TESIS DOCTORAL

Doctorado Internacional

Mechanisms and electrophysiological basis of exogenous attention

(Mecanismos y bases electrofisiológicas de la atención involuntaria)

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Mecanismos y bases electrofisiológicas de la atención involuntaria

Doctoranda:**Elisa Martín Arévalo**

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Fdo.:

Sin investigación hoy, sin soluciones mañana.

Por una educación e investigación pública.

…Conociéndome, no os extrañará que esté emocionada mientras escribo las últimas líneas de este trabajo.
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Estudiando la atención, estuadiamos – probablemente − la columna vertebral del psiquismo humano.

(Pío Tudela, RECA-9,
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Chapter I

Introducción

(Written in Spanish)

El medio que nos rodea, nuestro mundo, contiene mucha más información de la que podemos percibir y procesar en un solo vistazo. Por esta razón, tener un mecanismo que seleccione y aísle información relevante, con el fin de ser procesada, es crucial para un adecuada interacción con nuestro medio. El papel protagonista para este mecanismo de selección ha sido otorgado a la atención, entendida en este contexto como "*la conducta del organismo encaminada a optimizar la captación de los estímulos*" (Tudela, 1981). No obstante, el concepto de atención ha ido cambiando a lo largo de las décadas, no lejos de controversia, hasta nuestros días.

Modelos explicativos de la selección atencional

El modelo teórico de D.E. Broadbent (1958) es la primera teoría de la atención selectiva, centrándose básicamente en el estudio del mecanismo del filtro, relacionado con la pequeña parte de información que somos capaces de procesar. Así, este *filtro*, entendido como un cuello de botella, representaría un mecanismo protector contra la sobrecarga de la memoria a corto plazo (MCP), dejando pasar exclusivamente la información que es relevante (principalmente en términos de relevancia exógena generada por los propios estímulos, aunque también en función del estado interno del organismo) para su posterior paso a la memoria a largo plazo (MLP); que constituiría nuestro conocimiento del mundo. Según este modelo, toda la información que llegaba a nuestros sentidos era procesada en paralelo y almacenada temporalmente en lo que se denominó Memoria Sensorial (MS). Un vez allí, la información sería filtrada antes de ser procesada, funcionando bajo la ley del todo/nada (filtro rígido), permitiéndole el paso a MLP sólo a aquella información que hubiese conseguido superar dicho filtro. El modelo teórico de A. Treisman (1964) surgió como una reacción a la rigidez del filtro propuesto por Broadbent, elaborando un modelo de *filtro atenuado* en el que las estructuras de procesamiento eran similares a las del modelo anterior pero donde se explicaba de forma muy distinta el funcionamiento de dichas estructuras, y muy especialmente, la del filtro. En este modelo, el paso de la información dejaba de ser todo/nada para convertirse en información atenuada o no, recibiendo aquella no atenuada un tratamiento especial, y siendo por lo tanto traspasada MCP con la máxima intensidad. En cualquier caso, tanto el modelo de Broadbent (1985) como el modelo de Treisman (1964) otorgaron al filtro (como reflejo del mecanismo atencional) un rol de selección temprana (perceptual) en el procesamiento de la información.

Otros modelos post-perceptuales, de selección tardía, asumieron que todos los estímulos que llegaban a través de los sentidos eran procesados perceptualmente antes de ser seleccionados por la atención. Así, toda la información almacenada en la MS sería completamente procesada en paralelo por un sistema analizador (procesamiento pre-filtro; automático e inconsciente), siendo sólo después de éste análisis cuando la selección atencional entraría en juego. Entre estos modelos destacaron el de Deutsch y Deutsch (1963), el de Norman (1968), y el de Johnson y Heinz (1978).

El primer modelo que hizo un intento en conciliar las diferentes posturas que se habían adoptado respecto al lugar de selección del filtro (temprano vs. tardío) fue el modelo de Johnson y Heinz (1978), proponiendo una alternativa basada en la existencia de un filtro flexible en el cual la selección se podía llevar a cabo en diferentes momentos del procesamiento. No obstante, pronto se pusieron de manifiesto las limitaciones de modelos secuenciales y poco flexibles en la comprensión de la selección atencional. En líneas generales, el hecho de que los modelos previos llevasen implícita la concepción de filtro perceptual, dejaba un poco de lado la determinación más top-down, más voluntaria, en el mecanismo atencional. Fue a partir de los años sesenta cuando comenzaron a surgir una serie de modelos entre los que se manejaba un nuevo concepto de atención y que han sido conocidos como modelos de recursos limitados y modelos de automaticidad.

Dentro de los modelos de recursos limitados, el mayor interés se centró en saber cómo se distribuía la capacidad de procesamiento del sistema, dejando atrás el análisis de estructuras atencionales y los fenómenos de entrada de la información. El modelo de D. Kahneman (1973) posiblemente sea el modelo que mejor represente esta nueva concepción de la atención, centrándose en los aspectos intensivos de la atención. Kahneman argumentó que las limitaciones en la capacidad atencional podrían depender de la capacidad general disponible de un individuo, más allá de las limitaciones propuestas en los modelos anteriores en las estructuras implicadas en el procesamiento, estando ésta relacionada con el nivel de *arousal* o activación (determinando la cantidad de recursos disponibles en un momento dado), y relativa a la capacidad específica que se necesitaba al realizar las posibles actividades. Navon y Gopher (1979) dieron un paso más, dejando atrás la idea de recursos generales, estableciendo una diferencia entre procesos limitados por los recursos y procesos limitados por los datos, con la idea de dar una explicación a la distribución de esa capacidad general entre los diferentes procesos y actividades que se los disputaban. Casi de forma paralela a los modelos de recursos, surgieron los modelos conocidos como modelos de automaticidad (donde destacan los modelos de Posner y Schneider, 1975; Shiffrin y Schneider, 1977 y Hasher y Zachs, 1979), considerados como una crítica a los primeros modelos del filtro y como una continuación a los modelos de recursos. Estos modelos postularon la existencia de dos formas de procesamiento cualitativamente diferentes: los procesos automáticos y los controlados, con rasgos y criterios diferentes que permitían una clara distinción entre ellos, llegando a considerar la atención como un criterio básico para decidir entre la categorización de los dos procesos (si conllevaba atención sería controlado y de lo contrario, automático). Posteriormente, modelos como el de Kahneman y Treisman (1984) o Schneider y Shiffrin (1985) se alejaron de esta dicotomía proponiendo posturas alternativas donde se asumía un funcionamiento conjunto de ambos tipos de procesos.

Es a partir de la década de 1980 cuando la atención comienza a conceptualizarse como un mecanismo capaz de controlar la ejecución de los procesos mentales (Logan, 1981). Uno de los modelos más influyentes es el de Norman y Shallice (1986), conocido como *modelo de atención para la acción*. En este modelo se plantea la existencia de todo un conjunto de funciones cognitivas simples que se integran e interactúan entre sí, dando lugar a lo que se denomina esquemas de acción, que serían relativos a la actividad conductual llevada a cabo por un individuo. La atención sería entendida como la estructura de control, llamada Sistema Atencional Superior (SAS), con capacidad limitada, que se activaría cuando estos esquemas de acción no pueden ser desarrollados de manera automática. Así, la atención no sería localizada en un momento temporal del procesamiento, si no que estaría situada en un plano vertical ejerciendo su influencia sobre distintos procesos cognitivos (Posner & Presti, 1987).

En general, superar el concepto de la atención exclusivamente como un proceso de selección, junto a los cambios que en la concepción de la misma se han ido dando a lo largo de los años, ha llevado a una definición de la atención mucho más compleja, entendida como "*un mecanismo central de capacidad limitada cuya función primordial es controlar y orientar la actividad consciente del organismo de acuerdo a un objetivo determinado*" (Tudela, 1992).

Modelos teóricos posteriores como el de Lavie (1995) han intentado recoger los avances anteriores y aunarlos en el concepto de *carga perceptiva*, entendida como la combinación entre la cantidad de información que se necesita procesar y la naturaleza de ese procesamiento. Concretamente, en este modelo se plantea que situaciones o tareas poco demandantes, donde se presente poca cantidad de información (baja carga perceptiva), el sistema dispondría de recursos suficientes para procesar otro tipo de información ajena a la tarea y que podría generar algún tipo de interferencia. No obstante, cuando las situaciones sean altamente demandantes (alta carga perceptiva), entonces todos los recursos estarían puestos en esa situación y el resto de información irrelevante no sería procesada. Así, este modelo, aunque importante, genera un planteamiento donde la asignación de recursos es tarea-dependiente, y donde la atención voluntaria tendría poco lugar. Es el modelo de Pashler (1998), modelo de *Procesamiento Paralelo Controlado* (PPC) el que da cabida a la atención voluntaria, otorgando al sujeto la capacidad de seleccionar la información que será analizada dadas las limitaciones y la competición entre recursos del propio sistema. Asimismo, es este modelo el que parece cerrar la problemática del filtro, ya que plantea que ambos tipos de selección (temprana o tardía) son posibles dependiendo de cómo elegimos procesar la información.

Atención endógena versus Atención exógena

Esta "*orientación atencional hacia un objetivo determinado*" (Tudela, 1992) podría llevarse a cabo de acuerdo a dos criterios diferentes; se podría dirigir a los estímulos en relación a objetivos, metas e intenciones de la persona, denominada en este caso orientación atencional endógena o voluntaria, o bien hacerlo por las propias características de los estímulos, cuando por ejemplo, éstos son novedosos, inesperados, o potencialmente peligrosos para nuestra supervivencia (Ruz & Lupiáñez, 2002), lo que se denomina orientación atencional exógena o involuntaria.

El paradigma de Costes-Beneficios

El paradigma de costes y beneficios (Posner y Cohen, 1984) ha sido tradicionalmente usado para estudiar estas dos formas de orientación atencional, diseñado con el objetivo de explorar los afectos de la atención orientada a un lugar en el espacio. En este paradigma se presenta habitualmente un punto de fijación, y a cada lado una caja o marcador, en las cuales aparecerá el estímulo al que se ha de responder (denominado comúnmente *target*). Antes de la aparición de dicho estímulo objetivo, se presenta una señal que dirige la atención del participante a una de las dos posiciones, donde el estímulo objetivo podría aparecer o no, dando lugar a localizaciones señaladas o no señaladas. Manipulando la naturaleza de la señal, este paradigma ha permitido el estudio de la orientación endógena y exógena. Concretamente, mediante el uso de *señales centrales predictivas* (por ejemplo, un flecha en el centro que apunta a una de las dos posiciones, indicando por encima del azar donde se presentará el estímulo objetivo) se pueden medir los efectos de la orientación atencional endógena, mientras que, mediante el uso de *señales periféricas no predictivas* (señales exógenas: por ejemplo, un flash no predictivo en una de las cajas) se observan los efectos de la orientación atencional exógena, siendo el efecto comportamental de ambos tipos de señales claramente diferente (Müller y Rabbit, 1989). Así, las señales centrales endógenas usualmente producen respuestas más rápidas en las localizaciones del estímulo objetivo que fueron previamente señalas; un efecto de *facilitación* que se puede mantener durante intervalos de tiempo prolongados (Posner, 1980; Funes, Lupiáñez y Milliken, 2007). Sin embargo, cuando se usan señales exógenas no predictivas, si el SOA (*Stimulus Onset Asynchrony*; tiempo que transcurre entre que se presenta la señal hasta que aparece el estímulo objetivo al que se ha de responder) es menor de 300 ms en tareas de detección y alrededor de 500-700 en tareas de discriminación (Lupiáñez, Milán, Tornay, Madrid y Tudela, 1997; para ver las diferencias entre tareas), los participantes son normalmente más rápidos en responder al estímulo objetivo cuando éste se presenta en el mismo lugar en que se presentó la señal, mostrando un efecto de facilitación. Sin embargo, si el SOA es mayor de 300 ms o 500-700 ms respectivamente para tareas de detección y discriminación, el efecto se invierte, de forma que ahora los participantes son más rápidos en responder al estímulo objetivo si éste se presenta en el lugar contrario al lugar en que se presentó la señal. Este efecto, que consiste en mayores tiempos de reacción para responder a los lugares ya atendidos con anterioridad, es conocido como *Inhibición de Retorno* (IR) desde que Posner, Rafal, Choate y Vaughan (1985) lo denominaran así por primera vez.

Tradicionalmente, ambas formas de atención han sido concebidas como dos maneras distintas de poner en marcha un mismo mecanismo atencional (Jonides, 1981; Yantis, 1998; 2000). Así, tanto la atención endógena como exógena estarían en competición constante por el control atencional, determinando en cada momento qué atender o no en relación al objetivo del supuesto ganador de la competición. No obstante, la evidencia empírica pronto desbancó esta concepción dando paso a un nuevo marco de interpretación donde ambas formas de orientación atencional se han entendido como dos mecanismos atencionales distintos, que difieren en sus características (Müller y Rabbit, 1989) y que pueden producir sus efectos de manera independiente (Klein, 2004; Chica y Lupiáñez, 2004; Chica, Lupiáñez y Bartolomeo, 2013; Berger, Henik y Rafal, 2005). Sin embargo, aunque independientes, este hecho no descarta que ambos tipos de atención pueden interactuar entre sí bajo algunas circunstancias.

Modulación de la atención endógena sobre la exógena

Algunos estudios señalan que el efecto de IR, relativo a la atención exógena, puede ser modulado endógenamente en función del estado (*set*) adoptado por el participante para solventar las demandas de las tareas. Esta asunción se apoya en algunos resultados relevantes como las diferencias en el curso temporal del efecto en tareas de detección y discriminación (Lupiáñez y cols., 1997; Milliken, Lupiáñez, Roberts, y Stevanovski, 2003); en los efectos que se observan cuando se eliminan procesos de preparación temporal (por introducir una gran cantidad de ensayos sin estímulo objetivo) en una determinada tarea (Tipper y Kingstone, 2005); la influencia de la presentación de estímulos distractores (Lupiáñez y Milliken, 1999), los efectos de compatibilidad estímulo-respuesta (Khatoon, Briand, & Sereno, 2002), o el efecto del rango de SOAs (Cheal y Chastain, 2002), que en definitiva, hacen a los participantes adoptar una determinada estrategia (de manera endógena) para resolver las tareas.

Tradicionalmente, tal modulación endógena ha tenido cabida en relación a dos grandes hipótesis explicativas: la hipótesis de la *captura atencional* (Folk y Remington, 1998) y la hipótesis del *posterior desenganche* (Klein, 2000). Concretamente, la hipótesis relacionada con la captura atencional, plantea que dicha captura no es algo automático, sino que depende del establecimiento de un determinado set atencional. Así, por ejemplo, la aparición posterior de IR en tareas de discriminación se explicaría por la mayor demanda cognitiva que este tipo de tareas genera.

En cuanto a la hipótesis alternativa relacionada con el *posterior desenganche*, ésta asume que la atención es desenganchada de la señal en diferentes momentos en ambos tipos de tareas. Siguiendo con el mismo ejemplo, en tareas de detección se requeriría ser sensible sólo al comienzo del estímulo objetivo, por lo que el set adoptado por los participantes sería aquel que te permita segregar la señal de dicho estímulo. Asumiendo que el desenganche atencional es un modo de segregación de la señal-estímulo objetivo, se explicaría que el efecto de IR aparezca más rápidamente en tareas de detección comparadas con discriminación, en las que un set de integración de eventos se mantiene (Lupiáñez y Milliken, 1999; Klein, 2000; Lupiáñez, Milliken, Solano, Weaver y Tipper, 2001).

Con el objetivo de poner a prueba ambas hipótesis, Lupiáñez, Ruz, Funes y Milliken (2007) llevaron a cabo un estudio donde manipularon la frecuencia de los estímulos objetivos en un mismo bloque de ensayos, pero donde el mismo set de tarea se mantuvo lo largo del experimento, siendo lo prioritario en la tarea la detección de los estímulos frecuentes. Si las hipótesis explicativas de la modulación por el *set* de tarea fuesen correctas, bien en términos de captura o desenganche, no deberían encontrarse diferencias entre estímulos frecuentes e infrecuentes, dado que el set fue el mismo en todo el bloque de ensayos. No obstante, si el efecto de señalización estuviese basado en el procesamiento del propio estímulo objetivo, se deberían esperar diferencias en el efecto de IR entre estímulos frecuentes e infrecuentes. Los resultados mostraron IR para estímulos infrecuentes y facilitación para los frecuentes. Así, de estos datos se concluye que las diferencias observadas en el efecto de señalización para ambos estímulos no pueden ser explicada exclusivamente ni por diferencias en desenganche, ni por diferencias en captura atencional para estímulos frecuentes e infrecuentes, ya que ambas explicaciones se focalizan en procesos que ocurren antes de la aparición del estímulo objetivo.

Independencia de ambos tipos de atención

No obstante, aunque los datos previos apuntan a cierta modulación voluntaria sobre los distintos procesos de la orientación exógena, la distinción entre orientación atencional exógena y endógena ha sido apoyada por bastante evidencia en individuos sanos (Funes, Lupiáñez y Milliken, 2005; Berger y cols., 2006; Chica y Lupiáñez, 2004) y en pacientes con daño cerebral (Bartolomeo y Chokron, 2001; 2002), así como por la observación de diferentes sustratos neurales en cada una de ellas (Corbetta y Shulman, 2002).

En particular, los primeros estudios ya reflejaron una serie de diferencias cuantitativas entre los efectos generados por ambos tipos de atención (Jonides, 1981), encontrando grandes diferencias en su curso temporal (Müller y Findlay, 1988); así, las señales periféricas (reflejo de la atención exógena) producen mayores y más rápidos efectos que las señales centrales (reflejo de la atención endógena). Por su parte, Theeuwes (1992; 2004) asumió los efectos de señalización exógena como puramente reflexivos, donde la atención endógena no tendría lugar. Autores como Briand y Klein (Klein y Shore, 2000, en su artículo de revisión) examinaron el rol de la atención endógena y exógena en tareas de búsqueda visual (Brian y Klein, 1987; Briand, 1998; Klein y Shore, 2000), con la idea de ver si ambos tipos de atención ejercerían efectos cualitativamente diferentes en este tipo de tareas. Estos autores han mostrado una *disociación* entre ambos tipos de atención; mientras que la manipulación exógena interactuó con el tipo de búsqueda visual (conjuntiva versus de rasgo), mostrando mayores efectos de señalización en la tarea conjuntiva, la manipulación endógena mostró efectos similares en ambos tipos de tareas, argumentando que ambos tipos de atención podrían afectar a diferentes etapas de procesamiento (ver Klein, 1994, para conclusiones similares). Estudios llevados a cabo con medidas psicofísicas han respaldado también los resultados previos en esta línea de disociación (Müller y Humprheys, 1991; Lu y Dosher, 2000).

No obstante, quizás sea de los estudios de IR de donde provengan los mayores resultados relacionados con la disociación endógena-exógena (Taylor y Klein, 2000). Chica y Lupiáñez (2004; Chica, Lupiáñez y Bartolomeo, 2006) han hecho grandes esfuerzos para hallar disociaciones de ambos efectos atencionales usando el mismo conjuntos de estímulos. Concretamente, ellos desarrollaron un paradigma en el tuvieron al mismo tiempo medidas de efectos de atención endógena y efectos de atención exógena manipulando entre bloques de ensayos la predictividad de la señal, concretamente comparando localizaciones exógenamente señaladas o no señaladas y endógenamente atendidas o no atendidas. Sus resultados claramente mostraron que la IR es completamente independiente de la orientación endógena (ver también Berger y cols., 2005, para resultados similares), lo que les llevó a establecer que ambos tipos de atención son mecanismos completamente separados (Chica y Lupiáñez, 2009). Es importante destacar que tales disociaciones no sólo han sido establecidas comportamentalmente, sino que evidencia electrofisiológica (con medidas de potenciales evocados), mostrando diferencias en el curso temporal de los efectos endógenos y exógenos (Mort, Perry, Mannan, Hodgson, Anderson, Quest, McRobbie, McBride, Husain y Kennard, 2003; Eimer, 2000; Chica y Lupiáñez, 2009), junto a estudios de neuroimagen (Rosen, Rao, Caffarra, Scaglioni, Bobholz, Woodley, Hammeke, Cunningham, Prieto y Binder, 1999; Corbetta y Shulman, 2002; ver Chica, Bartolomeo y Lupiáñez, 2013, para una revisión) también la respaldan.

Sin embargo, los datos de disociaciones, aunque importantes, no determinan que ambos tipos de atención puedan entenderse como dos mecanismos cualitativamente diferentes, dado que se refieren a efectos de la atención endógena que no genera la exógena (y viceversa) y eso no es concluyente de la independencia de sistemas. Así, el dato que más avala y concluye la independencia de ambos tipos de atención es el que proviene de la *doble disociación*, donde un tipo de atención modula un efecto concreto en una dirección y el otro tipo de atención lo hace en la dirección contraria. El trabajo realizado por Funes, Lupiáñez, y Milliken (2005) ha sido determinante al respecto. Estos autores, usando una tarea de Stroop espacial, manipulando el tipo de señales que orientaban la atención en el espacio (señales centrales y periféricas como reflejo de ambos tipos de atención). Sus resultados mostraron modulaciones opuestas por ambas señales en el efecto de congruencia generado por la tarea. Concretamente, las señales periféricas redujeron el efecto de congruencia mientras que el uso de señales centrales lo aumentó. Estos datos, en conjunto con los trabajos llevados a cabo por Klein (1994) y Brian (1998) arrojan luz al hecho de concebir ambos tipos de atención como dos mecanismos atencionales independientes.

Nuestra propuesta experimental radica en la conceptuación de ambos tipos de atención −endógena y exógena− como dos mecanismos diferentes, como dos sistemas independientes que ejercen sus efectos e implementan sus funciones de manera autónoma, siendo nuestro interés de estudio la comprensión de la atención exógena en general y de los efectos comportamentales que ella genera en particular.

Atención exógena

Como hemos visto en un apartado anterior, cuando se utiliza el Paradigma de Costes y Beneficios para investigar los efectos de la atención exógena, usualmente se encuentran dos efectos a lo largo del tiempo; un primer efecto de *facilitación*, que es seguido del efecto de IR, siendo éste último nuestro principal objeto de interés.

Inhibición de retorno (IR)

Muchos han sido los autores que han señalado la eficacia, a nivel adaptativo, del efecto de IR, ya que de alguna manera maximizaría la búsqueda visual, previendo que la atención vuelva a los lugares u objetos que ya han sido examinados (Klein, 2000, para una revisión). Concretamente, Posner y Cohen (1984), como descubridores del mismo, lo explicaron en términos de *orientación-reorientación* de la atención, dando lugar al efecto de facilitación e IR, respectivamente, y remarcando un mecanismo subyacente que inhibe que la atención retorne a lugares recientemente atendidos; un proceso, por tanto, con valor adaptativo en situaciones que requieran algún tipo de búsqueda visual. No obstante, algunas particularidades del procedimiento y de los resultados encontrados en esta primera toma de contacto con el efecto, ya llevó a estos autores a tener en cuenta la posibilidad de que los efectos pudiesen ser explicados en términos sensoriales y no sólo en relación a la orientación atencional. Posner y cols. (1985) dieron un paso más para su comprensión usando esta vez respuestas sacádicas en lugar de manuales. Los resultados mostraron una reducción en el número de sacadas a la posición previamente señaladas, lo que les llevó a establecer una fuerte relación entre los movimientos oculares y la IR (ver Maylor, 1985, para resultados similares).

Así, desde el descubrimiento del efecto de IR y su estudio con diferentes tipos de respuestas, dos grandes teorías han tenido cabida como explicativas del mismo: por un lado, la inherente al propio nombre, que explica el efecto en términos atencionales-perceptuales, y una hipótesis alternativa que se centra en el componente motor.

