation that when an unconfounded test is done it often results in SAT effects that make strong conclusions difficult to draw. The current findings also suggest that further investigation is necessary in order to understand the relationships among temporal attention (alerting), and spatial attention, in temporal resolution tasks.

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