La primera interpretación, conocida como la hipótesis de la *orientación-reorientación atentional*, ha prevalecido hasta la actualidad casi como única explicación del efecto. Desde este planteamiento, un dato que ha avalado la naturaleza perceptual-atencional del efecto ha sido de nuevo la diferencia en el curso temporal de la IR dependiendo de las tareas (Lupiáñez et al., 1997; Pratt, Kingstone, & Khoe, 1997). Como hemos mencionado anteriormente, la IR es encontrada usualmente antes y en mayor medida en tareas de detección que en tareas de discriminación. Ya que la programación de las respuestas se asume igual en ambas tareas, las diferencias entre ellas en relación a la IR se ha interpretado en base a procesos perceptivo-atencionales. Esta interpretación se ha visto respaldada por datos relacionados con la teoría de detección de señales, que nos facilita una medida directa de sensibilidad perceptual (con la medida de d') y de criterio de respuesta (con la medida de β). Handy, Jha y Mangun (1999) observaron un efecto de IR acompañado por una disminución en la sensibilidad perceptual (disminución en d') en las posiciones previamente señaladas. Mas allá, algunos de los estudios previamente mencionados, relacionados con la búsqueda visual (Klein, 1988; Takeda y Yagi, 2000), también apoyan este tipo de procesos atencionales como explicativos del efecto, donde se ha encontrado IR sólo en aquel tipo de búsquedas visuales que requieren de atención serial.

Una idea inherente a este tipo de interpretación es la idea de *desenganche* atencional, en relación al concepto de reorientación (Klein, 2000). Este desenganche es una constante en la explicación de la mayoría de los efectos atencionales. Klein (2000) propone que por la dificultad de la tarea de discriminación en comparación con detección, el supuesto desenganche tendría lugar posteriormente en la primera con respecto a segunda, y eso daría lugar a la posterior aparición de IR. Danzinger y Kingstone (1999), encontraron un efecto de IR a los 50 ms que también fue interpretado por los autores en términos de desenganche temprano. Otros efectos relacionados con la modalidad sensorial de los estímulos, donde algunos autores encuentran que la IR es mayor para estímulos visuales que auditivos (Reuter-Lorenz, Jha y Rosenquinst, 1996), también han sido interpretados en esta línea. Los efectos relacionados con la presentación de una señal (denominada comúnmente *cue-back o fixation cue*) entre la señal y el estímulo objetivo, que acelera la aparición de IR principalmente en tareas de discriminación, se han interpretado también en términos de desenganche (Prime, Visser y Ward, 2006). En definitiva, hay una fuerte tendencia a asumir esta explicación como válida y a usarla como única interpretación posible en la mayoría de los efectos y manipulaciones en los que la IR se ve implicada.

Con respecto a la hipótesis alternativa (mucho menos aceptada) donde el *<u>componente motor</u>* tendría un rol explicativo del efecto de IR, se plantea este efecto como un sesgo de respuesta en no responder a objetos y/o localizaciones previamente atendidas (Taylor y Klein, 1998). Como hemos señalado en el comienzo de esta sección, hay evidencia que apoya la implicación de los procesos motores en la IR desde los primeros trabajos de Posner y cols. (1985). Rafal, Calabresi, Brennan y Sciolto (1989) propusieron que las señales exógenas producían IR aunque el movimiento ocular no tuviese lugar, ya que se suponía que de manera involuntaria estas señales generaban la preparación de un movimiendo sacádico (aunque ver Chica, Klein, Rafal, y Hopfinger, 2010, donde este efecto no pudo ser replicado). Autores como Klein, Taylor e Ivanoff (Klein & Taylor, 1994; Ivanoff y Klein, 2001; 2004) han concebido la IR como un efecto (un cambio) en el criterio de respuesta en términos motores basados en sus estudios, tanto en tareas de detección como en tareas de discriminación, donde la presencia de IR siempre la han observado acompañada de un menor porcentaje de falsas alarmas en esa misma condición. Desde su planteamiento de cambio de criterio, el mecanismo responsable de la IR actuaría sesgando el sistema en contra de responder al estímulo objetivo en la localización señalada, por lo que se necesitaría mas "evidencia" para responder en los ensayos señalados (mayor TR) pero las respuestas también deberían ser más exactas (menos falsas alarmas), por hacer el criterio de respuesta más estricto. Taylor y Klein (2000) llevaron a cabo una revisión al respecto, cruzando el tipo de señal (exógena/periférica − endógena/central), el tipo de estímulo de respuesta (periférico−central) y el tipo de respuesta (manual/sacádica o no respuesta), llegando a la conclusión de la existencia de dos tipos de IR; una manual y la otra sacádica. En esta línea, Hunt y Kingstone (2003) argumentaron que el tipo de respuesta que se demande a los participantes sería clave para determinar si el efecto de IR interacturía con procesos motores (Abrams y Dobkin, 1994, para resultados similares) o con procesos perceptuales (Reuter-Lorenz y cols., 1996). Chica, Taylor, Lupiáñez, y Klein (2010) también han apuntado resultados en esta línea, donde el efecto de IR puede producir efectos en los procesos atencionales/perceptuales o en procesos motores dependiendo de las demandas de las tareas requeridas (ver también Sumner, Nachev, Vora, Husain, & Kennard, 2004; Bourgeois, Chica, Migliaccio, Thiebaut de Schotten, & Bartolomeo, 2012; Bourgeois, Chica, Valero-Cabré, & Bartolomeo, 2012; para una disociación entre IR manual y sacádica).

La técnica de registro electroencefalográfico y las medidas de ***Potenciales Evocados*** asociados a eventos (PE), constituyen una herramienta que ha logrado ofrecer una respuesta adecuada a este debate perceptivo-atencional versus motor, permitiéndonos la obtención de índices de la actividad eléctrica cerebral a lo largo de las distintas etapas de procesamiento tras la aparición del evento de interés. Uno de los trabajos más influyentes y determinantes a este respecto fue realizado por Prime y Ward (2004), quienes mostraron su interés en discernir el predominio del componente perceptivo-atencional y/o motor en el efecto de IR. Estos autores utilizaron una clásica tarea de discriminación donde el estímulo objetivo fue predecido o no por una señal exógena, mientras registraban la actividad cerebral de los participantes. En particular, estos autores se interesaron por tres componentes diferentes: El P100 y N100, reflejo del procesamiento perceptual del estímulo de interés, y el LRP (*Lateralized Readiness Potential*), un componente relacionado exclusivamente con respuestas y preparación motora; así, mientras la latencia de aparición de este componente se relaciona con el momento de evaluación y selección de la respuesta (LRP anclado al *target*), el intervalo que transcurre desde la aparición del potencial hasta la respuesta (LRP anclado a la *respuesta*) lo hace con los procesos de planificación y ejecución de la misma. Los datos mostraron que el efecto de IR fue acompañado por una reducción significativa del P100 y del N100 en las posiciones señaladas (reflejando la implicación perceptivo-atencional) pero no por efectos en el LRP anclado a la respuesta (que reflejaría puramente el componente motor), lo que llevó a establecer una clara relación entre el efecto de IR y los procesos perceptuales, en decadencia de la relación con los procesos motores. Estos mismos autores (2006) llevaron a cabo un nuevo estudio donde, manipulando el tipo de tarea (localización, detección y go-no go) de nuevo replicaron los efectos; la IR se relacionó con una reducción en componentes perceptuales para localizaciones señalas y no por modulaciones en el LRP anclado a la respuesta, siéndo este resultado independiendemente del tipo de tarea usada. Estos resultados en su conjunto han dado un gran respaldo a los componentes perceptivo-atencionales como la base de los efectos de IR.

No obstante, dado que la hipótesis de orientación-reorientación atencional ha sido asumida por la mayoría de los investigadores como única hipotesis explicativa, contamos con un gran cantidad de trabajos previos y posteriores a los de Prime y cols. (2004; 2006) basados también en PEs, que se han sido interpretados con la la hipótesis de orientación-reorientación atencional (Eimer, 1994; Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999; Wascher & Tipper, 2004; Prime & Ward, 2006; Prime & Jolicouer, 2009). Existe entre ellos un gran consenso al asumir las modulaciones en el P100 y N100 como un puro reflejo perceptual de lo que se observa en el comportamiento: aumento en el componente P100 y/o N100 para las localizaciones señaladas cuando se observa facilitación comportamental, y en contraposición, disminución en estos mismos componentes en las localizaciones señaladas cuando lo observado es IR. Aunque presentaremos en las Series Experimentales 3 y 4 de la presente tesis una revisión de todos estos trabajos, queremos destacar en este punto que no todos los estudios arriba mencionados han observado lo asumido por su hipótesis de partida, y éste hecho, en parte, ha llevado a otros autores a establecer una hipótesis alternativa de interpretación (Chica & Lupiáñez, 2009; Washler y Tipper, 2004).

En definitiva, muchos de los hallazgos encontrados a lo largo de la literatura, junto al hecho de encontrar IR donde previamente no se ha encontrado facilitación (Danziger y Kingstone, 1999; Tassinari & Campara, 1996) y donde el supuesto desenganche de la atención no ha tenido lugar por tratarse de un lugar endógenamente señalado (Chica & Lupiáñez, 2004; Berger y cols., 2005; Chica y cols., 2006), cuestionan la validez de esta interpretación en términos de *desenganche* y nos lleva a la necesitad de establecer otras interpretaciones posibles *en pro* de una mejor comprensión de los efectos de la atención exógena (ver Berlucchi, 2006, para una revisión sobre la necesidad de una mejora en la conceptualización de la IR).

Interpretaciones alternativas

El trabajo de Dukewich y Boehnke (2008) y la posterior revisión de Dukewich (2009) sobre el efecto de IR, desde nuestro punto de vista, han marcado un punto de inflexión en el estudio de este fenómeno atencional. Concretamente, el modelo de Dukewich (2009) plantea entender la IR en base al concepto de *habituación*, donde la IR sería un reflejo de la habituación a posiciones previamente señaladas. En concreto, para poner a prueba su hipótesis, las autoras llevaron a cabo dos experimentos (2008) donde manipularon la tarea (detección y discriminación) y el número de presentaciones de la señal periférica, de una a cinco presentaciones en el mismo lugar del estímulo objetivo (o en el contrario), y el rango de SOA entre señales. Desde este planteamiento de la IR como habituación, la hipótesis de partida se tradujo en que manipulando la cantidad de señales periféricas (bien por frecuencia o bien por reducir el tiempo de presentación entre ellas) se esperaría una mayor habituación y por lo tanto un mayor efecto de IR. Los resultados en ambos tareas fueron similares; se encontró un efecto general de IR que fue aumentando a medida que lo hacía el número de señales presentadas y/o el SOA disminuía, independientemente de la tarea realizada. Estos datos le dieron suficiente apoyo a Dukewich en su revisión (2009) sobre el efecto de IR, para interpretarlo en estos términos de habituación.

No obstante, el hecho de que las repeticiones de la señal se produjesen en la misma posición donde aparecería el estímulo objetivo no descarta que en la base de esa habituación pueda estar la clásica reorientación atencional. De hecho, el modelo no es muy explícito con respecto a qué es habituado y deja entrever que podría ser la orientación atencional a las posiciones previamente atendidas, inherente a la hipótesis de la orientación-reorientación ampliamente cuestionada (Berlucchi, 2006).

En cualquier caso, este nuevo planteamiento puede apoyar en alguna medida lo que en la presente tesis se pretende abordar: entender los mecanismos que subyacen a los efectos de facilitación, y en particular, al efecto de IR, proponiendo un nuevo marco interpretativo para este fin.

Hipótesis de segregación-integración de eventos (Lupiáñez, 2010)

Desde este planteamiento, que será ampliamente desarrollado a lo largo de este trabajo (especialmente en la Serie Experimental 2), el efecto de señalización (facilitación o IR) sería el resultado de la contribución de tres procesos diferentes. Concretamente, cuando la señal se presenta, la atención se dirigiría rápidamente a esa localización, mejorando tanto procesos perceptuales como de respuesta. Este *proceso de orientación espacial* ha sido tradicionalmente considerado como el único proceso explicativo de los efectos de señalización producidos por una señal periférica no predictiva, y siendo el proceso a la base de la hipótesis clásica de reorientación atencional.

No obstante, esta señal puede ser considerada con un evento, como un objeto que ocupa una localización específica, y que produce otros efectos en el procesamiento del estímulo objetivo que van más allá de la mera orientación atencional. Concretamente, basada en la teoría de la integración de eventos, y donde se asume un cierto rol a los procesos de memoria (Kahneman, Treisman, & Gibbs, 1992; Hommel, 2004), la señal podría abrir un "fichero" donde el estímulo objetivo podría ser integrado cuando éste se presenta en proximidad espacio-temporal con la señal (misma posición y SOA corto), dando lugar a un proceso de integración señal-estímulo beneficioso, un *beneficio por la selección espacial,* para el posterior análisis del estímulo objetivo. Sin embargo, esta integración, al compartir características señal y estímulo (especialmente por la localización en el paradigma de costes y beneficios) puede llevar bien a efectos positivos (especialmente cuando se requiere una <u>discriminación</u> del estímulo objetivo, que al estar siendo ya procesado llevaría a un mejor y más rápido reconocimiento) o bien a efectos negativos (cuando lo que se requiere es simplemente la <u>detección</u> del estímulo objetivo, dado que el sistema atencional trabaja en base a la saliencia estimular), donde se mediría un coste en detectar el comienzo de éste por haber sido su localización previamente atendida, y por lo tanto, siendo ya menos saliente para el sistema perceptivo-atencional.

Como se puede sustraer de lo anterior, cuando sean los beneficios por la integración los que tengan más peso en esa suma final que representa el efecto comportamental, entonces es esperable encontrar un efecto de *facilitación* en el comportamiento; del mismo modo, cuando sea el coste en la detección el que cuente con más peso en dicha suma, se observaría un efecto de IR comportamental, como reflejo de ese coste en la detección para estímulos que ya no son relevantes para el sistema.

Este nuevo marco interpretativo otorga a las demandas de las tareas un papel protagonista en añadir o quitar peso a determinados componentes; mientras que en las tareas de discriminación entrarían en juego procesos discriminativos y de análisis del estímulo objetivo, por lo que es esperable más efectos de facilitación, en las tareas de detección éstos apenas tendrían cabida dado que lo más relevante sería la mera detección del estímulo objetivo, sin importar demasiado la naturaleza del mismo, y por tanto, donde el efecto que sería principalmente medido sería el de IR. Asimismo, esta hipótesis hace predicciones específicas sobre determinadas variables que, como hemos visto a lo largo de la introducción, influyen especialmente en los efectos atencionales, y que serán presentadas a lo largo del presente proyecto de investigación.

En definitiva, lo que este nuevo modelo de interpretación plantea es que, dependiendo de los procesos necesarios para resolver una determinada tarea o la influencia de unas determinadas variables, algunos de estos componentes (*orientación espacial, beneficio por la selección* *espacial y coste en la detección*) contribuirían al rendimiento más que otros, observándose diferentes cursos temporales y diferentes tamaños en los efectos de señalización atencional, siendo el hilo conductor de la presente tesis el poner a prueba algunas de las hipótesis que de él se derivan.

Chapter II

Motivation & Overview of research

According to the "*reorienting hypothesis*" (Posner & Cohen, 1985), both the facilitatory and IOR effect are explained by the same mechanism: engagement and disengagement of attention, respectively. This *disengagement* of attention has been considered a necessary and sufficient condition for IOR to be observed (see Klein, 2000, for a review). Moreover, it has been considered by Klein (2000) as the basis for the different IOR time-courses observed for different tasks, with IOR being observed at longer SOAs in discrimination than in detection tasks (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997). In particular, it was 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 (Klein, 2000). Other authors have also interpreted the appearance of IOR at short SOAs as a consequence of rapid disengagement of attention from the cued location (see e.g., Danziger & Kingstone, 1999; Dodd & Pratt, 2007). Indeed, most effects related to the early or delayed appearance of the IOR effect generated by some variables, such as target-difficulty (generated by target contrast, see e.g., Snowden, Willey, & Muir, 2001; or target-modality, see e.g., Reuter-Lorenz, Jha, & Rosenquist, 1996), or by the presence of intervening events between cue and target (Prime, Visser, & Ward, 2006), have been explained in terms of early or late attentional disengagement, respectively.

However, some researchers have recently shown that disengaging attention might be neither necessary nor sufficient for the IOR effect to be observed (see Lupiáñez, 2010, for a review; see also the introduction in Experimental Series 1, for an extensive review; see also Berger, Henik, & Rafal, 2005, Chica, Lupiáñez, & Bartolomeo, 2006, and Lupiáñez, Martín-Arévalo, & Chica, 2013, for similar conclusions). These results are consistent with other studies that have reported, with a variety of paradigms, IOR at endogenously attended locations (Riggio & Kirsner, 1997; Berlucchi, Chelazzi, & Tassinari, 2000; Berger et al., 2005; Chica et al., 2006; Chica & Lupiáñez, 2009), and even at fixated locations (Rafal, Davies, & Lauder, 2006).

Previous evidence with different paradigms has also shown that IOR is not always related to the disengagement of attention from the cued location (see e.g., Ivanoff & Klein, 2004; Lupiáñez, Ruz, Funes, & Milliken, 2007). In particular, IOR has been consistently reported with no evidence of previous facilitation (Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994; Tassinari & Campara, 1996; Danziger & Kingstone, 1999; Pratt, Hillis, & Gold, 2001; see also Experimental Series 2 for an extensive boarding of this issue); it is difficult to interpret IOR 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 (see also Mele, Savazzi, Marzi, & Berlucchi, 2008).

Given the aforementioned evidence, we can conclude that both facilitation and IOR at peripherally cued locations can be observed independently of the endogenous orienting of attention, and therefore, independent of the engagement-disengagement of attention. However, IOR has not yet been dissociated from exogenous disengagement. It might be argued that the same way as IOR is only observed with exogenous cues, attention should be disengaged exogenously in order to observe the IOR effect. In particular, this reasoning could fit with the fact that the presentation of a intervening event (also called *cue-back* or *fixation cue*) between cue and target leads to IOR in discrimination tasks, whereas the endogenous disengagement of attention does not (see, e.g., Cheal & Chastain, 1999; Kingstone & Pratt, 1999; Pratt & Abrams, 1999; Pratt, Kingstone, & Khoe, 1997; Pratt & Fischer, 2002; Prime & Ward, 2004). Concretely, the presentation of an intervening event is well known to favour the appearance of the IOR effect (Faust & Balota, 1997; MacPherson, Klein, & Moore, 2003; Pratt & Fischer, 2002; Prime, Visser, & Ward, 2006; Sapir, Henik, Dobrusin, & Hochman, 2000), and therefore most authors propose that the function of the intervening event is to capture attention back to fixation, ensuring that attention is withdrawn-disengaged from, and therefore less likely to return to, the cued location at the time of target onset (Pratt & Fischer, 2002; Prime & Ward, 2004; Prime et al., 2006).

This interpretation of the effects produced by intervening events is inherent to the framework of the reorienting hypothesis. However, even if endogenous disengagement is considered as different from exogenous disengagement, it will still be difficult, if not impossible, to explain why in detection tasks neither endogenous nor exogenous disengagementare necessary for IOR to be observed. Furthermore, and importantly, because most researchers assume a sequence of orienting and re-orienting of attention (i.e., a sequence of engagement-disengagement across time) from one to another location in space, as the basis for IOR, most of the research effort has been dedicated to understand the speed of attentional movements, rather than investigating the mechanisms underlying the cueing effects and the real relationship between the presence of the intervening event and the behavioural result observed (see e.g., McDonald, Ward, & Kiehl, 1999; Prime & Ward, 2004; Prime et al., 2006).

Therefore, a theoretical explanation of exogenous cueing effects in general and IOR in particular is awaiting. As an attempt to banish the idea of IOR as a consequence of disengagement of attention, Berlucchi (2006) carried out a review questioning the appropriateness of the term IOR itself and claimed for a better understanding of this phenomenon. Dukewich (2009) has also made efforts in this vein, suggesting an alternative explanation according to which IOR is due to the habituation of the orienting response triggered by the cue. However, in Dukewich's model what is habituated (although the model is not very explicit about it) seems to be the reorienting of attention to the cued location, therefore being inconsistent with all the evidence above-described in which IOR is dissociated from the spatial orienting of attention.

To our knowledge, it is the cue-target integration model (Lupiáñez, 2010), described in Chapter I of this thesis, which accommodates most of the results related to the facilitation and IOR effects observed with peripheral cues. According to this model, the appearance of the cue lead to other processes different from orienting–reorienting of attention. Namely, cue-target integration processes, which lead to opposite effects on target processing: *detection cost* and *spatial selection benefit*, respectively linked to detection and discrimination processes. The cueing effect measured in the RT to the target would be the result of the net contribution of these two processes to performance, as a function of task. Thus depending on the task one process would contribute more o less to performance. In detection tasks the most influential process would be the detection cost, most of the times leading to the IOR effect. In contrast, the contribution of the spatial selection benefits would be more important in discrimination tasks, leading to facilitatory effects most of the times. Importantly, however, the operation of these mechanisms can be also modulated by some variables, such as target duration or the presence/absence of intervening events.

Therefore, according to this model, which is the general framework that will be used throughout the present dissertation, the detection costs and spatial selection benefits of cue target integration processes would contribute to performance more or less, thus leading to different time courses (i.e., early or late appearance of IOR) and/or sizes of the cueing effect (e.g., larger or smaller facilitation or IOR), depending of the task at hand and the modulation of the different underlying mechanisms by different variables, among which target duration and the presence/absence of an intervening event between cue and target seems to be critical factors.

Aims of the present thesis

Once overcome the idea that endogenous and exogenous attention are two different ways of orienting the same mechanism, IOR being the consequence of the inhibition of the orienting of this attentional mechanism, the present thesis aims at going one step further and investigate, behaviourally and electrophysiological, and understand the basis of the mechanisms underlying exogenous attention effects (facilitation and IOR).

We progressed towards this general goal, by completing three more specific aims:

1. We first completed previous research dissociating IOR from endogenous orienting of attention, by dissociating IOR, an effect that is believed to be a hallmark of exogenous orienting, from exogenous orienting of attention to the cued location. Previous research has demonstrated that endogenous reorienting is neither necessary nor sufficient for IOR to be observed (Berger et

al., 2005; Chica et al., 2007; Lupiáñez, 2010; Lupiáñez et al., 2013, for a review). However, although assumed by most researchers in the field, no study had explored whether IOR can be observed independently of exogenous reorienting of attention. We wanted to do this first experiment in order to demonstrate that the IOR effect is unrelated to the disengagement of attention, either endogenous or exogenous, and then focus on understanding the underlying mechanisms.

2. Secondly, once the disengagement of attention was discarded as an explanation for the IOR effect, we were interested in exploring the actual role of the intervening event once its supposed function of disengagement attention were questioned. To this purpose, we jointly manipulated two variables we believed would have a determinant role on behavioural cueing effects (facilitation and IOR) generated by the absence/presence of the intervening event: target duration and task set. Importantly, we manipulated these variables in different experiments with different task demands. These experiments were carried out to test specific hypotheses of the framework adopted in this thesis related to the weigh of the different processes affected by cuing as a function of task.

3. Finally, in order to investigate the neural mechanisms underlying cueing effects (facilitation and IOR), we tested conditions of facilitation and/or IOR with electrophysiological recordings (ERPs) in detection and discrimination tasks, both when intervening events were present and when they were absent. Importantly, because we assumed that the behavioural effect that is measured (facilitation or IOR) is the sum of processes leading to opposite effects on target processing (detection cost and spatial selection benefit), using ERPs allowed us demonstrate the temporal course and the implications of these both processes in detection and discrimination task, where different behavioural effects were found depending on the presence/absence of the intervening event.

The first specific aim of this thesis will be presented in Experimental Series 1 (Martín-Arévalo, Kingstone, & Lupiáñez, 2013). In this study, we explored the independence of exogenous orienting and the IOR effect. To this purpose, we developed a paradigm in which a peripheral non-predictive cue was fully crossed with a non-predictive central cue. Following the additive factor logic (Stenberg, 1969), if the effects of automatic spatial cueing (generated by the spatially non-predictive peripheral cue), and automatic spatial orienting (generated by the spatially non-predictive central cue), are independent, then they should produce their effects without interacting with each other. Thus, we combined non-predictive peripheral cues with non-predictive central orienting cues (arrows gazing faces) in order to explore its dependence and/or independence in a standard spatial cueing paradigm. To anticipate some of our findings, the IOR effect was proved independent of the cuing effect produced by non-predictive central cues. These results, together with other results manipulating endogenous disengagement (Berger et al., 2005; Chica et al., 2006), lead to the conclusion that the IOR effect is independent of both endogenous attentional orienting (see also Berlucchi et al., 2000; Chica et al., 2006; Chica & Lupiáñez, 2009) and exogenous attentional orienting (see also Lupiáñez et al., 2013). Therefore, the IOR effect could not be a consequence of attention being disengaged from the cued location, either endogenously or exogenously (Klein, 2004).

Once we demonstrated that the cueing effects could not be explained in terms of engagement and disengagement of spatial attention, the second aim of this thesis (Experimental Series 2; Martín-Arévalo, Chica, & Lupiáñez, 2013) was to explore the function of the intervening event if its supposed role in disengagement of attention was challenged. We explored theoretically relevant variables as task demands and target duration, to determine the specific circumstances at which intervening events produce their modulations over cueing effects. Most authors assume that the function of the intervening event is to capture attention back to fixation, ensuring that attention is withdrawn from, and therefore less likely to return to, the cued location at the time of target onset (Pratt & Fischer, 2002; Prime & Ward, 2004; Prime et al., 2006). In this chapter we will try to explain the effects of intervening events (together with target duration and task demands) with an alternative hypothesis (Lupiáñez, 2010) rather than the generally accepted and above-questioned reorienting hypothesis (Klein, 2000). This alternative hypothesis assume the existence of independent processes contributing to the RT effect that is finally observed behaviourally.

The third goal will be presented in Experimental Series 3 and 4 (Martín-Arévalo, Chica, & Lupiáñez, submitted-a, submitted-b). It is important to note that with behavioural measures we can only get indirect evidence regarding the independent processes contributing to cueing effects. However, by assuming that these processes operate with different times courses and has different cerebral locus, we thought that with ERPs it would be possible to directly measure these independent processes. Thus, in Experimental Series 3 we used ERPs to further investigate the stages of processing influenced by the intervening event in situations of maximum modulation on the behavioural result. Thus, weused a similar paradigm to the one previously used in Experimental Series 2 (in which the presence/absence of an intervening event produced significant and opposite effects on RTs: a facilitatory effect in the absence of an intervening event, and IOR when the intervening event is presented), while recording ERPs to determine the stage or stages of processing influenced by the intervening event manipulation. If both facilitation and IOR effects were explained by the same mechanism (the orienting of attention), then we would expect a direct relationship between early occipital ERP components and the behavioural effect measured, depending on the absence/presence of the intervening event, respectively. Our data challenged the reorienting hypothesis about IOR, leading to alternative explanations of cuing effects that were beyond orienting of attention (Berlucchi, 2006; Dukewich, 2009; Lupiáñez, 2010).

Finally, to complete the fourth and last aim of the present research, we explored how the intervening event electrophysiological modulations of cueing effects depended on factors such as task set (Experimental Series 4; Martín-Arévalo, Chica, & Lupiáñez, submitted-b). In particular, we used a detection paradigm in which the presence/absence of an intervening event did not modulate cueing effects; that is, IOR was observed independently of the presence/absence of an intervening event. This approach would allow us to investigate the predictions assumed by the most influential hypotheses of the attention field about the electrophysiological modulations of cueing effects.

Taken all evidence together, in Chapter IV (General Discussion) we will present a summary of all results obtained in the present thesis, its possible neural implementations within different cognitive subsystems and cortical areas, as well as support from neuropsychological data[1.]

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[1] Note that every chapter of this dissertation consists of a research paper that has either been published, or is in the process of being published, in an indexed journal. Therefore, there might be certain overlap in the Introduction and General Discussion of the different chapters.

Chapter III

Experimental Series

Experimental Series 1

Is “Inhibition of Return” due to the inhibition of the return of attention?

The content of this chapter has been published as:
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Experimental Series 1

Abstract

Inhibition of Return (IOR) is usually explained in terms of orienting-reorienting of attention, emphasizing an underlying mechanism that inhibits the return of attention to previously selected locations (Posner & Cohen, 1984). Recent data challenge this explanation to the extent that the IOR effect is observed at the location where attention is oriented to, where no reorienting of attention is needed. To date, these studies have involved endogenous attentional selection of attention, and thus indicate a dissociation between the voluntary attention of spatial attention and the IOR effect. The present work demonstrates a dissociation between the involuntary orienting of spatial attention and the IOR effect. We combined nonpredictive peripheral cues with nonpredictive central orienting cues (either arrows or gaze). The IOR effect was observed to operate independent of involuntary spatial orienting. These data speak against the "reorienting hypothesis" of IOR. We suggest an alternative explanation whereby the IOR effect reflects a cost in detecting a new event (the target) at the location where another event (a cue) was coded before.

Introduction

Attentional orienting is traditionally described in the literature as driven by either of two mechanisms: endogenous orienting, which refers to the volitional generated allocation of attention; and exogenous orienting, which refers to the automatic allocation of attention often in response to an abrupt peripheral event (Jonides, 1981). This description of two mechanisms is supported by several lines of evidence indicating that the behavioral signatures and neural systems engaged by endogenous and exogenous orienting are both distinct (e.g., Corbetta & Shulman, 2002; Chica, Bartolomeo & Valero-Cabré, 2011).

The cost and benefit paradigm has been widely used to study these two forms of spatial orienting (Posner, 1980). In this paradigm, a fixation point is presented at the centre of a computer screen with one box positioned to the left and right of fixation. Normally, to study endogenous orienting, a central symbolic informative cue (e.g., an arrow, a number, etc.) is presented at fixation and it predicts the most likely location of an upcoming target. Participants are told that the cue indicates where the target is likely to appear. In contrast, for investigations of exogenous orienting, a spatially uninformative peripheral cue (e.g., a brief flash in one of the boxes) is normally used. This spatial cue does not provide any reliable information as to where the target will appear, and participants are informed of this fact (Ruz & Lupiáñez, 2002).

The behavioral effects of both types of cues are very different. Central spatially informative cues usually produce a long lasting facilitatory effect: shorter response times (RTs) to a target when it appears at an expected rather than at an unexpected location, even at relatively long (e.g., 1000 ms) cue-target stimulus onset asynchronies (SOAs, Posner, 1980; Funes, Lupiáñez, & Milliken, 2007). However, spatially uninformative peripheral cues produce two different effects depending on the cue-target SOA. A facilitatory effect is observed when the SOA is short (e.g., 100-300 ms), with RTs being faster at cued vs. uncued locations. However this effect reverses when the cue-target interval is long, with longer RTs at the cued vs. uncued locations (Posner & Cohen, 1984), an effect that was coined inhibition of return (IOR) by Posner, Rafal, Choate & Vaughan (1985). This term, IOR, reflects the traditional theory behind the effect, which is thought to consist of a bias against returning attention to previously attended locations. According to this "reorienting hypothesis", both the facilitatory and inhibition of return effects are explained by the same mechanism: When a peripheral cue appears attention is involuntarily drawn to its position, giving rise to the facilitatory effect; after a few hundred ms, attention is disengaged from that spatial position, after which an inhibitory mechanism starts to operate, inhibiting the return of attention to that previously attended location, giving rise to the IOR effect. Therefore, the disengagement of attention has been considered a necessary and sufficient condition for the IOR effect (see Klein, 2000, for a review). Importantly, this disengagement of attention has also been considered by some (e.g., Klein, 2000) as the basis for why the IOR effect has a different time-course for different tasks, e.g., the IOR effect is observed at longer SOAs for discrimination taks than detection tasks (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997).

Though the reorienting hypothesis is widely accepted in the attention field, there is reason to question its validity (Berlucchi, 2006). For instance, the reorienting hypothesis predicts that an IOR effect should not occur if attention does not leave (i.e., is not disengaged from) the cued location. The data does not support this prediction. Research with different paradigms has demonstrated that IOR can be observed even if attention is not disengaged endogenously from the cued location. In short, although there is no attentional return required, IOR effect is observed. Berger, Henik and Rafal (2005) used a paradigm in which a predictive central cue (a left-right pointing arrow with 80% validity) was crossed with a peripheral nonpredictive cue. The aim was to study, within the same paradigm, the effect of endogenous attention (a central spatially predictive cue) and exogenous attention (a peripheral uninformative cue) and their possible interaction (or lack of). The results were clear. A significant endogenous orienting effect was observed with benefits, i.e., shorter RT on valid than neutral trials, and costs, i.e., longer RT on invalid than neutral trials. More importantly, these effects were independent of exogenous orienting (facilitation and IOR effects at the short and long SOAs, respectively). Crucially, the IOR effect was observed at both endogenously unattended and attended locations. In other words, IOR was observed at the location where attention was oriented to and maintained, where no IOR effect should be observed according the reorienting hypothesis, since attention did not disengage from that location.

Subsequently, Chica, Lupiáñez and Bartolomeo (2006) used a paradigm in which endogenous and exogenous orienting of attention were manipulated orthogonally in a manner in keeping with Berger, Henik and Rafal (2005). But now an informative peripheral cue was used, which predicted in different blocks that a target would appear either at the same or the opposite location as the cue (75% validity). Crucially, with this manipulation, expected and unexpected positions could be either cued or uncued, thereby enabling one to test whether IOR is observed at the expected location contrary to the prediction of the reorienting hypothesis. Detection and discrimination tasks were used to examine any potential difference in the mechanism responsible for IOR. Again, the results were clear: IOR was observed at the expected location, contrary to the reorienting hypothesis. Additionally, the IOR effect had a different time course for the detection and discrimination task (see also Chica & Lupiáñez, 2004), with the effect appearing later in the discrimination task. In other words, in the discrimination task, facilitation instead of IOR was observed at SOAs at which attention was disengaged from the cued location (see also Danzinger & Kingstone, 1999, Experiment 2). This led Lupiáñez (2010) to propose that disengaging attention might be neither necessary nor sufficient for the IOR effect to be observed: IOR can be observed without disengaging attention from the cued location (disengaging of attention is not necessary), and facilitation instead of IOR can be observed after disengaging attention from the cued location (disengaging of attention is not sufficient).

Therefore, as shown above, previous research suggests that the IOR effect is separable from endogenous attentional orienting (Berger et al., 2005; Lupiáñez et al., 2004). However, can we state that IOR is really independent of all forms of attentional orienting? It may be that spatial attention must be disengaged from a cued location exogenously instead of endogenously for an IOR effect to be observed (Chica et al., 2006). A study by Friesen and Kingstone (2003) could be important in this regard. They demonstrated that IOR did not vary as a function of the facilitatory effect of gaze, which is considered to generate a reflexive shift of attention to a gazed-at location (Friesen & Kingstone, 1998; Friesen, Ristic and Kingstone, 2004). They used a paradigm in which the peripheral cue was the presentation of a schematic face in one of four possible target locations around the central fixation point. The face could be gazing at one of the other three locations or straight ahead. Then, the target occurred at either the gazed-at location, at one of the uncued locations, or at the location where the onset gazing face was presented. The results showed that the same directed gaze stimulus that caused a significant reflexive shift of attention to the gazed-at location (i.e., a facilitatory effect) also produced a significant IOR effect at the location where the gazing face was presented. Most importantly, the IOR effect was not affected by the facilitatory effect of gaze, i.e., a similar IOR effect was observed for gazing and eyes-straight faces. This result led the authors to conclude that reflexive orienting to gaze direction and IOR are separable effects, which can co-occur in response to the same stimulus. Nevertheless, in the Friesen and Kingstone (2003) study there was no condition in which attention was automatically oriented to the location where IOR was observed; thereby leaving open the question of whether IOR operates independent of exogenous orienting of attention.

In the present study, we investigated whether such dissociation is possible. We used a paradigm similar to that used by Berger et al. (2005), but combined with stimuli that generated reflexive orienting, instead of endogenous orienting (Ristic, Wright & Kingstone, 2007). More concretely, as in Berger et al., (2005), we used a paradigm in which a peripheral nonpredictive cue was fully crossed with a central cue. However, in this case, a nonpredictive orienting cue (a gazing face or an arrow) was used as a central cue, in order to dissociate the effects of automatic spatial cueing, generated by the spatially nonpredictive peripheral cue, and automatic spatial orienting generated by the spatially nonpredictive central cue (see Procedure section for details). Most importantly, we presented the peripheral cue before the central cue, a key reversal from the order used by Berger et al. (2005), as this enables us to manipulate whether attention is automatically disengaged or not from the peripherally cued location. In other words, by presenting the peripheral cue first, followed by a spatially nonpredictive central cue, allowed the automatic effect of the central cue to modulate the engagement or disengagement of attention at the peripherally cued location, and the IOR effect that could emerge there.

The second aim of the present study was to investigate whether different types of central cues could produce a different pattern of involuntary orienting, i.e., whether differences in social relevance of the central orienting cues produce different orienting effects, and/or different modulation over the IOR effect. We used two types of central orienting cues, nonpredictive arrows (biologically irrelevant) and nonpredictive eye-gaze (biologically relevant), with the same general automatic orienting component but with different social relevance (Friesen, Ristic, & Kingstone, 2004). Friesen et al. (2004; see also Stevens, West, Al-Aidroos, Weger, & Pratt, 2008) reported that, although both arrows and gaze generated a reflexive shift of attention, the gaze-triggered attention is more strongly reflexive than orienting to arrows (Friesen, Ristic, & Kingstone, 2004; Ristic, Wright, & Kingstone, 2007). More recently, some authors have found that arrows and gaze can also produce qualitatively different effects (Marotta, Lupiáñez, Martella & Casagrande, 2012).

Therefore, our strongest hypothesis is that IOR will be independent of arrow or gaze orienting in the present series of experiments. This is based on the proposition that the IOR effect is independent of spatial orienting, whether it is endogenous or involuntary; and whether the involuntary orienting is triggered by a gaze or arrow cue. A much more nuanced prediction is that the IOR effect, while independent of endogenous orienting, it will not be independent of a strongly automatic cue, i.e., the gaze cue.

To anticipate our findings from two studies composed of three experiments, the IOR effect was independent of the cuing effect for gaze and arrow cues. This suggests that the IOR effect is not mediated by spatial orienting, and by extension, it does not reflect the inhibition of attention returning to a previously attended location. We suggest as an alternative explanation that the IOR effect reflects a detection cost (Lupiáñez, 2010) mediated by habituation (Dukewich, 2009). According to this theory, IOR effect is observed because attention is captured more by an uncued target than a cued target because an uncued target is more novel than cued targets.

Experiment 1

An adaptation of the paradigm introduced by Berger et al., (2005) was used to investigate whether the IOR effect is affected by the presentation of central directional nonpredictive cues which generate a reflexive shift of attention to the cued location. An arrow or a gazing-face, indicating one of four possible target locations, was presented at fixation after the onset of a peripheral cue and before the onset of a target.In keeping with the typical methodology used in IOR studies, a simple target detection task was used.

Methods

Participants

A total of 38 participants, naïve to the purpose of the study and drawn from the University of British Columbia or the University of Granada took part in the study in exchange for course credit. Data from two participants were excluded due to a large number of anticipatory responses (42.43 % and 33.43% of responses with RT below 200 ms). Only data from 36 participants (18 participants in “Arrow Cueing” and 18 participants in “Eye-Gaze Cueing”) were considered for the analyses.

All participants in this and the following experiments reported having normal or corrected to normal vision. All experimental procedures were approved by the University of British Columbia and University of Granada Research Ethics Boards, and informed consent was obtained from all participants.

Display Apparatus and Stimuli

Experiments were run on a computer with a 1GHz Pentium III processor, connected to a 15-inch color VGA monitor. E-primer software (Schneider, 1998) controlled the presentation of the stimuli and the acquisition of data throughout the experiments. All stimuli were white line drawings on black background. Peripheral cues were created by thickening the outline of one of four placeholder boxes. Each box was 11 mm in width by 13 mm in height (subtending 1.05 and 1.24 degrees of visual angle (°) at a viewing distance of 60 cm). Each box was positioned 22 mm (1.91°) away from central fixation along the horizontal plane and 25 mm (2.39°) along the vertical plane, as measured from the center of the placeholder to the fixation point in the center of the screen. A central arrow was created by combining a 30 mm straight line (2.86°) with an arrowhead and arrowtail. The round face outline subtended 5.33° and contained two circles representing the eyes, a circle in the middle representing the nose and a line representing the mouth. The eyes subtended 1.34° and black filled-in circles appears within the eyes representing the pupils, subtended 0.38°. The center of each eye was located 0.95° to the right and left of the central vertical axis and 1.15° above of the central horizontal axis of the face. For the gaze-direction cues, the pupils touched either the left, right, top or down of the eyes, for left, right, top or down gaze-direction cues, respectively. The nose subtended 0.19° and the mouth was centered 0.95° below the nose and was 1.15° in straight length. The target was a circle of 10 mm (0.95°) with vertical or horizontal stripes of 0.5 mm (0.05°) that appeared in the middle of one of the placeholder.

Procedure

Stimuli and the sequence of events on each trial are illustrated in Figure 1. Each trial began with the presentation of the fixation display, containing the fixation point and the four markers, where the target could appear, with a variable duration between 750-1250 ms. Participants were asked to keep their eyes on the fixation point throughout the experiment. The peripheral cue was presented in one of the four possible locations (left, right, up or down) for 50 ms. This peripheral cue was not informative about target location. After the peripheral cue, another fixation display of 250-350 ms was presented. Subsequently, the central cue (arrow or eye-gaze depending on the group) was presented, for a variable duration of 750-950 ms, after which the target was presented. The central cue was not predictive of target location. After 200 ms the target disappeared, and the fixation fixation display remained until a participant responded or 1000 ms had elapsed, whichever came first. The screen was then blackened for 750 ms, signaling the end of a trial. Participants were instructed to detect the target by pressing the response key on the keyboard (half of participants pressed the “z” key whether the other half pressed the “m” key) as soon as they saw the target (independently of the target type).

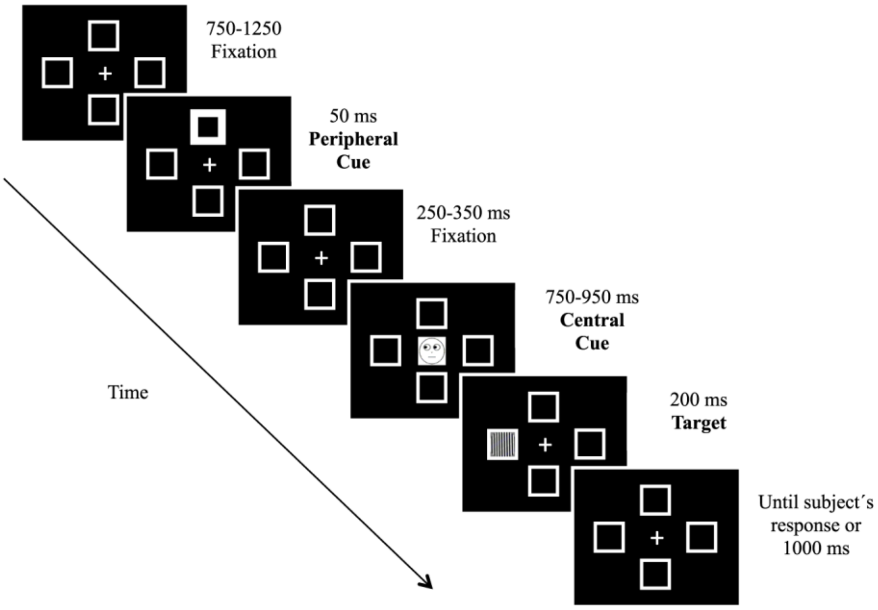

*Figure 1.*Illustration of the trial sequence in the three Experiments. Each trial began with the Fixation Display. After 750-1250, a peripheral cue appeared in one of four boxes during 50 ms. After 250-350 ms in which the fixation display was presented the central cue (arrow or gaze) was presented during 750-950 ms, after which the target was presented during 200 ms. Finally, the Response Display was presented during 1000 ms or until subject's response. The picture shows an example of a peripherally uncued but centrally indicated location trial.

Design

The experiment consisted of a three-factor mixed design. Peripheral cueing and Central cueing were manipulated within participants, while Cue-type (Arrow or Eye-Gaze) was manipulated between participants. Peripheral cueing had two levels: Cued (the target appeared at the same location as the peripheral cue) and Uncued target trials (the cue and target appeared at different locations). Central cueing also had two levels: Indicated and not-indicated target trials (i.e., the target appeared at the location that was, or was not, indicated by the central cue). The experiment consisted 404 trials. The first 20 trials were practice, and were not analyzed. Rest breaks were provided every 64 trials.

Results

Participants missed the target (i.e., no response was made) on 2.07% of the trials. Responses faster than 200 ms (7.57% of trials) were excluded from the RT analysis [2](Table 1).

The mean RT data were submitted to a 2 (Cue-Type) x 2 (Peripheral Cueing) x 2 (Central Cueing) mixed ANOVA, with Cue-Type (Arrow or Gaze) as between-participant factor and the rest as repeated measures factors.

The analysis revealed a highly significant main effect of Peripheral cueing, F(1, 34)=65.34, MSE=217, p<.0001, η2=0.66, showing that RT was reliably slower when the target appeared at a position previously occupied by the cue (i.e., a 20 ms IOR effect was observed). The Central cueing effect was also significant, F(1, 34)=4.11, MSE=289, p=.0506, η2=0.11, reflecting that RT was faster when the target was presented at the position indicated by the central cue. This central cueing effect was not modulated by the type of central cue, F(1,34)=3.196, MSE=289, p=.0827, η2=0.08, nor was there a main effect of cue-type, F<1; converging on the conclusion that both biologically irrelevant (arrow) and relevant (gaze) cues were similar in their capacity to orient attention.

Crucially, the interaction between Peripheral cueing x Central cueing was not significant, F(1,34)=1.55, MSE=158, p=.2208, η2=0.04. Thus while both peripheral and central cuing effects were significant, they did not interact with each other (see Figure 2). The Peripheral cueing x Cue-type interaction was significant, F(1, 34)=6.06, MSE=217, p=.0191, η2=0.15, with a larger IOR effect when the central cue was an arrow (-26 ms) than was it was a gaze (-14 ms). Nevertheless, in neither case did the IOR effect depend on whether the arrow or the gaze indicated the location of the target or the other locations.

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[2] Note that in this first experiment no catch trials were included (i.e., a target was always presented). The peripheral-central SOA was variable, and the central cue had a variable duration, and we reasoned that this was sufficient condition to control for anticipatory responses. The fact that the target was missed 2% of the time supports our line of thought. However, a lack of catch trials might have contributed to the anticipatory responses. Thus, in the following study (Experiment 2A and 2B) 11% of the trials were catch.

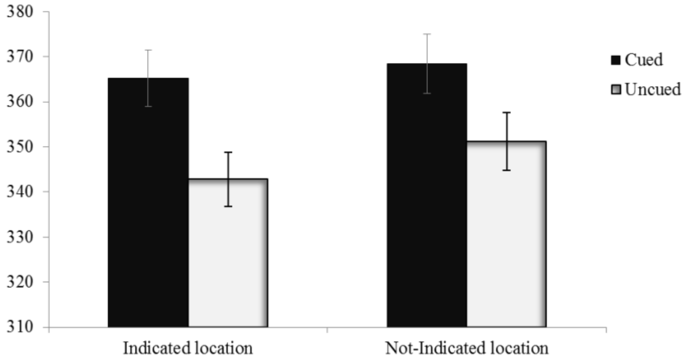

Figure 2. Mean response times (RTs) for cued and uncued trials as a function of indicated vs. not indicated location, in Experiment 1.

Discussion

The results of the present experiment indicate that the automatic effects generated by peripheral cues (i.e., IOR effect), and central cues were significant. For peripheral cues participants were faster at uncued locations than at the cued location (i.e., IOR effect); and for central cues participants were faster to respond to a target that appeared at an indicated vs. not-indicated location. Thus, the participants were able to process and shift attention in response to the two cues (peripheral and central).

Importantly, the IOR effect was not affected by the automatic spatial orienting of attention as triggered by the nonpredictive central cue. These results clearly differ from those predicted by the reorienting hypothesis of IOR. According to the reorienting hypothesis, the central cue must affect the IOR effect as attention is automatically allocated to the indicated location, and consequently no IOR effect should occur (as no return of attention is needed there). However, in the present experiment, IOR was observed at the indicated location. Therefore, IOR was not affected by the automatic spatial orienting triggered by the nonpredictive cue. This result supports the view that IOR is independent from attentional orienting, whether orienting is endogenous (Berlucchi et al., 2000; Berger et al., 2005; Chica et al., 2006; Chica & Lupiáñez, 2009) or automatic, as shown in this experiment.

Concerning the differences between arrow and gaze cues -- stimuli with different social relevance; contrary to our initial expectation, the present results showed that arrows and gaze cues generate a comparable effect in orienting attention. Cue-type did, however, interact with the IOR effect, as the IOR effect was of a larger magnitude in the arrow condition than the gaze condition—that is, the IOR effect was reduced when a gaze was presence as compared with the presence of an arrow.

This result could be taken to support the idea that the IOR effect reflects a habituation process, i.e., a reduced capacity of the cued location or object to recapture attention. According to this interpretation, there is less habituation when the cue is a socially relevant gaze stimulus.

Experiments 2A and 2B

Experiment 2 was designed to replicate the results of Experiment 1 and to further explore differences between arrow and gaze as orienting cues, by manipulating the two cue types within participants, between blocks of trials in Experiment 2A, and within blocks of trials in Experiment 2B. Therefore, the second aim of Experiment 2 was to test whether the interaction between IOR and Cue-type was a robust interaction, stable across manipulations, or a rather spurious effect.

Methods

Participants

A total of 28 participants from the University of Granada took part for course credit, 16 in Experiment 2A and 12 in the Experiment 2B. All were naïve to the purpose of the study.

Procedure and Design

The procedure and design was the same as in the Experiment 1, except in the following: Each experiment had a 2 Cue-type (Arrow or Eye-gaze) x 2 Peripheral cueing (Cued vs. Uncued location) x 2 Central cueing (Indicated vs. Not-indicated location) design, with the three variables being manipulated within participants. Cue type was manipulated between blocks of trials (in counterbalanced order) in Experiment 2A and within blocks of trials in Experiment 2B; the remaining two variables were manipulated randomly within blocks of trials. Catch trials (11.11%) were included in both experiments. For each experiment a total of 576 trials were presented, divided in 4 blocks of 144 trials. For Experiment 2A, 2 consecutive blocks (288 trials) were presented for each Cue-type. In both experiments participants completed 10 practice trials before the experimental trials started.

Table 1- Mean RTs (in ms) for each condition (Peripheral x Central Cueing) in arrow and gaze cue blocks. Percentage of target misses (no response) are presented in parenthesis.

	Arrow				Gaze			
	Cued Location		Uncued Location		Cued Location		Uncued Location	
	Indicated	Not-Indicated	Indicated	Not-Indicated	Indicated	Not-Indicated	Indicated	Not-Indicated
Experiment 1	366 (0.02%)	361 (0.08%)	334 (0.05%)	341 (0.24%)	364 (0.08%)	376 (0.36%)	351 (0.29%)	361 (1.01%)

Table 2-Mean RTs (in ms) for each condition (Peripheral x Central Cueing) in arrow and gaze cue blocks. Percentage of target misses (no response) are presented in parenthesis.

	Arrow				Gaze			
	Cued Location		Uncued Location		Cued Location		Uncued Location	
	Indicated	Not-Indicated	Indicated	Not-Indicated	Indicated	Not-Indicated	Indicated	Not-Indicated
Experiment 2A	442 (0.01%)	445 (0.11%)	414 (0.09%)	421 (0.14%)	442 (0.03%)	443 (0.06%)	410 (0.06%)	427 (0.14%)
Experiment 2B	404 (0.10%)	415 (0.10%)	385 (0.19%)	397 (0.49%)	415 (0.00%)	427 (0.10%)	390 (0.17%)	394 (0.48%)

Results

False alarms accounted for 0.10% and 0.47% of the trials in the Experiment 2A and Experiment 2B, respectively. Participants missed the target (i.e., no response was made) in 0.6% and 1.63% of the target-present trials in the Experiment 2A and Experiment 2B, respectively. Finally, responses faster than 200 ms (0.12% and 0.65% of trials in Experiment 2A and 2B, respectively) were eliminated from the RT analysis (see Table 2).

Given that preliminary analyses revealed similar effects for the two experiments, and for the sake of simplicity, we analyzed together the data from Experiment 2A and 2B with a 2 (Experiment; 2A vs. 2B) x 2 (Cue-Type) x 2 (Peripheral cueing) x 2 (Central cueing) mixed ANOVA, with Experiment as a between participants factor. The main effect of Experiment was not significant, F(1,26)=1.08, MSE=36394, p=.3072, η2=0.04, nor did Experiment interact with any factor. Thus, there were no differences between manipulating the central cue type between or within blocks of trials.

The peripheral cueing effect was highly significant, F(1,26)=127.40, MSE= 256, p<.0001, η2=0.83, showing again that RT was slower when the target appeared in a position previously occupied by the peripheral cue. The central cueing effect was also highly significant, F(1, 26)=12.62, MSE=320, p=.0015, η2=0.33. The cue-type effect was not significant, F<1, and did not interact with either peripheral cueing, F(1, 26)=1.56, MSE=186, p=.2226, η2=0.05, or central cueing, F<1 (see Figure 3). Thus the IOR effectwas independent ofcue-type, as the magnitude of the IOR effect was similar whether the central cue was an arrow cue (-22 ms) or a gaze cue (-26 ms).

Finally, and most importantly, the was no interaction between peripheral cueing and central cueing, nor was there an interaction between peripheral cueing, central cueing and cue-type, all Fs<1. This shows that the significant peripheral and central cuing effects operate independently.

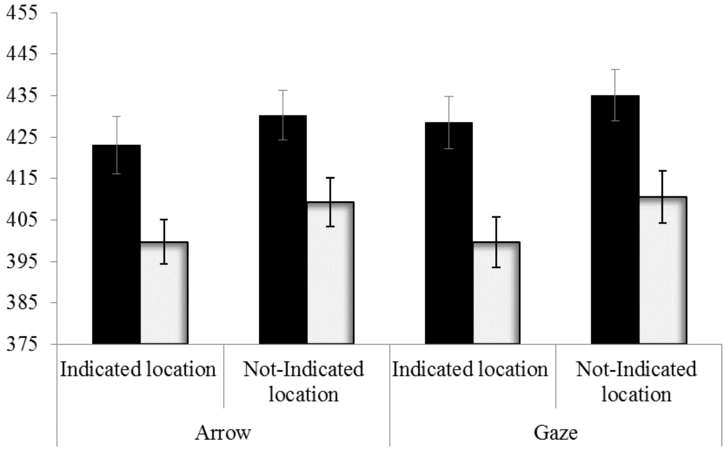

Figure 3. Mean response times (RTs) for cued and uncued trials, as a function of indicated vs. not indicated location, Cue-type and Task, in the analysis of the Experiments 2A and 2B.

Discussion

In Experiment 2, as in Experiment 1, participants were sensitive to the attentional effects elicited by the two automatic cues (peripheral and central), as both the IOR effect and the central cueing effect were significant. Again, the most important result was that those effects were independent of each other. Critically, the IOR effect was not modulated by the spatial orienting of attention generated by a nonpredictive central cue. Again, this result is important as it shows the IOR effect operates independent of the orienting of attention, and it implies that this dissociation i observed whether attentional orienting is endogenous (Berger et al., 2005; Chica et al., 2006; Chica & Lupiáñez, 2009) or exogenous (as in the current experiments).

Regarding the differences between arrow and gaze cues, the present result replicate what was found in Experiment 1: arrow and gaze cues generate comparable attention effects. Furthermore, the interaction between cue-type and IOR observered in Experiment 1 was not replicated in Experiment 2, both when the cues were manipulated between blocks (Experiment 2A) and within the same block of trials (Experiment 2B).

The most critical finding in Experiment 2 was that the IOR effect was again independent of any central cueing effect, i.e., Experiment 2 replicated fully Experiment 1 in this regard. Whether arrow or gaze cues served as central cues, and whether they were manipulated between participants, within participants or randomly within the same blocks of trials, their attentional orienting effects did not impact the emergence or magnitude of the IOR effect. In short, participants processed the peripheral cues as a significant IOR effect was generated; and they concurrently and significantly oriented attention to the location indicated by an arrow or gaze cue. Crucially, these two effects were independent. The implications of these data are discussed below.

General Discussion

In the present series of experiments we investigated the effects of involuntary orienting of attention and peripheral cueing, both exogenous, simultaneously and orthogonally, by using a different set of cues to produce each effect: automatic orienting was manipulated by central non predictive arrows or gaze indicating one of the potential target locations, whereas peripheral cueing was manipulated by presenting an onset cue in one of these locations. The results showed a clear dissociation between the two effects across three different experiments in which the type of central orienting cue (i.e., arrow or gaze) was manipulated between participants, between blocks or randomly within-blocks (Experiment 1, and Experiment 2A and 2B, respectively).

Three main results were observed. First, the facilitatory automatic orienting effect generated by a central nonpredictive arrow or gaze cue was significant in all cases, with no meaningful differences emerging as a function of cue type (arrow vs. gaze). Second, a significant IOR effect was observed in all experiments. Finally, and most importantly, the IOR effect operated independent of the automatic orienting effect induced by central cues; this independence held whether the central cues were biologically irrelevant (arrows) or biologically relevant (gaze). In short, a significant IOR effect was observed independent of involuntary spatial orienting induced by qualitatively different central nonpredictive cues.

An overall reanalysis3 of the three experiments was carried out in order to increase statistical power, focusing on the interaction between central cueing and peripheral cueing. The previous results were confirmed. For the arrow condition, the peripheral cueing effect was highly significant, F(1,45)=100.45, MSE=261, p<.0001, η2=0.69, as was the central cueing effect, F(1, 45)=4.40, MSE=273, p=.0415, η2=0.08. And crucially, the interaction between peripheral cueing and central cueing fell far short of significance, F(1,45)=1.28, MSE=319, p=.2629, η2=0.02. Similarly, for the gaze condition, both the peripheral cueing, F(1,45)=100.02, MSE=211, p<.0001, η2=0.68; and the central cueing effects were highly significant, F(1, 45)=13.74, MSE=308, p=.0005, η2=0.23. And again, the interaction between peripheral cueing and central cueing did not

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[3] Note that in this reanalysis of three experiments we did different ANOVAs per Cue-type conditions. The fact that the cue-type variable was manipulated between participants in Experiment 1 and within participants in Experiments 2A and 2B, did not allowed us to carry out an overall ANOVA with Cue-type as another factor.

approach significance, F(1,45)=1.04, MSE=130, p=.3127, η2=0.02. Thus, the lack of interaction cannot be attributed to a lack of statistical power. Furthermore, converging evidence for this independence between arrow and peripheral cuing has been reported recently by Ristic and Kingstone (2012).

According to the popular reorienting hypothesis, the IOR effect emerges because a mechanism inhibits the reorienting of attention to a previously attended location (Posner & Cohen, 1984). It follows then that no IOR effect should be observed at a location indicated by a central cue because attentional disengagement from the cued location is unnecessary and absent, and therefore it is unnecessary to inhibit the return of attention to the cued location. However, a significant IOR effect was found both at the location indicated by the central cue and in the other locations. In short, the IOR effect was completely independent of the automatic spatial orienting generated by the central cue. Consequently, the results from the three experiments argue against the reorienting hypothesis.

Collectively these results point to the conclusion that the IOR effect is independent from attentional orienting, whether it is endogenously (Berlucchi et al., 2000; Berger et al., 2005; Chica et al., 2006; Chica & Lupiáñez, 2009) or exogenously controlled[4]. Therefore, the IOR effect cannot be a consequence of attention being disengaged from the cued location.

In light of the above evidence, we suggest an alternative, and possibly more parsimonious, explanation for the IOR effect. Specifically, the IOR effect could be the product of attention being captured poorly by cued targets, as the target is appearing where attention was captured previously. According to this detection cost hypothesis, it is more difficult to detect a target at a location where another object (the cue) was previously presented, and this leads to the IOR effect. That is, IOR is due to attention being captured less effectively at a location where it has already been captured. To put it another way, given that attention is captured by novelty (Ruz & Lupiáñez, 2002), it follows that a target will be "less new" at a cued location than at an uncued location. The prediction, which is supported by the data, is that as the attributes that are shared by a cued and target increase, so will the magnitude of the IOR effect (Hu, Samuel, & Chan, 2010). This is very possibly why an IOR effect is more robust for target detection than target discrimination, as

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[4] Note also that in detection tasks like the one used in our experiments no cue is necessary at fixation, supposedly to disengage attention purely exogenously; Prime, Visser and Ward, 2006.

noticing the appearance of a new stimulus (i.e., the target) is all that is needed in a detection task (Lupiáñez et al., 1997).

Indeed, this tendency for the IOR effect to manifest itself as a detection cost rather than a discrimination cost can be understood with reference to the object-file theory of Kahneman, Treisman, and Gibbs (1992). Here, a target is treated by the perceptual system as an update of an object file representation that is triggered by the cue, thus being easier to select for analytic processing. This cue-target integration process would be beneficial when determining what the target is, as it would help to select the target location in advance (i.e., a spatial selection benefit). However, consideration of the target as an update on the cue's representation should constitute a cost in detecting the onset of the target (an onset detection cost) in so far as it would be more difficult for an observer to detect the target's onset because no new object file is created. In short, the final effect that is measured in responding to a target at the cued location will depend on the task to be performed on the target stimulus.

Our proposition of the detection cost hypothesis fits with the recent work and model of Prinzmetal and colleagues (Prinzmetal, Taylor, Myer & Nguyen-Espino, 2011). They investigated the cause(s) of two effects associated with involuntary attention in the spatial cueing task: contingent capture and IOR. They investigated which of two previously identified mechanisms, a serial search mechanism and a decision mechanism (Prinzmetal, Ha, & Khani, 2010), was responsible for each effect. Critically, the IOR data conformed to the predictions of the decision mechanism, based on a competitive accumulator model. Furthermore, within the context of this model, which consider two parameters for this mechanisms, threshold setting and a data accumulation factor, the IOR effect was best accounted for as change in the threshold, i.e., after the cue was presented the threshold was raised at the cued locations. We consider these results, and correspondingly, the model, to be consistent with our detection cost theory, which could be considered as a change in the threshold for detection (detection cost) produced by the previous attentional capture at the same location/object. It should be noted, however, that Prinzmetal and colleagues also conceive, at the same time that the threshold for detection is increased at the cued location, other processes take place at the same location/object representation, which could lead to a different effect on other processes. To the extent that performance (as a function of the task to be performed with the target) taps some of these processes more than others, either IOR or facilitation would be observed.

Likewise, Dukewich (2009) has recently offered an explanation of the IOR results in terms of habituation that could also fit with our theory. In her model, the typical delay that is observed for targets presented at a cued location is due to the general phenomenon of habituation: The presence of a an event (the cue) leads to a weakened orienting response to a subsequent similar event (the target). If we consider that what is habituated is the orienting of attention to the previously cued location, our data would speak against Dukewich's model (2009), as IOR was independent of attentional orienting. However, our data would be supportive if we consider that what is habituated is the attentional capture by the target itself. In other words, Dukewich's habituation hypothesis can be recast in terms of cue-target similarity, with larger similarity between cue and target leading to more habituation, in line with the detection cost hypothesis proposed by Lupiáñez and colleagues (2010; Lupiáñez et al., 2007).

Conclusion

The major empirical and theoretical contributions of the current study were to dissociate the IOR effect from automatic spatial orienting by central cues. These results challenge the prevailing reorienting hypothesis, and can be explained, leading to a more parsimonious assumption of the mechanism that produces the IOR effect, in terms of a detection cost at previously cued locations (Lupiáñez, 2010).

Experimental Series 2

Task dependent modulation of exogenous attention: Effects of Target Duration and Intervening Events

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Abstract

Inhibition of Return (IOR) consists of slower reaction times in respond to stimuli appearing at previously attended or inspected locations. The exact mechanisms underlying the effect have not yet been determined. In the present work, we manipulated two variables, which modulated the IOR effect as a function of task: target duration and intervening event (fixation cue between cue and target). When the target was presented until response, the presence of an intervening event made the cueing effect more negative in all tasks, although facilitation in the absence of intervening event was only observed in discrimination and go-no go tasks. When target duration was 50 ms, the effect of the intervening event on cueing was only observed for the discrimination and go-no go tasks. Target duration had no effect at all in the discrimination task. Possible mechanisms for these modulations (detection cost and spatial selection benefit, both based on cue-target integration processes) are discussed.

Introduction

Attentional orienting is described in the literature as driven by two mechanisms: endogenous and exogenous orienting (Jonides, 1981). The cost and benefit paradigm has been widely used to study these two forms of spatial orienting (Posner, 1980). In this paradigm, a fixation point is presented at the centre of a computer screen with one box positioned to the left and one to the right of the fixation point. To study *endogenous orienting*, a central symbolic spatially informative cue (e.g., an arrow, a number, etc.) is presented at fixation, predicting the most likely location of an upcoming target. 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). This effect is known as facilitation. In contrast, for investigations of *exogenous orienting*, a spatially uninformative peripheral cue (e.g., a brief flash in one of the boxes) is normally used. This spatial cue does not provide reliable information about the target location (Posner & Cohen, 1984). At short SOAs, RTs are usually faster for targets appearing at the same location as the peripheral cue (i.e., the cued location) as compared to RTs for targets presented at the opposite location (i.e., the uncued location), i.e., a facilitatory effect is observed. At longer SOAs, however, the opposite pattern of results emerges: RTs are faster for targets appearing at the uncued location as compared to the cued location. This effect, first reported by Posner and Cohen (1984), and named *Inhibition of Return* (IOR) by Posner, Rafal, Choate, and Vaughan (1985), was initially thought to reflect a bias against returning attention to previously explored locations (see Lupiáñez, Klein, & Bartolomeo, 2006; Klein, 2000; for reviews). However, although these effects of peripheral cueing were thought to be highly automatic, research has shown that they are modulated by different variables. In fact, the expected results of facilitatory effects at short SOAs (i.e., before attention is disengaged from the cued location) and IOR effect at long SOAs (i.e., after attention is disengaged from the cued location) are not at all as usual as one could think, and have been shown to depend on many variables, some of which are reviewed below.

Modulation of Peripheral Cueing Effects by Task Demands

Many studies have found that the magnitude and time course of cueing effects is sensitive to task factors. Lupiáñez and colleagues have consistently demonstrated that facilitation is larger in magnitude in discrimination than in detection tasks. Moreover, IOR emerges at longer cue-target intervals, and is smaller in size, in discrimination than in detection tasks (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997; Lupiáñez & Milliken, 1999; Lupiáñez, Ruz, Funes & Milliken, 2007). A review of the literature on cueing effects with detection tasks indicates that, contrary to

IOR, which is an extremely robust effect when participants detect the appearance of targets, the occurrence of early facilitation is difficult to observe (see e.g., Tassinari & Berlucchi, 1995; Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994; Collie, Maruff, Yucel, Danckert, & Currie, 2000; Mele, Savazzi, Marzi, & Berlucchi, 2008). Instead of being a rather general finding, it may indeed require special stimulus conditions. Thus, in most of the classic studies that show evidence of early facilitation in a detection task, the effect is observed at very brief cue-target SOAs (i.e. < 250 ms) (Posner & Cohen, 1984; Maylor, 1985; Maylor & Hockey, 1987), or with relatively long cues (i.e. displayed until target offset) that overlap in time with the target (Collie et al., 2000). Concretely, Collie *et al.* (2000) showed that with temporal overlap between the cue and target, significant facilitatory effects were observed at the short 150 ms-SOA. In contrast, other studies have shown facilitation in detection tasks no matter whether the cue and target overlapped or not (Berger, Dori & Henik, 1999). In particular, although target duration seemed not to have a determinant role in the observation of facilitatory effects in Berger *et al.*'s (1999) study, a long cue duration (200 ms) might have been crucial for observing facilitation in their detection task. Additionally, Tassinari and colleagues repeatedly failed to observe facilitation using SOAs as short as 65 ms (Tassinari & Berlucchi, 1995). It is therefore unknown whether the occurrence of early facilitation in detection tasks crucially requires a very short cue-target SOA, or a temporal (as well as spatial) overlap between the cue and target, or both factors conjointly. In fact, IOR has been observed in many studies without any hint of facilitation at shorter SOAs (see e.g., Tassinari, et al., 1994; Mele, et al., 2008).

Taken all the above evidence, cueing effects seem to be more negative (less facilitation and/or larger IOR) in detection than in discrimination tasks. Therefore, any explanation of cueing effects should elucidate why they are rather flexible effects with a variable time course and different sign (facilitation or IOR) depending on different factors such as the task at hand.

Modulation by Target Characteristics

Others studies have revealed differences in the magnitude, time-course, and even the sign of cueing effects depending on target characteristics. When target contrast was manipulated in a discrimination task (Snowden, Willey, & Muir, 2001), facilitatory effects were observed for both levels of target contrast (high and low), although the effects were much larger for low-contrast target trials than for high-contrast target trials. Moreover, Taylor and Donnelly (2002) found that the IOR effect in a target-target discrimination task depended on the interaction between the features of the cue and target. They showed that IOR was completely absent when the cues and targets were identical in identity and orientation (i.e., the physical similarity between the cue and target led to modulations of cueing effects). Reuter-Lorenz, Jha, and Rosenquist (1996) also studied the effect of target intensity, target modality, and response modality on the magnitude of the IOR effect in a detection task. They reported that IOR was larger when target luminance was low than when it was high, and when the target modality was visual rather than auditory. Moreover, Lupiáñez and colleagues (2007) carried out a study in which target frequency was manipulated; they introduced a frequent target (letter “X”) on 75% of the trials, and two different infrequent targets (letter “O” and “U”) on 25% of the trials. Participants were instructed to detect the frequent target and to discriminate the identity of the other two infrequent letters. Qualitatively different cueing effects were observed as a function of target type. The IOR effect was observed when the most frequent target was to be detected, while a facilitatory effect was revealed for those trials in which one of the infrequent targets occurred and its identity had to be discriminated. Importantly, the sequence of events occurring in a given trial was identical for all conditions with the exception of target type, making it impossible for the participant to know in advance which target would be presented until its onset, and therefore equating attentional orienting in both conditions. Thus, these cueing effects were completely depended on target characteristics, task set being identical in all conditions prior to target appearance.

In addition, some studies highlight the relevance of the temporal relationship between cues and targets in determining the magnitude and time course of cueing effects. Maruff and colleagues observed a facilitatory effect in a detection task only with short SOAs, temporal overlap between cue and target, and when the target remained visible until the participants’ response (Maruff, Yucel, Danckert, Stuart, & Currie, 1998). Concretely, they manipulated the temporal overlap between cues and targets, varying cue and target duration. The results showed facilitatory effects when there was a temporal overlap between the cue and target at the short SOA (i.e., 150 ms), and no effect at longer SOAs (i.e., 350 and 850 ms); when no overlap was present, no facilitation was found at the shortest SOA, and an IOR effect was observed at the longest SOAs. Importantly, the target duration manipulation also modulated cueing effects; in the overlapping condition, no facilitatory effect was observed at the short SOA when the target duration was brief (i.e., 50 ms). Additionally, in the non-overlapping condition, the IOR effect was observed for all SOAs when the target duration was brief (i.e., 50 ms).

In sum, given the aforementioned evidence, we can establish that the relationship between visual and temporal properties of cues and targets can impact the overall cueing effects that are measured.

Modulation by Intervening event (fixation cue)

The presentation of a cue at fixation between the peripheral cue and the target (referred to as "intervening event" in this manuscript; see Spadaro, He, &Milliken, 2012, for a definition of intervening event) is known to favour the appearance of the IOR effect (Faust & Balota, 1997; MacPherson, Klein, & Moore, 2003; Pratt & Fischer, 2002; Prime, Visser, & Ward, 2006; Sapir, Henik, Dobrusin, & Hochman, 2000). Prime, Visser, and Ward (2006) investigated the effectiveness of an intervening event in revealing IOR in situations in which it would not be observed otherwise. The presence of an intervening event produced IOR in identity-based discrimination tasks, at cue–target SOAs at which no IOR effect was observed in the absence of an intervening event. However, in detection and localization tasks they found that the magnitude of the IOR effect was not affected by the presence of an intervening event (see also Pratt & Fischer, 2002). Indeed, there are many examples of the effectiveness of intervening events in revealing IOR in discrimination tasks (see, e.g., Cheal & Chastain, 1999; Kingstone & Pratt, 1999; Pratt & Abrams, 1999; Pratt, Kingstone, & Khoe, 1997; Prime & Ward, 2004), but we are not aware of many examples revealing IOR in the presence of intervening events in detection tasks. In fact, to our knowledge, the intervening event has been shown to be effective in producing IOR in visual detection tasks only in special populations where orienting is altered or is not fully developed, such as in Alzheimer patients (Faust & Balota, 1997), young children (MacPherson, et al., 2003), or brain damaged patients suffering from neglect (Bourgeois, Chica, Migliaccio, Thiebaut de Schotten, & Bartolomeo, 2012). Also, in gaze cueing paradigms, it has been shown that an intervening event is necessary for IOR to be observed (Frischen & Tipper, 2004; Marotta, Pasini, Ruggiero, Maccari, Rosa, Lupiáñez, & Casagrande, 2013). It is important to note that in all these studies, the target was displayed until a response was detected, which might be responsible for the intervening event modulation of cueing effects in detection tasks.

Similar modulations of IOR have been observed in discrimination tasks for the so-called "non-spatial IOR" (Spadaro et al., 2012). In this paradigm, participants are to identify the color of a centrally presented target. They manipulated the presence of an intervening event between the presentation of the two consecutive targets, and whether participants had to respond to the intervening event. When the intervening event was presented, and participants had to respond to it, an IOR effect was observed, with slower responses for repeated color targets than for non-repeated color targets. However, when no intervening event was presented and therefore no response was required, a facilitatory effect was instead observed, with responses being faster for repeated color targets than for non-repeated color targets. In a following up study, Spadaro, Lupiáñez, and

Milliken (under review) observed that responding to the intervening event was not necessary for the IOR effect to be observed in this paradigm, to the extent that the intervening event was treated as a distinct event, different from the cue and target.

Importantly, although the presentation of an intervening event can be effective in generating IOR, many studies have observed IOR in the absence of an intervening event (see, e.g., Danziger & Kingstone, 1999; Ivanoff & Klein, 2001; Chica, Bartolomeo, & Lupiáñez, 2006; Lupiáñez et al., 1997; Tassinari et al., 1994). This is true for long and short SOAs (see e.g., Maruff et al., 1998; McAuliffe & Pratt, 2005), for detection and discrimination tasks (see e.g., Lupiáñez et al., 1997; Chica et al., 2006; Lupiáñez et al., 2007; Pratt & Fischer, 2002), for long and short target durations (see e.g., Berger et al., 1999; see also Maruff et al., 1998), etc. Therefore, these results seem to suggest that intervening events may be unnecessary for obtaining IOR under certain conditions, but they might be necessary for observing IOR in other conditions.

What is clear from the above-reviewed literature is that, far from being strictly automatic, peripheral cueing effects are modulated by variables such as the task demands, target characteristics, and the presence/absence of an intervening event. Moreover, despite the numerous studies on cueing effects manipulating task demands (e.g., Lupiáñez et al., 1997; Lupiáñez & Milliken, 1999; Lupiáñez et al., 2007), target characteristics (e.g., Snowden et al., 2001; Maruff et al., 1998), and the presence/absence of an intervening event (e.g. Prime et al., 2006), a systematic study of the effects of all these variables, as well as their interactions, on cueing effects is still to be performed.

Aims of the present work

We assume that part of the current theoretical uncertainty about cueing effects, and more concretely about the IOR effect, is that many of the cue and target characteristics that modulate peripheral cueing effects (e.g., timing between cue-target, task demands, target modality, target intensity, cue type, intervening event, etc) have not been jointly studied in a systematic way. Although there are some studies in this vein (for an illustrative example, see Taylor & Klein, 2000; Prime et al., 2006, and Spadaro et al., 2012, for the effects of intervening event; Berger et al., 2005; Maruff et al., 1998, for the effects of target duration; and Lupiáñez et al., 2007, for the effect of the task at hand), further research is essential for integrating results from experiments that differ in a variety of experimental conditions, and for manipulating some of these relevant factors together, to better understand their possible interactions. With this aim in mind, the main purpose of the current paper is to systematically investigate the effect of two of these variables (target duration and the presence/absence of an intervening event) across different tasks (detection, discrimination, and go-no go[5] tasks), emphasizing the importance of the effects of task set on the presence (or absence) of IOR and facilitatory effects.

According to our general framework to explain spatial cueing effects (Lupiáñez, 2010; see also the General Discussion), we assume that peripheral cues, apart from orienting attention automatically to the cued location, produce other effects: a *detection cost*, i.e., a cost in detecting the presence of the target; and a *spatial selection benefit,* i.e., discrimination benefits due to the spatial selection of the target, when it is integrated within the object file representation opened by the cue. Therefore, we postulate that the larger the contribution of detection processes to target processing, the larger the detection cost will be, and therefore the larger IOR that is measured; likewise, the larger the contribution of integration/discrimination processes to target processing, the larger the spatial selection benefit will be, and therefore the larger the facilitation effect that is measured. In general, even in a simple detection task, it is necessary both to detect the target and to discriminate its presence from noise. However, different variables (perhaps the most important being the task at hand) will decrease or increase the contribution of detection and integration/discrimination processes, leading to different modulation over cueing effects. Thus, we establish two main hypotheses:

1) Regarding *target duration*, we assume that very short target durations (i.e., 50 ms) will emphasize the need of the target to be detected, which could lead to larger IOR effects due to a larger contribution to performance of the detection process (i.e., reflecting the *detection cost* effect); while target duration until response will rather emphasize integration/discrimination process (i.e., reflecting the *spatial selection benefit* effect), thus leading to larger facilitatory effects. Importantly, interacting with the task, this variable would be important in the detection task and go-no go tasks. i.e., long target durations could reduce the contribution of the detection process inherent to these tasks. In discrimination tasks, target duration might produce no effects, as spatial selection of the target is necessary no matter for how long the target is presented.

2) Regarding the *intervening event,* we assume that the presence of the intervening event will disrupt cue-target integration processes, making target detection more necessary, and therefore leading to IOR. In interaction with the task at hand, we hypothesize that the presence of the

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[5] Note that this task not only demands a detection process (i.e., respond to the presence/absence of the target) but also demands a discrimination process (i.e., discriminate go stimuli from no-go stimuli).

intervening event would have a greater effect in those tasks in which more integration usually happens (discrimination task and go-no go task), revealing IOR when the intervening event is present. In detection tasks, task demands to detect the target already tune the system to be mainly driven by target detection processes.

Experiment 1(Detection Task)

A simple target detection task was used to investigate whether cuing effects (facilitation and IOR) would be modulated by the manipulation of the target duration (i.e., 50 ms vs. target until response) and/or by the presentation of an intervening event (i.e., intervening event absent vs. present) between the cue and target.

Methods

Participants

A total of 48 participants volunteered for this experiment, 12 in each group, from the crossing of the two between-participants variables: target duration (50 ms vs. until response), and intervening event (absent vs. present). All of them were naïve students from the University of Granada, and participated in the experiment for course credits. All participants in this and the following experiment reported to have normal or corrected to normal vision. This and the following experiments were conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada, in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Apparatus and Stimuli

The experiment was run on a computer with a 1GHz Pentium III processor, connected to a 15-inch color VGA monitor. E-prime 2 software (Schneider, 1998) controlled the presentation of the stimuli and the acquisition of data. All stimuli were white line drawings on a black background. Two placeholder boxes were presented, one on each side of the fixation point. Each box was 20 mm in width by 20 mm in height (subtending 2.0 x 2.0 degrees of visual angle at a viewing distance of 57 cm, at which 1 cm correspond to 1 degree of visual angle). The boxes were positioned 25 mm away from the central fixation along the horizontal plane, as measured from the center of the bottom edges of each placeholder to the center of the screen (fixation point), and positioned 10 mm above the central fixation along the vertical plane, as measured from the center of the inner lateral edges of each placeholder to the center of the screen. Peripheral cues were created by thickening the outline of one of two placeholder boxes. The intervening event was created by presenting a smaller box around the fixation cue (10 mm in width by 10 mm in height). The target was either the letter “X” or “O” (2 mm).

Procedure

The stimuli used, and the sequence of events on each trial, are illustrated in Figure 1. Each trial began with the presentation of the fixation display (containing the fixation point, and the two boxes), with a duration varying randomly between 1000 and 1500 ms. Participants were required to keep their eyes on the fixation point throughout the experiment. The peripheral cue was presented in one of the two possible locations with equal probability during 50 ms. After the peripheral cue, the fixation display was presented again for a duration varying randomly between 100 and 300 ms. Next, the intervening event was presented during 50 ms. In the group with intervening event absent, the fixation display was maintained on the screen during these 50 ms, keeping a constant SOA for both groups. After this intervening event (or 50 ms with the fixation display), another fixation display of random variable duration (100-300 ms) was presented. The target was displayed for 50 ms or until response (depending on the target duration condition) in one of the two peripheral boxes with equal probability. Participants were instructed to detect the appearance of any of the two letters by pressing the appropriate response key on the keyboard as fast as possible (half of the participants pressed the “Z” key, whereas the other half pressed the “M” key). On 33% of the trials (catch trials[6]) no target was presented, and no response was required. The inter-trial interval, in which the screen remained black, was 2000 ms in duration. An auditory feedback was presented for wrong, missing, or premature responses (faster than 200 ms).

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[6] Although some studies have shown that the proportion of catch trials can modulate the IOR effect (see e.g., Tipper & Kingstone, 2005; Gabay & Henik, 2008), other studies did not find such modulations in discrimination tasks (Lupiáñez & Milliken, 1999). Note that catch trials were used in order to avoid anticipatory responses.

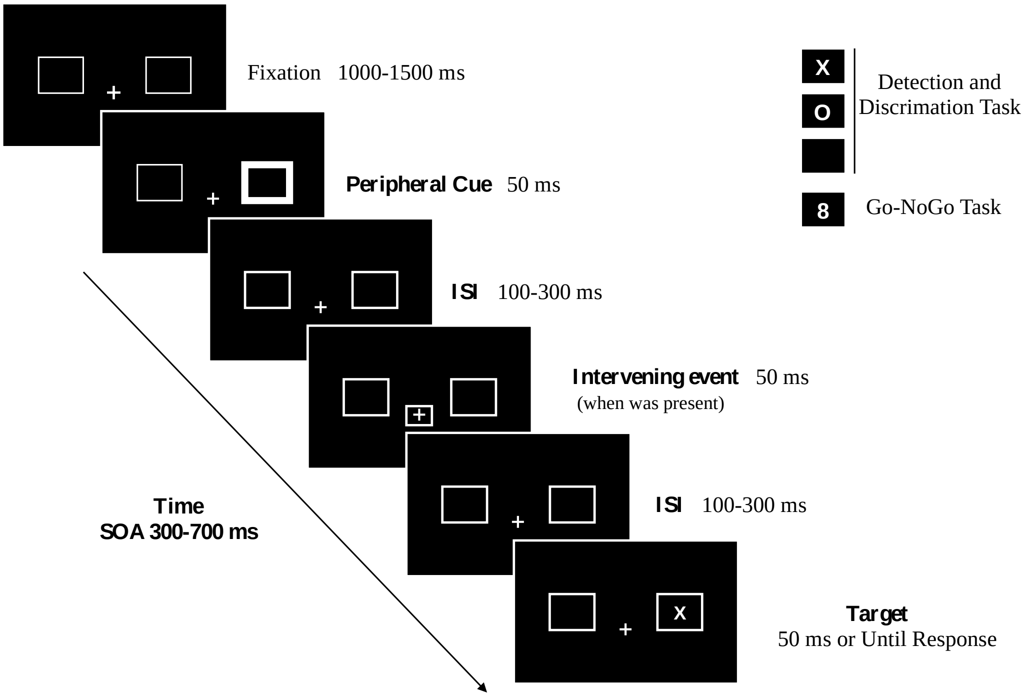

*Figure 1.*Illustration of the trial sequence. In each experiment (detection, discrimination, and go-no go tasks), the intervening event was present or absent (depending on the group of participants), and target duration was either 50 ms or until response. The picture shows an example of a peripherally cued target, in an intervening event trial.

Design

The experiment consisted of a three-factor design[7]. Peripheral cueing was manipulated within participants, while target duration and the intervening event were manipulated between participants. Peripheral cueing had two levels: cued or uncued location trials. Target duration had two levels: 50 ms or until response; and intervening event had also two levels: absent or present after the peripheral cue.

The experiment consisted of 15 practice trials, which were not analyzed, followed by 576 experimental trials (12 blocks of 48 trials each; 16 cued location, 16 uncued location trials, and 16 catch trials).

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[7] We carried out a mixed analysis of variance (ANOVA) including the SOA as factor. In none of the three experiments reported in the paper the SOA factor was statistically significant or significantly interacted with any other variable (all ps>.21). Thus, we did not include SOA as factor in the main analyses.

Results and Discussion

False alarms (i.e., responses to catch trials) accounted for 0.66% of the trials in this experiment. Participants missed the target (i.e., no response was made) on 0.38% of the trials, which were not analyzed. Responses faster than 200 ms (0.42%) were considered anticipations and were from the RT analysis.

Mean correct RT data were submitted to a mixed analysis of variance (ANOVA) with the following factors: 2 (target duration: 50 ms vs. until response) x 2 (intervening event: absent vs. present) x 2 (peripheral cueing: cued vs. uncued). Table 1 shows the mean RTs and percentage of errors for each experimental condition. The analysis revealed a highly significant main effect of peripheral cueing, F(1, 44)=69.69, MSE=9715, p<.0001, η2=0.61, showing that RT was overall slower when the target appeared in a position previously occupied by the cue as compared to the uncued location (i.e., IOR was observed). Importantly, as can be observed in Figure 2, the peripheral cuing effect was significantly modulated by target duration, F(1, 44)=4.88, MSE=680, p=.0324, η2=0.09. Although IOR was significant both for the 50 ms target duration, F(1, 44)=55.55, MSE=7741, p<.0001, and when target duration was until response, F(1, 44)=18.91, MSE=2635, p<.0001, IOR was larger in the former (-25 ms) that in the latter (-15 ms). The main effect of target duration was not significant, F<1. The effect of the intervening event was marginally significant, F(1, 44)=3.98, MSE=36406, p=.0502, η2=0.08, with faster overall responses when an intervening event was present as compared to when it was absent. Importantly, the intervening event did not interact with peripheral cueing, F(1,44)=1.56, MSE=218, p=.2181, η2=0.03), or target duration, F(1, 44)=2.00, MSE=18272, p=.1642, η2=0.04. The interaction between all three factors (peripheral cueing x target duration x intervening event) was not significant either, F(1, 44)=1.31, MSE=183, p=.2583, η2=0.02.

The results of the present experiment indicate that in detection tasks, the automatic effect generated by peripheral cues (i.e., IOR effect) was observed in all conditions. When participants were required to detect the target, an IOR effect was always observed. This result is usually found in detection tasks, in which IOR appears at short SOAs, and it is unusual to observe facilitatory effects (see above; Tassinari et al., 1994; Tassinari & Campara, 1996). Importantly, the IOR effect, although always observed, was only modulated by the manipulation of target duration, with a reduced IOR when the target duration was until response as compared to the 50 ms target duration. IOR was not modulated by the intervening event in this experiment.

These results support the view that the intervening event and target duration might affect peripheral cueing in different ways; intervening events do not always modulate IOR, as it is assumed in the literature. However, note that although the interaction between the three factors (peripheral cueing x target duration x intervening event) was not significant, as it can be observed in Figure 2, IOR tended to be larger when the intervening event was present than when it was absent, but only when target duration was until response. In order to explore this question, we compared the present data with data from an additional experiment[8], which used a detection task, target duration until response, and intervening event present vs. absent. We pooled together the data from the two experiments (only data from the target duration until response in Experiment 1) and submitted mean RTs to a mixed analysis of variance (ANOVA) with the following factors: 2 (intervening event: absent vs. present) x 2 (peripheral cueing: cued vs. uncued) x 2 (experiment) as factors. Importantly, peripheral cueing significantly interacted with the intervening event factor, $F(1, 36)=5.54$, $MSE=171$, $p=.0241$, $\eta 2=.13$, showing a non-significant IOR (-7 ms, $p=.1330$) when the intervening event was absent, and a significant IOR (-20 ms, $p<.0001$) when the intervening event was presented. The three-way interaction between peripheral cuing, intervening event, and experiment was not significant, $F<1$, indicating that the modulation of IOR when the intervening event was present was similarly observed in both experiments.

In sum, our results suggest that although the automatic effect generated by peripheral cues (i.e., IOR effect) was observed in all conditions in the detection task, its magnitude was reduced when target duration was until response as compared to the 50 ms target duration. No modulations of the intervening event were found when the target duration was 50 ms, but IOR was increased when the intervening event was present and target duration was until response. The implications of these data are discussed in the General Discussion.

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[8] This new experiment was a pilot carried out in order to use event related potentials (ERPs) to investigate the electrophysiological basis of behavioral exogenous cueing effects. A total of 16 participants from the same pool and conditions of Experiment 1 took part in this experiment. The procedure and design were identical to Experiment 1, except for the following: The experiment consisted of 20 practice trials, which were not further analyzed, followed by 392 experimental trials (7 blocks of 56 trials each; 24 cued location, 24 uncued location trials, and 8 catch trials). Target duration was always until response, and the SOA was jittered between 500-700 ms. As in Experiment 1, the presence/absence of the intervening event was manipulated between participants.

Table 1- Mean RTs (in ms) for each condition (Intervening event x Target duration) across all experiments. Percentage of target misses (no response) are presented in parenthesis, and erroneous response in the discrimination task are presented in squared brackets.

	Intervening event							
	Absent				Present			
	Target Duration				Target Duration			
	50 ms		Until response		50 ms		Until response	
	Cued	Uncued	Cued	Uncued	Cued	Uncued	Cued	Uncued
Detection Task	394 (0.0%)	369 (0.01%)	426 (0.0%)	417 (0.01%)	383 (0.01%)	357 (0.0%)	366 (0.0%)	345 (0.0%)
Discrimination Task	581 (0.07%) [3.07%]	597 (0.09%) [4.11%]	528 (0.0%) [1.51%]	542 (0.01%) [1.95%]	557 (0.05%) [3.21%]	547 (0.04%) [3.64%]	570 (0.01%) [2.47%]	561 (0.03%) [1.86%]
Go-NoGo Task	470 (0.02%)	468 (0.02%)	481 (0.0%)	501 (0.0%)	482 (0.0%)	470 (0.0%)	486 (0.0%)	483 (0.0%)

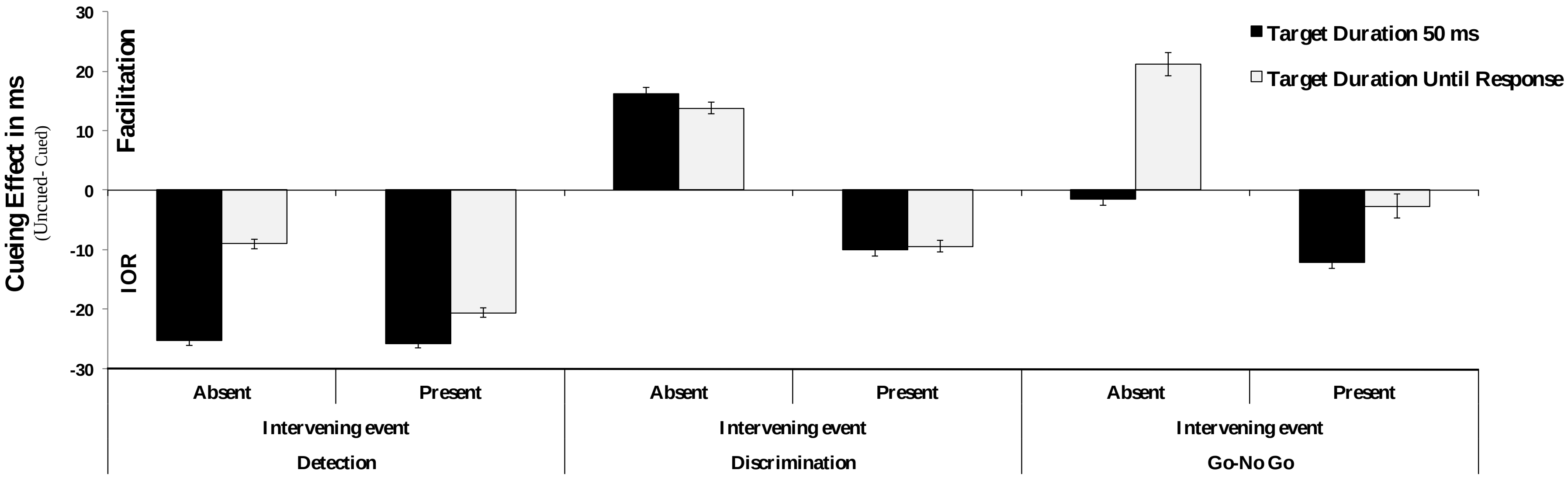

Figure 2. Mean cueing effect (Mean RT for Cued - Uncued conditions) as a function of intervening event (absent vs. present) and target duration (50 ms vs. until response), in the detection (Experiment 1), discrimination (Experiment 2) and go-no go task (Experiment 3). Error bars represent the Standard Error of the Mean (SEM).

Experiment 2 (Discrimination Task)

A target discrimination task was used to further investigate whether cueing effects (i.e., facilitation and IOR) are affected by the manipulation of target duration (i.e., 50 ms vs. until response) and the presentation of an intervening event (i.e., absent vs. present) when target detection is not sufficient to perform the task, being necessary to discriminate the target's features.

Methods

Participants

A total of 48 new participants from the same pool and conditions of Experiment 1 took part in this experiment, 12 in each of the 4 groups. Data from one participant were excluded due to low accuracy (below 50%).

Apparatus, Stimuli, and Procedure

The procedure and design were identical to Experiment 1, except for the following: Participants had to discriminate the identity of the letter by pressing one key ("Z" or "M") for each letter; the letter-key assignment was counterbalanced across participants.

Results and Discussion

Trials with incorrect responses (2.71%), those in which no response was made (0.29%), and those with RTs shorter than 200 ms (0.001%) were excluded from the RT analysis.

Mean correct RTs data were submitted to the same ANOVA as in Experiment 1. Target duration and intervening event were manipulated between-participants, and peripheral cueing was manipulated within-participants. The mean RT and percentage of errors for each experimental condition are presented in Table 1. Importantly, the analysis of mean RTs revealed a non-significant main effect of peripheral cueing, F<1. However, peripheral cueing interacted with the intervening event factor, F(1, 43)=19.18, MSE=3601, p<.0001, η2=.30, showing a significant facilitatory effect (15 ms) when the intervening event was absent, F(1, 43)=13.81, p=.0005, and a significant IOR effect (-10 ms), F(1, 43)=6.07, p=.0177, when the intervening event was present (see Figure 2). Crucially, none of the others main effects, F<1, nor the target duration x intervening event interaction, F(1, 43)=1.87, MSE=27280, p=.1786, η2 =.04, were significant. The three-way interaction was not significant either, F<1.

The mean percentage of error analysis showed a main effect of target duration as the only significant effect, F(1, 43)=5.32, MSE=10.7265, p=.0258, η2=.11. More errors were observed when the target duration was 50 ms (3.9%) than when the target was presented until response (1.8%).

Importantly, in contrast to Experiment 1, in Experiment 2, the automatic effect generated by peripheral cues was highly modulated by the intervening event factor, leading to different cueing effects (i.e., facilitation or IOR) depending on the presence or absence of this event. In the discrimination task, a significant facilitatory effect was observed the intervening event was absent, while a significant IOR effect was observed when the intervening event was present. Moreover, no effect of target duration was found. Again, as previously described, these results support the view that intervening events and target duration affect peripheral cueing in different ways, and their effects depend on the task at hand (detection vs. discrimination).

Experiment 3 (Go-No Go Task)

Finally, in this third experiment, a go-no go task was used to investigate the effects of target duration and intervening event when the task at hand not only demands a detection component (i.e., respond to the presence/absence of the target), but it also has an important discrimination process (i.e., discriminate the go target from the no-go stimuli). Concretely, in this task the go stimuli were perceptually similar to the no-go stimulus in order to increase the contribution of discrimination processes.

Methods

Participants

A total of 56 participants from the same pool and conditions of Experiments 1 and 2 took part in this experiment; 14 in each of the 4 groups.

Apparatus, Stimuli, and Procedure

The procedure and design were identical to the previous experiments, except in the following. In the third of trials in which no target was presented in the previous experiments (i.e., catch trials), the number 8 was presented, serving as a no-go stimulus. Participants were instructed to press a response key on the keyboard as fast as possible when one of the two letters (X or O) was presented (go condition), but to withhold the response when the number 8 was presented (no-go condition). On “go” trials, half of the participants were to press the “Z” key, whereas the other half were to press the “M” key.

Results and Discussion

False alarms (i.e., responses to the no-go condition) accounted for 7.80% of the trials. Participants missed the target (i.e., no response was made) on 0.54% of the trials. Responses faster than 200 ms (0.04%) were excluded from the RT analysis as outliers (see Table 1).

Mean RT data were submitted to a mixed analysis of variance (ANOVA) with the following factors: 2 (target duration: 50 ms vs. until response) x 2 (intervening event: absent vs. present) x 2 (peripheral cueing: cued vs. uncued). None of the main effects were significant (all Fs<1). There was a significant interaction between peripheral cueing and target duration, F(1, 52)=11.47, MSE=1815, p<.001, η2=.18, showing a significant IOR effect (-7 ms, p=.0468) when target duration was 50 ms, and a significant facilitatory effect (9 ms, p=.0080) when target duration was until response. The interaction between peripheral cueing and intervening event was also significant, F(1, 52)=13.14, MSE=2081, p<.0001, η2=.20, showing a significant facilitatory effect (10 ms, p=.0051) when the intervening event was absent, and a significant IOR effect (-8 ms, p=.0319) when the intervening event was present (see Figure 2). The three-way interaction was not significant, F(1, 52)=1.94, MSE=308, p=.1688, η2=.03.

The percentage of false alarms analysis revealed a main effect of peripheral cueing as the only significant effect, F(1, 52)=5.44, MSE=55.95, p=.0235, η2=.09. Fewer false alarms were observed when the target appeared in a position previously occupied by the cue (7.1%) as compared to the uncued location (8.6%).

In this experiment, peripheral cueing effects were modulated both by target duration and intervening event, leading to opposite effects with both manipulations. Importantly, the three-way interaction was not significant. As it can be observed in Figure 2, the cueing effect was more negative (i.e., leading to an IOR effect) when target duration was 50 ms and/or when the intervening event was present; in contrast, the cueing effect was more positive (i.e., leading to a facilitatory effect) when target duration was until response and/or the intervening event was absent. Both factors (target duration and intervening event) produced additive modulations over the cueing effect; IOR was only significant when target duration was 50 ms and the intervening event was present (-12 ms, p=.0135), while the facilitatory effect was only significant with the target duration until response and no intervening event (21 ms, p<.001). Therefore, the manipulation of target duration and intervening event in this go-no go task, seems to generate similar effects (that is, both target duration of 50 ms and intervening event present lead to a more negative cueing effect (i.e., IOR effect), while target duration until response and intervening event absent lead to a more positive effect (i.e., facilitatory effect), but without significantly interacting with each other.

Nevertheless, as observed in the detection task (see Figure 2), it seems that the intervening event tended to modulate cueing effects specially when target duration was until response. In order to explore this effect in the three tasks, mean RT data when target duration was until response were submitted to a mixed analysis of variance (ANOVA) with the following factors: 2 (intervening event: absent vs. present) x 2 (peripheral cueing: cued vs. uncued) x 3 (experiment: detection, discrimination, and go-no go tasks) as factors. Importantly, the intervening event factor interacted with peripheral cueing, F(1, 70)=28.55, MSE=3613, p<.0001, η2=.28, showing an overall significant facilitatory effect when the intervening event was absent (9 ms, p<.0001), and a significant IOR effect (-11 ms, p<.0001) when the intervening event was present. The interaction between all three factors was clearly not significant (p>.35). This result demonstrates that the intervening event increased the IOR effect as compared to the condition where the intervening event was not present, and this was similarly observed in the detection task (-9 ms and -21 ms, respectively for the intervening event absent vs. present, p=.0793), discrimination task (14 ms and -9 ms, p=.0006), and the go-no go task (21 ms and -3 ms, p=.0001). However, although cueing effects were more positive (or less negative) in all tasks when the intervening event was absent, significant facilitation was only observed in the discrimination task (14 ms, p=.0044) and in the go-no go task (21 ms, p<.0001), while a marginally significant IOR was observed in the detection task (-9 ms, p=.0529).

The same analysis was carried out for the 50 ms target duration. This time, the interaction between peripheral cueing and intervening event factor was significant, F(1, 69)=7.34, MSE=1445, p<.0001, η2=.26, showing an overall non-significant IOR effect when the intervening event was absent (-4 ms, p=.2955), and a significant IOR effect (-16 ms, p<.0001) when the intervening event was present. Importantly, however, this interaction was marginally modulated by task, F(1, 69)=2.51, MSE=495, p=.0883, η2=.09. The peripheral cueing x intervening event interaction was significant when the detection and discrimination tasks were compared, F (1, 43)=5.26, MSE=185, p=.0267, η2=.10. As can be observed in Figure 2, the presence of the intervening event made the cueing effect more negative (or less positive), as compared to the condition where the intervening event was absent, especially in the discrimination task (-10 ms and 16 ms, respectively). The same (although reduced) tendency was observed in the go-no go task (-2 ms and -12 ms), and was completely absent in the detection task, where IOR had the same magnitude independently of the intervening event (-25 ms and -26 ms).

In sum, we can conclude that when the target is displayed until response, the intervening event modulates cueing effects in the three experiments (i.e., detection, discrimination, and go-no go task). In the detection task, this modulation consists of an increase on the magnitude of IOR observed when the intervening event is absent; while in the go-no go and discrimination tasks, the intervening event produces IOR in conditions at which facilitation is observed in the absence of such intervening event. However, when the target is displayed for 50 ms, the intervening event modulates the cueing effects only in the discrimination and go-no go tasks. In both tasks, larger IOR is observed when the intervening event is present. No modulations were observed in the detection task. The implications of these data are discussed below.

General Discussion

Attentional orienting produced by spatially non-informative peripheral cueing is considered involuntary, because there is no incentive to maintain attention at the cued location. However, this type of orienting is far from being automatic (Ruz & Lupiáñez, 2002), being modulated by many variables such as the timing between the cue and target, task demands, target modality, target intensity, cue type, the presence of intervening events, etc. (see e.g., Maruff et al., 1998; Reuter-Lorenz, et al., 1996; Taylor & Donnelly, 2002; Snowden et al., 2001; Kingstone & Pratt, 1999; Pratt & Fischer, 2002; Prime et al., 2006; see Lupiáñez, 2010, for a review). A review of the literature (see Introduction) reveals that we have acquired some knowledge about the modulation of cueing effects by some of these variables, although they have not yet been jointly studied in a systematic way. In the present series of experiments we manipulated two of these variables, target duration (i.e., 50 ms or target until response) and the presence/absence of an intervening event, in order to understand how they modulate cueing effects, as a function of task demands: detection, discrimination, and go-no go tasks.

The results showed that the presence of IOR and facilitatory effects was sensitive to target duration or to the presence of an intervening event depending on the task. Three main results were observed: First, in the detection task, IOR was always observed, and it was mainly modulated by target duration. When the target was presented until response, IOR was reduced as compared to the 50 ms target duration. The presence/absence of the intervening event only modulated IOR when the target was presented until response. Second, in the discrimination task, cueing effects were only modulated by the presence of the intervening event, while target duration did not produce any modulations over the cueing effects; when the intervening event was absent, a significant facilitatory effect was observed, while a significant IOR appeared when the intervening event was presented. Importantly, in the discrimination task, the intervening event modulated even the sign of the peripheral cueing effect (facilitatory effect and IOR effect with absent/present intervening event, respectively). Finally, in the go-no go task, the two variables additively modulated peripheral cueing effects; IOR was observed only with 50 ms target duration, and the presence of the intervening event, while the facilitation effect occurred only when the target was presented until response, and the intervening event was absent. As it can be observed in Figure 2, the intervening event factor modulated the cueing effect similarly for the two target durations: the cueing effect was more negative (with less facilitation or more IOR), when target duration was 50 ms (changing from an IOR effect to a null effect) or when it was presented until response (changing from a null effect to a facilitation effect). If there were a there-way interaction in this go-no go task, it would show differences in magnitude rather than nature of the effects. As we point out, facilitation was only significantly observed when target duration was until response and the intervening event was absent. We therefore believe that finding this significant three-way interaction will not affect the interpretation of the results.

Taken together the above results, we conclude that the manipulation of target duration and intervening event, in a general way, seems to generate similar effects; that is, both target duration of 50 ms and the presence of the intervening event lead to more negative cueing effects (i.e., IOR and/or less facilitation effect), while target duration until response and intervening event absent lead to more positive effects (i.e., facilitation and/or IOR effect), depending on the cueing effects that are observed with the task at hand.

According to the traditional “*reorienting hypothesis*” (Posner &Cohen, 1984; Klein, 2000), both facilitation and IOR are explained by the same mechanism, the orienting of attention, which is engaged and subsequently disengaged from the cued location. For example, the disengagement of attention has been used to explain the different time course of IOR observed in detection and discrimination tasks (Klein, 2000). In most studies using an intervening event (called fixation cue or cue-back), it is assumed that this fixation cue captures attention and reorients it back to fixation, leading to an earlier appearance of IOR by anticipating the disengagement of attention (MacPherson et al., 2003; Pratt & Fischer, 2002). However, accumulative evidence shows that this hypothesis might not be correct (Berlucchi, Chelazzi, & Tassinari, 2000; Berlucchi, 2006; Berger, Henik, & Rafal, 2005; Chica, Bartolomeo, & Lupiáñez, 2006; Chica & Lupiáñez, 2009; Martín-Arévalo, Kingstone, & Lupiáñez, 2013). In short, IOR has been observed in conditions in which attention is not disengaged from the cued location. Furthermore, it has been shown that facilitation instead of IOR can be observed even after attention has been disengaged from the cued location (Danziger & Kingstone, 1999; Experiment 2; Chica & Lupiáñez, 2004; Lupiáñez, Martín-Arévalo,

& Chica, 2013; see also Gabay, Chica, Charras, Funes, & Henik, 2012). Importantly, the aforementioned pieces of evidence allow us to conclude that cueing effects (facilitation and IOR) cannot be explained by the engagement or disengagement of spatial attention, as attentional disengagement seems to be neither necessary nor sufficient for the IOR effect to be observed.

A rather more parsimonious hypothesis regarding the mechanisms that produce the facilitation and IOR effects might be possible according to the "*object file segregation/integration hypothesis*" (Lupiáñez, 2010), framed in the object-file theory proposed by Kahneman, Treisman, and Gibbs (1992). It is suggested that the appearance of a cue shortly before target appearance, apart from orienting attention automatically to the cued location ("*spatial orienting*" process), produces other effects, which seem to be independent of attentional orienting, but nevertheless also affect the processing of the subsequent target. We reckon that the peripheral cue is an event, an object that occupies a specific location and therefore produces different effects on the processing of subsequent stimuli appearing at the same location. Concretely, the subsequent target could be integrated within the same object file when it appears spatio-temporally around the cue (i.e., the cue representation could be updated incorporating the target's features), thus being more easily selected for further discriminative processing. Then, cue-target integration processes (Kahneman et al., 1992; Hommel, 2004) would be beneficial to determine what the target is, as they would help to select the target location in advance ("*spatial selection*" benefit). In fact, whenever the target appears at the same location as the cue, it would be treated by this system, which integrates information across time, not as a new object but as an update of the object-file representation just opened by the cue. This process can lead to benefits in determining what the target is, due to the accumulation of information over time.

However, discrimination is not all that is needed to respond to the target. Detecting the target is also important for fast responding to it. In fact, other tasks might tap into these detection processes to a greater extent. Importantly, in order to detect the appearance of a new object, it is necessary that the perceptual system treat any piece of information as different from previous information. Therefore, 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 ("*detection cost*"), producing the standard IOR effect. According to this view, IOR constitutes a cost in detecting new information, with attention being less captured (by the target) at the location where it was captured before (by the cue). Therefore, we propose that cueing a location hinders detection of a subsequent object at the very same location (i.e., leading to IOR), whereas at the same time it facilitates selecting this object for subsequent perceptual discriminative processing leading to its recognition (i.e., leading to facilitatory effect, mostly found in discrimination tasks).

In conclusion, the final effect that is measured in responding to a target presented at the cued location, apart from spatial orienting, will be sum of the net contribution of spatial selection benefits and detection costs. Therefore, depending on the nature of the task (Lupiáñez et al., 2007), timing, and characteristics of the targets and cues, some process will contribute to performance more than others, therefore producing a positive (facilitatory effect) or negative (IOR effect) net cueing effect.

In sum, this new framework can draw two different assumptions: First, whereas the benefits of spatial selection would be more pronounced in discrimination tasks (i.e., leading to more facilitation or less IOR), the detection costs would be more pronounced in detection tasks (i.e., leading to more IOR or less facilitation). Moreover, in go-no go tasks, both effects (*detection cost* and *spatial selection benefit*) would be important, and therefore, both facilitation and IOR could be measured; the latter task not only demands a detection process (i.e., respond to the presence/absence of the target), but also a discrimination process (i.e., discriminate “go” stimuli from “no-go” stimuli). This assumption fits well with the results observed in the third experiment (i.e., go-no go task): A non-significant main effect of peripheral cueing was presented, which was however modulated both by target duration and intervening event, leading to opposite effects with both manipulations. This result support the idea about the peculiarity of the go-no go task, in which depending on the presence/absence of an intervening event, and/or the target duration, a *detection cost* or *spatial selection benefit* would be mainly measured. In contrast, an overall IOR effect was only observed in the detection task, while cueing effects were overall non-significant in the discrimination task. In the detection task, target duration and intervening events manipulations led to a reduction of IOR, but never to facilitatory effects, since the spatial selection benefit is almost absent in this task.

Second, our main hypothesis postulated that the larger the contribution of detection processes to target processing generated by any variable (e. g., short target duration of 50 ms, detection task, and/or the presence of an intervening event, in the present study), the larger the detection cost will be, and therefore the larger IOR that is measured. Likewise, the larger contribution of integration/discrimination processes to target processing generated by any variable (e.g., long target duration, discrimination task, and/or the absence of an intervening event), the larger the spatial selection benefit will be, and therefore the larger the facilitatory effect that is measured. In fact, in relation to the variables investigated in the present paper, the event integration/segregation hypothesis predicts that when targets are presented until response, discrimination processes will be emphasized, thus leading to larger facilitatory effects; on the other hand, short target durations (i.e., 50 ms) could emphasize target detection, which could lead to larger IOR effects (i.e., reflecting a detection cost). Both assumptions are based on spatio-temporal resolution; longer time duration allows accumulation of information over time that it is necessary to bind together the different object-constituting features into an integrated representation; on the other hand, short target duration increases the need to rapidly detect the target because it disappears quickly and would be unnoticed otherwise.

Moreover, the role of the intervening event could be to interfere with or disrupt integration processes, eliminating spatial selection benefits and enhancing the detection cost (i.e., increasing the IOR effect). Again, this results fit with what we found in the detection task: No effect of the intervening event was found overall, the spatial selection benefit is almost absent in the detection task. However, when the target was presented until response, thus enhancing integration processes, IOR was increased with the presentation of the intervening event, even in the detection task.

Importantly, the findings of the present paper are in good agreement with this new framework. Our results support the view that, as previously described, the presence of an intervening event and target duration until response could affect peripheral cueing in different ways, the first probably eliminating spatial selection benefits, and the latter probably decreasing the contribution of detection processes. Thus, in the detection task, in which the detection process is emphasized by task demands, and the spatial selection benefits barely contribute to performance, IOR mainly depended on target duration, as the contribution of detection processes decreases when the target duration is long. However, even in the detection task, when the target duration was until response, the intervening event could disrupt integration processes, leading to an increased IOR effect. In the discrimination task, the results also fit with our hypothesis about peripheral cueing effects: in this task, target detection is not sufficient to perform the task, being necessary to discriminate the target’s features. In this case, other processes that are beneficial for target discrimination also contribute to performance (i.e., spatial selection benefits), leading to facilitatory effects. However, when the intervening event was presented, the cueing effect reversed into IOR, probably due to the disruption of the spatial selection benefits. Because in this task the detection cost in less relevant, target duration had no effect (integration processes are already emphasized by the discrimination task), while the intervening event produces a large effect by eliminating the spatial selection benefits usually observed in the discrimination task. Finally, we assume that in the go-no go task both the *detection cost* and the *spatial selection benefit* play a role. The go-no go task not only demands a detection process, but it also has an important discrimination component. The results showed that the IOR effect was only significant with 50 ms target duration and intervening event (i.e., when detection processes are emphasized by the two manipulated factors), and the facilitation effect was only significant with target duration until response and when no intervening event was presented (i.e., when discrimination processes are emphasized by the two manipulated factors).

Conclusion

The main result reported in this paper is that the magnitude, and even the sign (facilitation or IOR), of cueing effects are modulated by target duration and the presence/absence of an intervening event, depending on the task at hand. We assume that IOR mainly reflexes the fact that attention is poorly captured by targets at the cued location, since the target appears at a previously attended location (detection cost); while facilitation mainly reflexes the benefits of integration of cue and target within the same object file for discrimination processes. Thus, the larger the contribution of detection processes to target processing (e.g., 50 ms target duration, presence of intervening event, and/or detection tasks), the larger the detection cost will be, and therefore the larger the IOR effect that is measured. Contrary, the larger the contribution of integration/discrimination processes to target processing generated by any variable (e.g., target duration until response, absence of intervening event, and/or discrimination tasks), the larger the spatial selection benefit will be, and therefore the larger the facilitatory effect that is measured.

Experimental Series 3

Electrophysiological modulations of exogenous attention by intervening events

The content of this chapter has been submitted as:
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Abstract

The present study used event related potentials (ERPs) to investigate the electrophysiological basis of behavioural exogenous cueing effects. We used a cue-target paradigm in which the presence/absence of an intervening event produced opposite effects on RTs (i.e., facilitation in the absence of the intervening event, and inhibition of return –IOR, when the intervening event was presented between the cue and target). Peripheral cues always produced a detection cost (reflected in a reduced amplitude of the P100 component for cued as compared to uncued trials), independently on the behavioural effect that was measured. In contrast, facilitation and IOR effects were related to the modulation of later-stage components (namely N100, Nd, and P300), and were also reflected in modulations of the attentional selection (reflected in the N2pc component). While facilitation was associated to modulations of all the above-mentioned components, the IOR effect was related to a lack of modulations on N100, Nd, and P300 components, but it was associated to changes in attentional selection (as revealed by the N2pc). The present results suggest that facilitation and IOR can arise from changes at different stages of processing. We propose that the perceptual detection cost (reflected on the P100), and the hindered attentional selection (reflected on the N2pc) at the cued location determine the IOR effect, while the contribution of the later-stage components, beside attentional processes, determines other facilitatory effects of cueing, which altogether determine the behavioral effect that is measured.

Introduction

Spatial attention can be driven by either of two mechanisms: *endogenous orienting*, in accordance with the observer's goals and intentions; and *exogenous orienting*, in response to salient stimulus events (Jonides, 1981). Recent cumulative evidence suggests that two separate attentional systems support the exogenous and endogenous orienting of spatial attention (e.g., Corbetta & Shulman, 2002; Chica, Bartolomeo, & Valero-Cabré, 2011; Chica, Bartolomeo, & Lupiáñez, 2013). The Posnerian cueing paradigm has been widely used to study these two spatial attention mechanisms (Posner, 1980). Using spatially non-informative peripheral cues, we can observe two different behavioural effects across time: At short cue-target stimulus onset asynchronies (SOAs), reaction times (RTs) are usually faster for targets appearing at the same location than the peripheral cue (i.e., the cued location) as compared to RTs for targets presented at the opposite location (i.e., the uncued location), i.e., a *facilitatory effect* is observed. At longer SOAs, however, the opposite pattern of results emerges: RTs are faster for targets appearing at the uncued location as compared to the cued location (Posner & Cohen, 1984). This effect was named *Inhibition of Return* (IOR) by Posner, Rafal, Choate, & Vaughan (1985), reflecting the traditional theory behind the effect, which is thought to consist of a bias against returning attention to previously-explored locations (Klein, 2000, for a review).

Although this hypothesis about IOR effect has been widely accepted by most researchers in the attention field, there is recent accumulative evidence questioning its appropriateness (see e.g., Klein, 2000; Berlucchi, 2006; Chica, Lupiáñez, & Bartolomeo, 2006; Chica & Lupiáñez, 2009; Dukewich, 2009; Gabay, Chica, Charras, Funes, & Henik, 2012), and no consensus has yet been reached regarding the mechanisms underlying the cueing effects. Recently, the detection cost theory of IOR suggested by Lupiáñez and colleagues (Lupiáñez 2010; Lupiáñez, Martín-Arévalo & Chica, 2013; see also the General Discussion) seems to accommodate most of the results related to these effects. Concretely, it suggests that peripheral cues, apart from orienting attention automatically to the cued location, produce two other effects: a *spatial selection benefit*, that facilitates discrimination processes at the cued location, and a *detection cost* that impairs the detection of new information at the previously cued location. According to this model, the behavioural cueing effect that is measured (facilitation or IOR) would depend on the summed contribution of these processes to performance.

This theoretical approach of IOR can explain the existing experimental evidence showing that the IOR effect occurs in a wide variety of experimental situations (for an illustrative example, see Taylor & Klein, 1998), and can be modulated by many variables (see e.g., Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997, Lupiáñez & Milliken, 1999, for task demands; Maruff, Yucel, Danckert, Stuart, & Currie, 1999, Reuter-Lorenz, Jha, & Rosenquist, 1996; for target characteristics; Collie, Maruff, Yucel, Danckert, & Currie, 2000, for temporal properties of cue and target; Lupiáñez, Ruz, Funes, & Milliken, 2007, for target frequency; Pratt & Fischer, 2002; MacPherson, Klein, & Moore, 2003; Prime & Ward, 2004; Spadaro, He, & Milliken, 2012; for the presence/absence of an intervening event).

Of particular relevance to our current aims, the appearance of an intervening event (i.e., a cue presented at fixation between the peripheral cue and target) is known to favour the appearance of the IOR effect (see e.g., Faust & Balota, 1997; Lupiáñez, Martín-Arévalo, & Chica, 2013; MacPherson, Klein, & Moore, 2003; Martín-Arévalo, Chica, & Lupiáñez, submitted; Pratt & Fischer, 2002; Prime, Visser, & Ward, 2006; Spadaro, He, & Milliken, 2012; Spadaro, Lupiáñez, & Milliken, under review). In particular, we have recently manipulated the presence/absence of an intervening event across three different tasks (detection, discrimination, and go-no go tasks; Martín-Arévalo et al., submitted). Our results demonstrated that intervening events did not modulate cuing effects in detection tasks (at least for short target durations when detection processes are more relevant) (see also Pratt & Fischer, 2002), but it did in discrimination tasks (see also Prime, Visser, & Ward, 2006), and go-no go tasks (Martín-Arévalo et al., submitted). In both the discrimination task and the go-no go task, a facilitatory effect was observed when the intervening event was absent, while this effect reversed into IOR when the intervening event was presented. Importantly, similar modulations of IOR have been observed in discrimination tasks for the so-called "non-spatial IOR" effect (Law, Pratt, & Abrams, 1995; Fox & deFockert, 2001; Spadaro et al., 2012; Spadaro et al., under review).

A review of the above-presented studies shows that there are many examples of the effectiveness of intervening events in revealing IOR in discrimination tasks (see, e.g., Kingstone & Pratt, 1999; Pratt & Abrams, 1999; Pratt, Kingstone, & Khoe, 1997; Prime & Ward, 2004; Spadaro et al., 2012), although the effect seems to be observed independently of the presence/absence of an intervening event in detection tasks (see also Pratt & Fischer, 2002; Martín-Arévalo et al., submitted). Moreover, many studies have observed IOR in the absence of an intervening event, no matter the task at hand (see, e.g., Danziger & Kingstone, 1999; Chica, et al., 2006; Lupiáñez et al., 1997). Taken all this evidence together, these results seem to suggest that intervening events may be unnecessary for obtaining IOR effects under certain conditions (e.g., in detection tasks), but they might be necessary or helpful for observing IOR in other conditions (e.g. in discrimination tasks).

Although some consensus has been reached throughout the literature regarding the empirical effect of intervening events, there is no agreement about its putative function in the orienting of spatial attention. Most authors propose that the function of the intervening event (also called *fixation cue*, or *cue-back*) is to capture attention back to fixation, ensuring that attention is withdrawn from, and therefore less likely to return to, the cued location at the time of target onset (Pratt & Fischer, 2002; Prime & Ward, 2004; Prime et al., 2006). However, this logic collapses when we take into account that disengaging of attention seems to be neither necessary nor sufficient for IOR to be observed (Lupiáñez, 2010; Lupiáñez et al., 2013). According to our general framework to explain spatial cueing effects (Lupiáñez, 2010; Lupiáñez et al., 2013), the intervening event might disrupt cue-target integration processes, which help to select the target and therefore facilitates discrimination at the cued location. By disrupting the selection benefits, the intervening event leaves the detection cost and the most important cueing factor contributing to performance and therefore an IOR effect is measured.

Importantly, techniques such as event-related potential (ERP) recordings could be critical for clarifying the contribution of the different intermediate cueing factors to the overall performance that is measured on RT. ERPs have played an increasingly important role in our understanding of the mechanisms of attention, and the level-of-processing of attended and non-attended information (Luck, Woodman, & Vogel, 2000).

Several studies have used ERPs to investigate perceptual modulations related to the IOR effect (Eimer, 1994; Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999; Prime & Ward, 2004; Wascher & Tipper, 2004; Chica & Lupiáñez, 2009). Research has focused on the amplitude of the early posterior ERP peaks, such as the occipital P100, and the occipito-parietal N100 (for review, see Mangun, 1995). Most ERPs studies suggested that the IOR effect consists of a suppression of perceptual processing, as indicated by a reduction in the amplitude of the visual P100 component for cued as compared to uncued locations (Mangun, Hansen, & Hillyard, 1987; Eimer, 1994; Hopfinger & Mangun, 1998; McDonald et al., 1999; Prime & Ward, 2004; Prime, Visser, & Ward, 2006; Doallo, Lorenzo-Lopez, Vizoso, Holguin, Amenedo, & Bara, 2004; Wascher & Tipper, 2004; Tian & Yao, 2008; Satel, Hilchey, Wang, Story, & Klein, 2013). In addition, the facilitatory effect has also been related to an enhanced P100 component for cued as compared to uncued locations (see e.g., Luck, 1995; Hopfinger & Mangun, 1998). Source localization studies (e.g., Mangun, Hillyard, & Luck, 1993) have suggested that the neural generators responsible for the visual P100 component are located in relatively early extrastriate cortical regions in the middle and ventral occipital cortex, suggesting a direct link between attentional effects produced on the amplitudes of early sensory-specific ERP components and spatially selective attentional modulations of early stages of sensory-perceptual processing (Eimer, in press).

Importantly to the present study, relatively few ERPs studies have examined the effect of an intervening event on the appearance (or lack) of the IOR effect (see Prime & Jolicoeur, 2009). In fact, to our knowledge, Prime and Jolicoeur (2009) is the only ERP study exploring this issue. They manipulated the presence or absence of an intervening event (which they called reorienting event) in a cue-target discrimination task. The authors provided evidence supporting a relatively early visual locus for the IOR effect. Concretely, when the intervening event was presented, a significant IOR was observed, accompanied by reductions in the amplitude of the occipital P100, occipito-parietal N100, and anterior N100 peaks, for cued as compared to uncued locations. In contrast, when the intervening event was absent, neither a significant IOR effect was observed on RTs, nor significant modulations of the early posterior ERP peaks were observed. Importantly, in none of their experiments (Prime & Ward, 2004; Prime et al., 2006; Prime & Jolicoeur, 2009), the absence of the intervening event was accompanied by behavioral facilitation on RTs, a result that could be necessary to conclude that both facilitation and IOR effects are explained either by the same mechanism or by different mechanisms.

In sum, in light of the previous work, a large body of ERPs investigation on the effects of exogenous spatial attention assume that both the facilitatory and IOR effects are at least partially due to changes in perceptual quality, with improved perception for cued as compared to uncued trials at short delays (i.e., at which the facilitatory effect is observed), and impaired perception for cued as compared to uncued trials at long delays (i.e. when the IOR effect is observed) (Luck & Thomas, 1999). Nevertheless, as we have been emphasizing throughout the Introduction, no consensus has yet been reached regarding the stages of information processing at which the intervening event could operate on the attentional cueing effect, and importantly, none of the previous studies have used a paradigm in which both significant facilitatory and IOR effects are observed, in order to directly compare the electrophysiological modulations produced at early and late stages of processing.

Aims of the present work

In the present study, we attempted to further investigate the possible relationship between behavioural cueing effects generated by the presence/absence of an intervening event, and ERP components, using a similar paradigm to the one previously used by Prime and Jolicoeur (2009), but in which the presence/absence of an intervening event produces significant and opposite effects on RTs: a facilitatory effect in the absence of an intervening event, and IOR when the intervening event is presented. Concretely, as in Prime and Jolicoeur's (2009) study, we used a cue-target discrimination task in which the intervening event was manipulated between groups of participants. However, in our paradigm (see also Experiment 2; Martín-Arévalo et al., 2013), the automatic effect produced by peripheral cues was highly modulated by the intervening event, leading to a significant facilitatory effect in the absence of an intervening event, and a significant IOR effect when the intervening event was presented (see Procedure section for details). Therefore, using this paradigm while recording ERP components could be very useful for determining the stage or stages of processing influenced by the intervening event manipulation.

If both facilitation and IOR effects are explained by the same mechanism, then we would expect a direct relationship between early occipital ERP components and the behavioural effect measured, i.e., an enhanced P100 amplitude for cued as compared to uncued trials when no intervening event is presented and facilitation is behaviourally observed, and a reduced P100 amplitude for cued as compared to uncued trials when the intervening event is presented and behavioural IOR is observed. However, if several mechanisms do in fact underlie spatial cueing effects (Lupiáñez, 2010; Lupiáñez et al., 2013), only some of them being affected by the presence of the intervening event, some ERP components might be independent of the intervening event modulation, whereas other components might be modulated by its presence/absence. Thus, if, as observed elsewhere (Wascher & Tipper, 2004; Chica & Lupiánez, 2009; Satel, Wang, Hilchey, & Klein, 2012), peripheral cues impaired perceptual processing at long enough SOAs, independently of the behavioural result that is measured, then the P100 component should always be reduced for cued as compared to uncued trials, independently of whether facilitation or IOR is behaviourally observed. We consider this P100 reduction by cueing is be related to the *detection cost* suggested by Lupiáñez, 2010, generated by the very appearance of the cue at the cued location. Other later-stage ERP components should be differentially modulated in relation to the behavioural effect that is measured (facilitation or IOR). The modulation of cueing over these other ERP components might be related to the presence/absence of the *spatial selection benefit*, respectively; Lupiáñez, 2010.

Finally, most of the previous studies reported measures of brain activity related to target processing, while ERPs associated to cue processing were not considered. Only a few studies have recently considered cue-related activations during the time interval between cue and target onset (see Tian, Klein, Satel, Xu, & Yao, 2011; Chica, Lasaponara, Lupiáñez, Doricchi, & Bartolomeo, 2010; Chica, Botta, Lupiáñez, & Bartolomeo, 2012). Thus, in order to address the electrophysiological correlates of attentional orienting when the intervening event was present or absent, ERPs locked to the appearance of the cue were also explored.

Methods

Participants

A total of forty-eight healthy volunteers participated in this experiment. Sixteen participants (one right-handed, 12 women, mean age of 24 years, SD=5.34) participated in a behavioural session. Thirty-two further participants (all right-handed, 28 women, mean age of 20 years, SD=1.96) participated in the electroencephalographic (EEG) study. Data from one participant from the behavioural experiment were excluded from the analyses due to a high error rate (over 40%), and data from one participant from the EEG experiment were also excluded from the analyses due to a technical error. All participants were naïve students from the University of Granada, who participated in the experiment for course credits. They reported having normal or corrected to normal vision. The experiment was conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada, in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Apparatus and Stimuli

The experiment was run on a computer with a 1GHz Pentium III processor, connected to a 15-inch colour VGA monitor. E-primer software (Schneider, 1998) controlled the presentation of stimuli and the acquisition of data throughout the experiment. Two placeholder boxes were presented, one on each side of the fixation point. Each box was 20 mm in width by 20 mm in height (subtending 2.0 and 2.0 degrees of visual angle at a viewing distance of 57 cm, at which 1 cm corresponds to 1 degree of visual angle). The boxes were positioned 25 mm away from central fixation along the horizontal plane, as measured from the centre of the bottom edges of each placeholder to the centre of the screen (fixation point), and positioned 10 mm above the central fixation along the vertical plane, as measured from the centre of the inner lateral edges of each placeholder to the centre of the screen. Peripheral cues were created by thickening the outline of one of two placeholder boxes. The intervening event was created by presenting a smaller box around the fixation point (10 mm in width by 10 mm in height). The target was either the letter “X” or “O” (2 mm).

Procedure

The stimuli used, and the sequence of events in each trial, are illustrated in Figure 1. Each trial began with the presentation of the fixation display (containing the fixation point, and the two boxes), with a duration varying randomly between 1000 and 1500 ms. Participants were required to keep their eyes on the fixation point throughout the experiment. The peripheral cue was presented in one of the two possible locations with equal probability for 50 ms. After the peripheral cue had disappeared, the fixation display was presented again for a duration varying randomly between 200 and 300 ms. Next, the intervening event was presented for 50 ms. In the group with intervening event absent, the fixation display was maintained on the screen for these 50 ms, keeping a constant SOA for both groups. Another fixation display, of random variable duration (200-300 ms), was then presented[9]. The target was displayed for 1200 ms in one of the two peripheral boxes with equal probability. Participants were instructed to discriminate the identity of the letter by pressing one key (“Z” or “M”) for each letter; the letter-key assignment was counterbalanced across participants. On 15% of the trials (catch trials) no target was presented, and no response was required. The inter-trial interval, in which the screen remained black, was 2000 ms in duration. An auditory feedback was presented for wrong, missing, or premature responses (shorter than 200 ms).

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[9] Note that cueing effects usually shift from facilitation (observed at short SOAs) to IOR (observed longer SOAs). The temporal transition between facilitation and IOR depends mainly on task-set: IOR is observed at longer SOAs in discrimination tasks than in detection tasks (Lupiáñez et al., 1997). Based on previous results (Martín-Arévalo et al., submitted), we choose a SOA at which both facilitation and IOR could be observed, in order to investigate how the intervening event can modulate these effects.

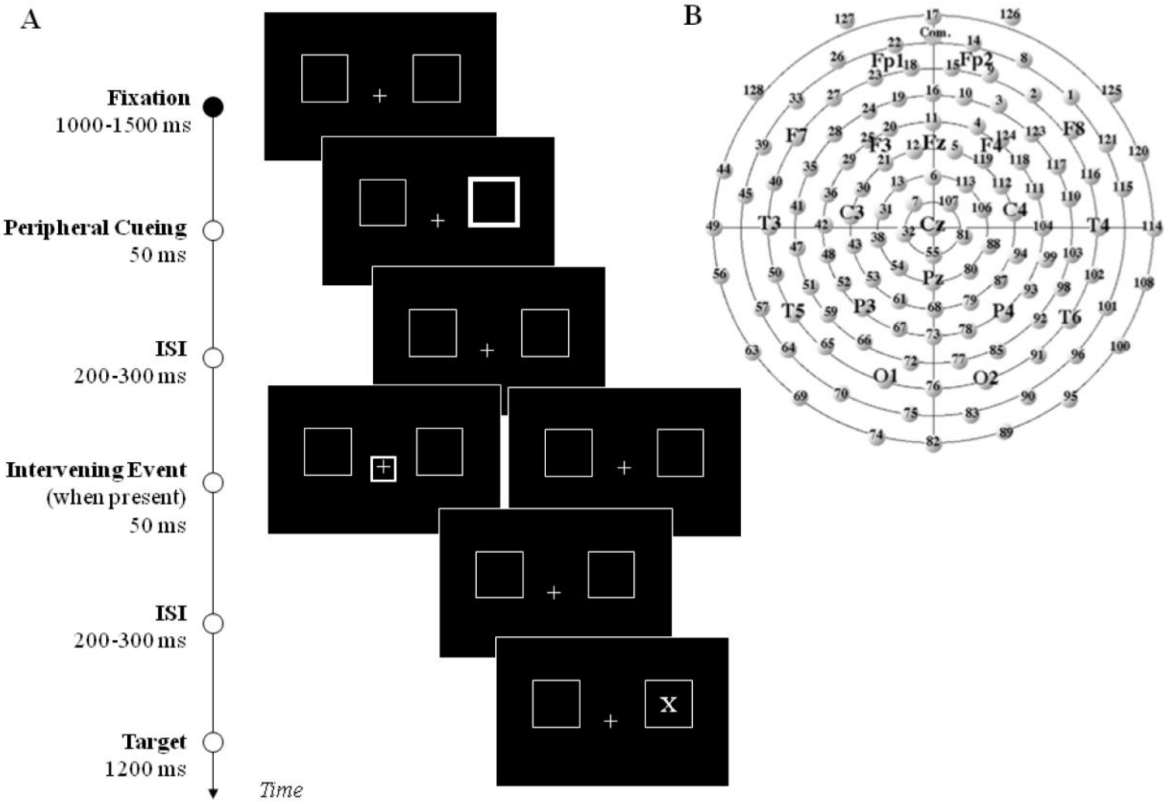

Figure 1. A) Sequence of events in a given trial. B) Sketch of the electrodes distribution around the scalp as viewed from above (the top of the figure represents the frontal area). Additional sites according to the 10–20 International system are shown for further reference.

Design

The experiment consisted of a three-factor design. Peripheral cueing was manipulated within participants, while Intervening event was manipulated between participants. Peripheral cueing had two levels: cued and uncued location trials; Intervening event had also two levels: intervening event absent and present. Experiment (behavioural and EEG experiment) was included in the analysis as a between participants factor. The experiment consisted of 20 practice trials, which were not further analyzed, followed by 392 experimental trials (7 blocks of 56 trials each; 24 cued location, 24 uncued location trials, and 8 catch trials).

EEG experiment: 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 offline. The EEG was amplified with a band pass of .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. For the cue analysis, epochs were segmented from 200 ms before cue appearance to 300 ms after the cue presentation. For the target analysis, epochs were segmented from 200 ms before target appearance to 700 ms after its presentation. All trials containing eye movements, blinks, or artefacts, as well as trials with anticipatory responses were rejected. An average of 15.35% and 12.75 % of the trials were excluded in the cue and target analysis, respectively. A 200 ms segment previous to the cue or the target presentation was used to calculate the baseline. A minimum of 40 trials per condition was required to ensure a sufficient signal-to-noise ratio.

Results

Behavioural results

Participants missed the target (i.e., no response was made) on 1.66% of the trials in the behavioural experiment, and 0.94% for the trials in the EEG experiment, which were no further analyzed. Incorrect responses (3.28% and 3.42% for the behavioural and EEG experiment, respectively) were also excluded from the RT analysis. Neither false alarms (i.e., responses to catch trials) nor anticipations (responses faster than 200 ms) were observed in both experiments. Mean correct RT data were submitted to a mixed analysis of variance (ANOVA) with the following factors: 2 (Experiment: behavioural and EEG) x 2 (Peripheral cueing: cued vs. uncued) x 2 (Intervening event: absent vs. present). Table 1 shows the mean RTs and percentage of errors for each experimental condition. The analysis demonstrated that neither the main effects of Experiment, F(1, 42)=1.93, MSE=16572, p=.1717, η2=.04, nor the main effect of Intervening event, F(1, 42)=1.40, MSE=16572, p=.2418, η2=.03, or the main effect of Peripheral cueing, F<1, were significant. Experiment did not interact with any other factor (F(1, 42)=1.81, MSE=16572, p=.1854, η2=.04, for the interaction between Experiment and Intervening event, and F<1 for the interaction between Experiment and Peripheral cueing,). Peripheral cueing interacted with the Intervening event factor, F(1, 42)=14.83, MSE=157, p=.0003, η2=.26, showing a significant facilitatory effect (mean RT for cued minus uncued trials = 11 ms) when the intervening event was absent (planned comparison, p=.0066), and a significant IOR effect (-10 ms) when the intervening event was presented (planned comparison, p=.0131). The three-way interaction was not significant, F(1, 42)=1.15, MSE=157, p=.2887, η2=.02.

The percentage of error analysis showed that none of the main effects or interactions were significant, all ps>.11. Only the interaction between Peripheral cueing x Intervening event was marginally significant, F(1, 42)=3.98, MSE=8.2321, p=.0523, η2=.08, mirroring the interaction observed in RT.

Table 1- Mean RTs (in ms) for each condition of Peripheral cueing, Intervening event, and Experiment.Mean percentage of errors are presented in squared brackets.

		Cueing		Cueing Effect (Uncued - Cued)
	Intervening Event	Cued	Uncued	
Behavioral experiment	Absent	605 [3.14.%]	620 [3.40%]	15
	Present	546 [3.19%]	534 [3.19%]	-12
EEG experiment	Absent	530 [2.26%]	538 [2.86%]	8
	Present	543 [5.11%]	534 [3.41%]	-9

ERP results

Event-related potentials (ERPs) locked to the appearance of the cue and target were analyzed. Visual inspection[10] of cue-related ERPs revealed the appearance of a single component during the cue period; this component was a P100, peaking at ~170 ms, and observed in lateral occipital electrodes, ipsilateral to the cue side. Visual inspection of target-related ERPs revealed five main components during the target period. The first component was the P100, peaking at ~160 ms, and observed in lateral occipital electrodes, ipsilateral to the target side. This component was followed by a lateral occipital negativity (N100), peaking at ~200 ms in lateral occipital electrodes, contralateral to the target side. The N2pc was computed by subtracting the amplitude of the wave in the lateral occipital electrodes, peaking at ~220 ms, of contralateral minus ipsilateral electrodes. Around ~220-280 ms, the wave was more negative for cued as compared to uncued targets

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[10] The visual inspection was based on the grand average waveforms and topographic maps, according to previous literature.

(Negative difference, Nd) at midline electrodes, followed by the P300 component, peaking at ~390 ms at central and lateral occipital electrodes.

For cue-locked analyses, we calculated the mean amplitude of the P100 component (time window from 100 to 200 ms after cue onset), for each participant in a sample of representative electrodes covering the scalp (PO7/PO8, P3/P4, T5/T6, Pz/Cz, electrodes 12/5 representing Fz, F7/F8, Fp1/Fp2; see Fig. 1B; see Chica et al. 2012, for a similar analysis). For target-locked analyses, we calculated the mean amplitude of the P100 component (time window from 100 to 200 ms after target onset), N100 (time window from 150 to 250 ms), N2pc (time window from 150 to 250 ms), Nd (time window from 220 to 280 ms), and P300 (time window from 370 to 410 ms), for each participant in the same sample of representative electrodes covering the scalp. In order to determine the scalp location where each component was maximally elicited, we performed a one-way ANOVA for each component, with Electrode as a factor. For the cue-locked components, the main effect of Electrode was significant for the P100 component (p=.0015), showing that the component was largest at PO7/PO8 electrodes (M=0.29µ), followed by P3/P4 electrodes (M=0.12µ). These two amplitudes were statistically different (planned comparison, p=0.0247). For the target-locked components, the main effect of Electrode was also significant (all ps<.05). Consistent with previous results (see e.g., Prime & Ward, 2006; Chica & Lupiáñez, 2009), the largest mean amplitude of the P100 component was observed at PO7/PO8 electrodes (M=1.51µ), followed by P3/P4 electrodes (M=1.42µ). These two amplitudes were not statistically different (planned comparison, p=0.3217). The largest mean amplitude of the N100 component was observed at Fp1/Fp2 electrodes[11] (M=−1.26µ), followed by PO7/PO8 electrodes (M=−1.15µ). Although these two amplitudes did not statistically differ (planned comparison, p=0.7702), we choose PO7/PO8 electrodes for the analyses because, as noted elsewhere (see e.g. Mangun & Hillyard, 1991), the N100 deflection may be detected at most recording sites, but the visual N100 is widely distributed over the posterior regions of the scalp (i.e., over visual cortical areas) (see e.g., Primer & Jolicoeur, 2009; Eimer, 1994). The largest mean amplitude of the Nd component was observed in the Cz electrode (M=1.87µ), followed by Fz electrodes (M=1.83µ), consistent with previous results (see e.g., Eimer, 1994). These two amplitudes did not statistically differ

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[11] We can rule out that eye movements or blinks might have generated these amplitudes because we carefully checked that all trials containing this kinds of artifacts were rejected (for more details, see section *EEG experiment: Recording and analysis*).

(planned comparison, p= 0.8348). Finally, the largest mean amplitude of the P300 component was observed in the Pz electrode (M=3.68μ), followed by P3/P4 electrodes (M=3.66μ). These two amplitudes did not statistically differ (planned comparison, p=0.9553).

We subsequently analyzed the modulation of each component (i.e, cue- and target-locked) when the intervening event was present or absent by calculating its adaptive mean amplitude (20 ms before and after the higher peak) at those electrodes where the components were maximally elicited based on the previous analyses (PO7/PO8 for the cue-locked P100 component, PO7/PO8 and P3/P4 electrodes for the target-locked P100 component, PO7/PO8 electrodes for the target-locked N100 component, PO7/PO8 electrodes for the target-locked N2pc component, Cz and Pz electrodes for the target-locked Nd component, and Pz and P3/P4 electrodes for the target-locked P300 component). Moreover, the latency associated to the maximum peak was analyzed for each component within the same temporal window and electrodes sites as those used for the mean amplitude analysis.

Cue-locked P100 component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the cue-locked P100 component, considering Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes to the presentation of the cue) as factors. Note that Peripheral cueing was not introduced as a factor in this analysis because trials cannot be considered as cued or uncued until the target is presented.

The mean amplitude analysis demonstrated a significant main effect of Laterality, F(1, 29)=6.89, MSE=1.1562, p=.0136, η2=.19, showing that the P100 component was maximally elicited at ipsilateral electrodes to the cue as compared to contralateral electrodes. Neither the main effect of Intervening event, F(1, 29)=2.22, MSE=1.5203, p=.1468, η2=.07, nor the interaction between Laterality and Intervening event were significant, F<1.

The mean latency analysis demonstrated a significant main effect of Laterality, F(1, 29)=7.91, MSE=117, p=.0087, η2=.21, showing an earlier peak of the component at contralateral (M=153 ms) as compared to ipsilateral electrodes to the cue location (M=161 ms). The main effect of Intervening event was significant, F(1, 29)=8.31, MSE=518, p=.0073, η2=.22, showing that the P100 component peaked earlier when the intervening event was presented (M=149 ms) than when it was absent (M=165 ms). This effect was independent of Laterality (F<1, for the interaction between Intervening event and Laterality) (see Figure 2).

These results therefore suggest that the processing of the peripheral cue is modulated by the presentation of an intervening event (at least when it is manipulated between groups of participants, as it was the case in the current study). Peripheral cue processing is accelerated, with P100 peaking earlier when the intervening event is presented than when it was absent. The implications of this result are discussed in the General Discussion.

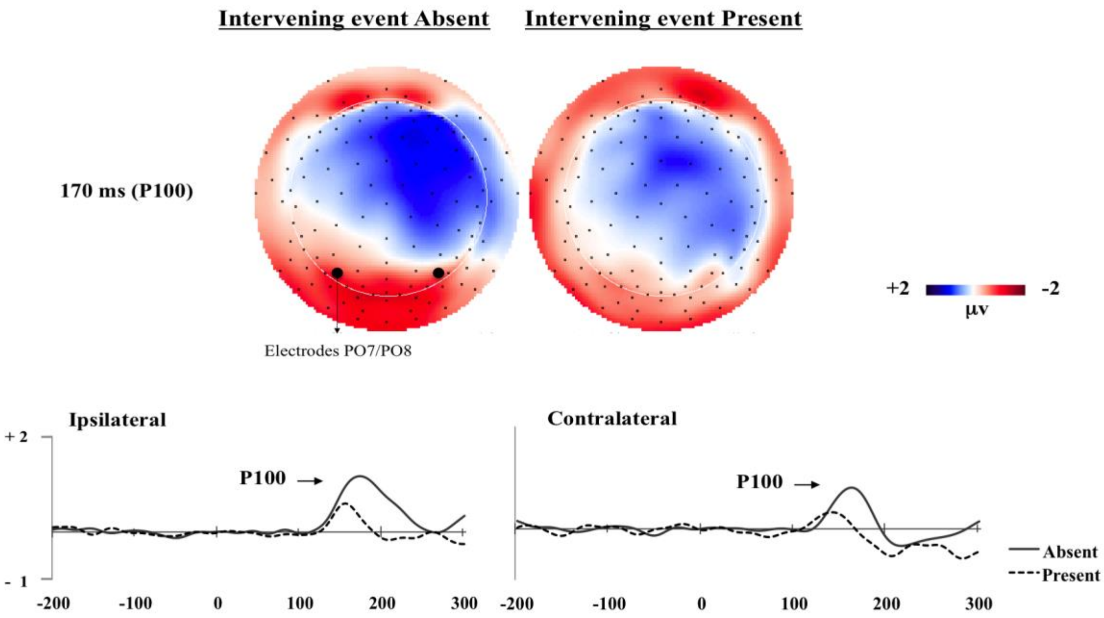

Figure 2. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the cue-locked P100 component (170 ms). Topographic maps are shown for each condition of Intervening event (left cues are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral sides, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean cue-locked ERPs waveforms for the P100 analysis for each condition of Intervening event.

Target-locked components

P100 component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the P100 component, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes[12] to the presentation of the target) as factors. The analysis of the amplitude demonstrated that the P100 component was maximally elicited at ipsilateral electrodes to the target, F(1, 29)=38.01, MSE=0.5271, p<.0001, η2=.56, but laterality did not interact neither with Intervening event nor with Peripheral Cueing, F<1 (see Figure 3). The main effect of the Peripheral cueing was also significant, F(1, 29)=4.88, MSE=0.2912, p=.0351, η2=.14, showing a reduced P100 amplitude when the target appeared in a position previously occupied by the cue (cued position) than at an uncued position. Importantly, as can be observed in Figure 3, this reduced P100 amplitude for cued as compared to uncued trials was similarly observed when the intervening event was present or absent (F<1, for the interaction between Peripheral cueing and Intervening event), no matter whether the behavioural effect measured was either facilitation or IOR. No significant main effect of Intervening event was found, F(1, 29)=3.33, MSE=2.4458, p=.0782, η2=.10. None of the other interactions reached significance, F<1.

The analysis of the mean latency demonstrated a significant main effect of Laterality, F(1, 29)=41.75, MSE=25, p<.0001, η2=.59, showing an earlier peak at contralateral (M=143 ms) than ipsilateral electrodes to the target location (M=148 ms). None of the other main effects or interactions were significant, all ps>.2571.

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[12] Data from PO7/PO8 and P3/04 were collapsed since the first analysis did not show differences between both electrodes groups.

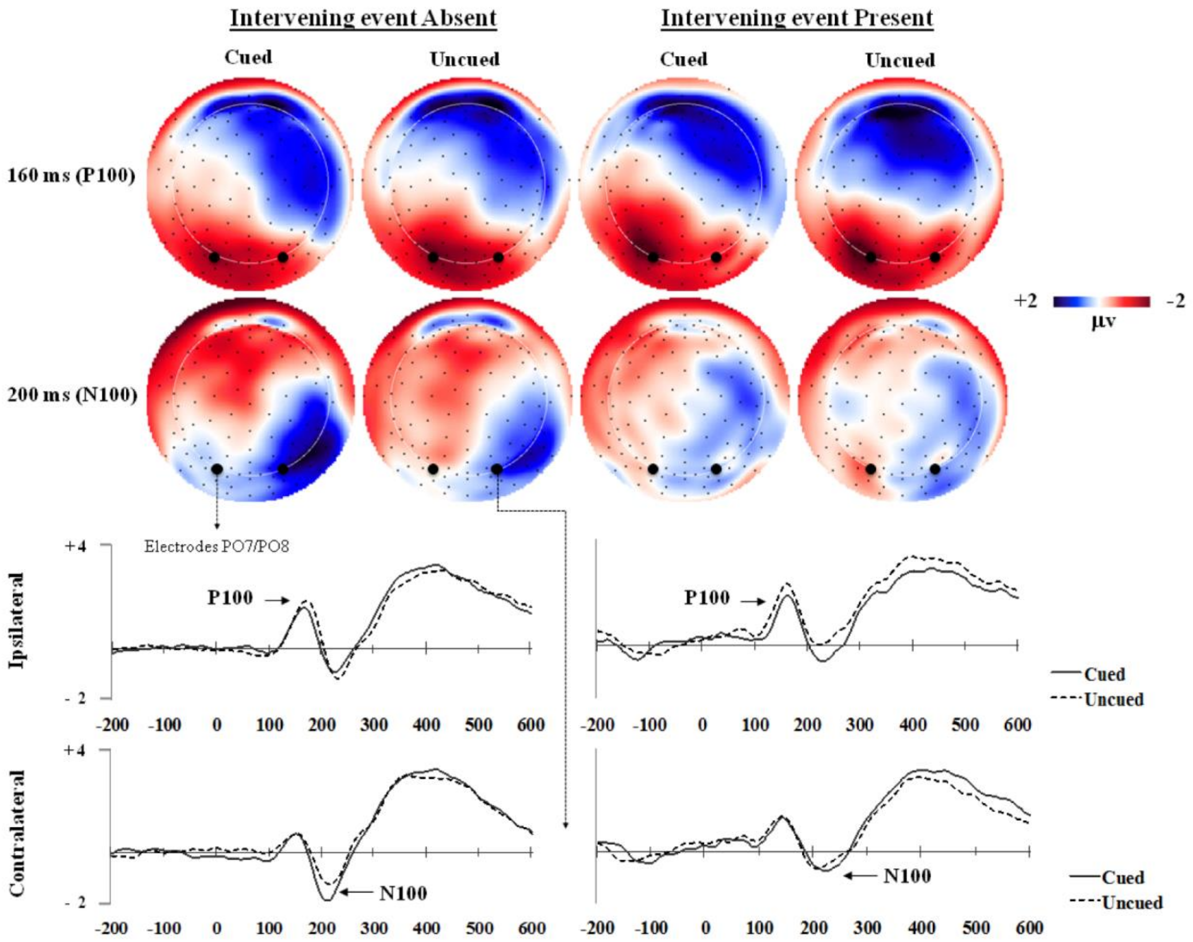

Figure 3. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the target-locked P100 (160 ms) and N100 (200 ms) components. Topographic maps are shown for each condition of Peripheral cueing and Intervening event (left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral sides, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean target-locked ERPs waveforms for the P100 and N100 analysis for each condition of Peripheral cueing and Intervening event.

N2pc component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the N2pc component, considering Peripheral cueing (cued vs. uncued conditions), and Intervening event (absent vs. present) as factors. Note that to compute the N2pc component, ipsilateral waveforms were subtracted from contralateral waveforms. The analysis of the mean amplitude demonstrated that neither the main effect of Peripheral cueing nor the main effect of Intervening event reached significance, both Fs<1. The interaction between Peripheral cueing and Intervening event was significant, F(1, 29)=8.83, MSE=0.5000, p=.0059, η2=.2334. As it can be observed in the Figure 4 this interaction reveals an enhancement in the amplitude of the N2pc component for targets appearing at cued as compared to uncued locations (planned comparison, p=.0378) when the intervening event was absent (and a significant facilitatory effect was found on RTs), while the amplitude of the N2pc component was reduced for cued as compared to uncued trials (planned comparison, p=0.0517) when the intervening event was presented (and a significant IOR effect was measured on RTs).

The analysis of the mean latency demonstrated that neither the main effects nor the interaction were significant, all ps>.2450.

N100 component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the N100 component, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes to the presentation of the target) as factors. The analysis of the mean amplitude demonstrated that the N100 component was maximally elicited at contralateral electrodes to the target location, F(1, 29)=14.06, MSE=0.5117, p=.0007, η2=.32, (see Figure 4). Neither the main effect of Peripheral cueing, F(1, 29)=3.77, MSE=0.3125, p=.0617, η2=.11, nor the main effect of the Intervening event, F(1, 29)=1.92, MSE=6.9184, p=.1763, η2=.06, were significant. The interaction between Peripheral cueing, Laterality, and Intervening event reached significance, F(1, 29)=8.82, MSE=0.2503, p<.0001, η2=.2334. As shown in Figure 3, no modulation of the N100 component was observed (planned comparison, p=0.7575) at electrodes contralateral to the target location, where the N100 component was maximally elicited, when the intervening event was presented (and a significant IOR effect was measured on RTs), while the amplitude of the N100 component was enhanced for cued as compared to uncued trials (planned comparison, p=0.0103) when the intervening event was absent (and a significant facilitatory effect was measured on RTs). None of the other interactions reached significance, F<1.

The analysis of the mean latency demonstrated a marginally significant main effect of Peripheral cueing, F(1, 29)=3.69, MSE=249, p=.0644, η2=.11, showing an earlier peak at cued trials (M=175 ms) as compared to uncued trials (M=180 ms). None of the other main effects or interactions reached significance, all ps>.1044.

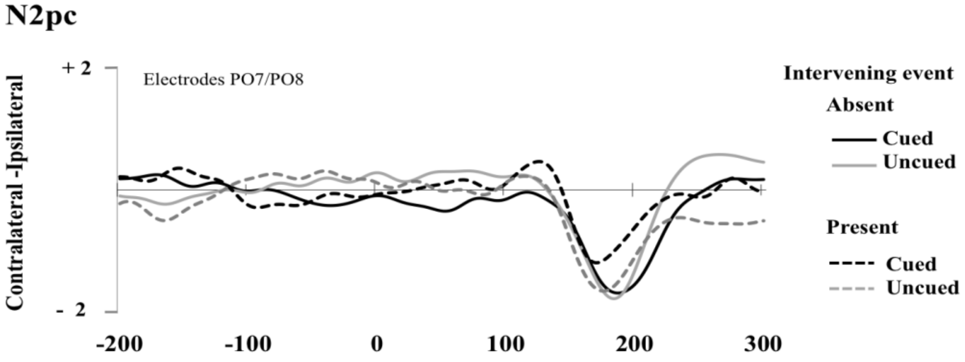

Figure 4. Mean target-locked ERPs waveforms for the N2pc analysis for each condition of Peripheral cueing and Intervening event.

Nd component

Separate mixed-design ANOVAs[13] on the mean amplitude and latency of this component were performed, with Peripheral cueing and Intervening event as factors. The analysis of the mean amplitude showed that the main effect of Intervening event was not significant, F<1. The main effect of Peripheral cueing was marginally significant, F(1, 29)=3.67, MSE=0.1599, p=.0651, η2=.11, and significantly interacted with the Intervening event factor, F(1, 29)=5.81, MSE=0.1599, p=.0224, η2=.16 (see Figure 5). This interaction reveals an enhancement in the amplitude of the Nd component for cued trials as compared to uncued trials, but only when the intervening event was absent (planned comparison, p=.0041). When the intervening event was presented, similar amplitudes were observed for cued and uncued trials (planned comparison, p=.7335).

The analysis of the mean latency demonstrated that the main effect of Peripheral cueing was significant, F(1, 29)=5.60, MSE=51, p=.0247, η2=.16, showing an earlier peak for cued trials (M=252 ms) as compared to uncued trials (M=257 ms). Neither the main effect of Intervening event nor the interaction between Intervening event and Peripheral cueing were significant, F(1, 29)=2.15, MSE=732, p=.1525, η2=.06, and F<1, respectively.

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[13] Note that the data from Cz and Fz were collapsed because the first analysis did not show differences between both electrodes, F<1. Moreover, we did not include Laterality as factor because the largest mean amplitude of the Nd component was observed at central electrodes (i.e., Cz and Fz electrodes).

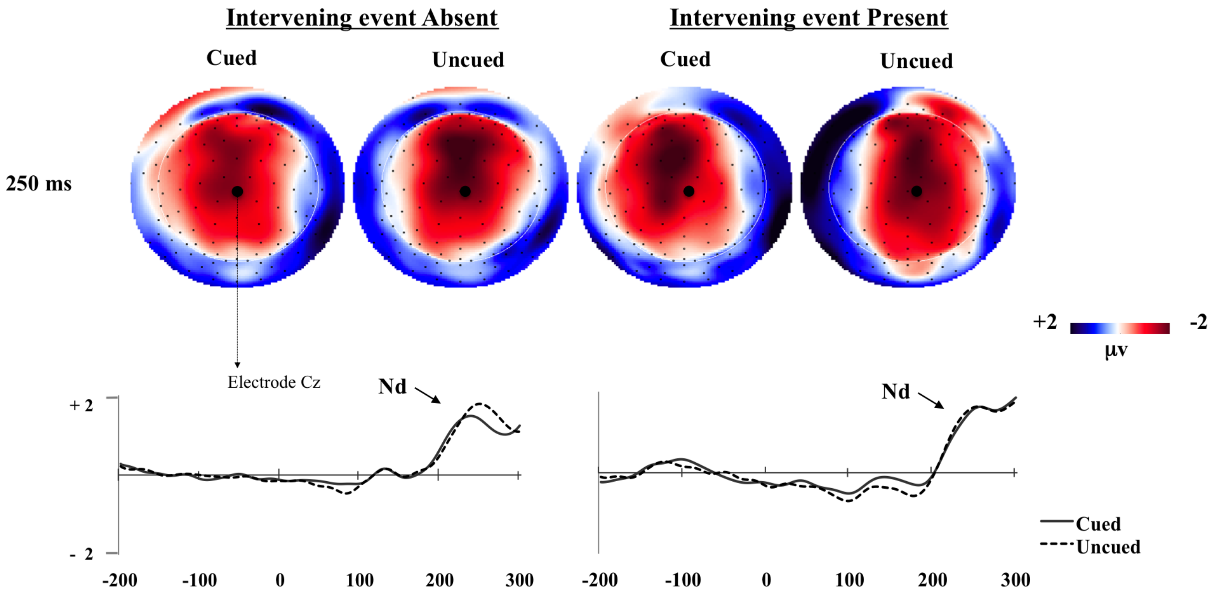

Figure 5. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the target-locked Nd (250 ms) component. Topographic maps are shown for each condition of Peripheral cueing and Intervening event (left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral sides, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean target-locked ERPs waveforms for the Nd analysis for each condition of Peripheral cueing and Intervening event.

P300 component

Finally, we analyzed the P300 component, by performing a similar mixed-design ANOVAs on the mean amplitude and latency of this component, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral, contralateral or central electrodes) as factors. The analysis of the mean amplitude demonstrated that neither the main effect of Laterality nor the main effect of Intervening event reached significance, both Fs<1. The main effect of the Peripheral cueing was significant, F(1, 29)=6.73, MSE=0.310, p=.0147, η2=.18, showing that the amplitude of the P300 component was enhanced for cued as compared to uncued conditions. As it can be observed in Figure 6, the interaction between the Peripheral cueing and Intervening event was significant, F(1, 29)=4.53, MSE=0.310, p=.0419, η2=.13, revealing an enhanced amplitude of the P300 component for targets appearing at cued as compared to uncued locations (planned comparison, p=.0020) when the intervening event was absent (and a significant facilitatory effect was measured on RTs). No differences between cued and uncued trials were observed (planned comparison, p=.7480) when the intervening event was presented (and a significant IOR effect was measured on RTs). None of the other interactions were significant, all ps>.2114.

The analysis of the mean latency demonstrated that none of the main effects or interactions were significant, all ps>.1364.

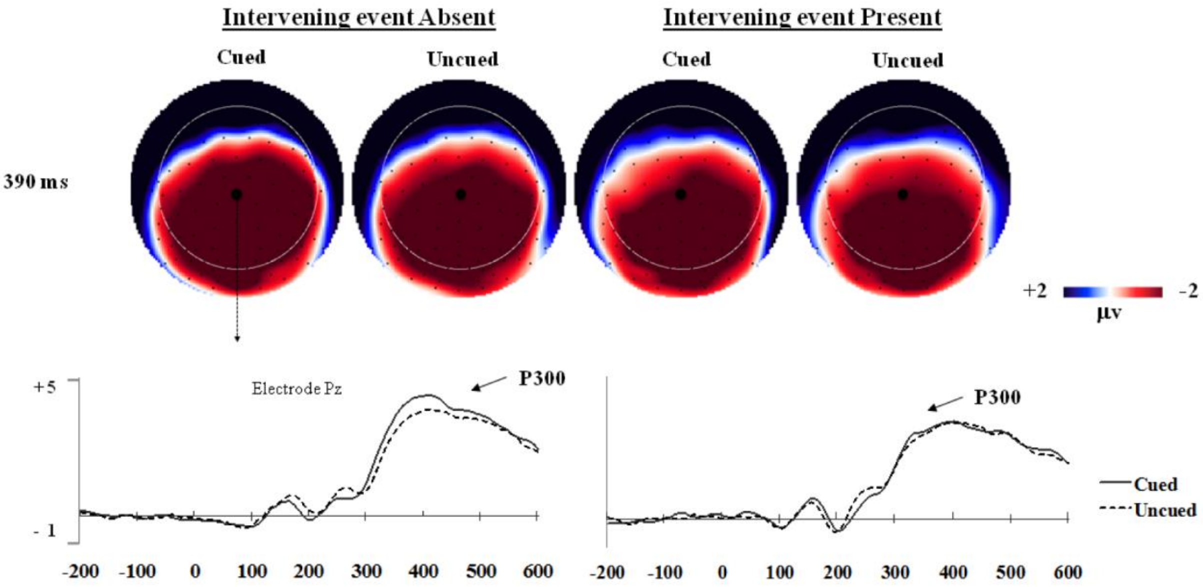

Figure 6. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the P300 (390 ms) component. Topographic maps are shown for each condition of Peripheral cueing and Intervening event (left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral sides, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean target-locked ERPs waveforms for the P300 analysis for each condition of Peripheral cueing and Intervening event.

General Discussion

The present study aimed at investigating the electrophysiological modulations of behavioural exogenous cueing effects (i.e., IOR and facilitation), in order to explore the stages of information processing at which both effects operate. Considerable ERPs research has provided evidence supporting that both facilitation and IOR effects arise, at least in part, from changes in visual processing in posterior visual areas. Concretely, facilitatory effects have been associated to an enhanced P100 amplitude for cued as compared to uncued locations (see e.g., Luck, 1995; Hopfinger & Mangun, 1998), while IOR has been associated to a reduced P100 amplitude for cued as compared to uncued locations (Eimer, 1994; Hopfinger & Mangun, 1998; Doallo et al., 2004; Wascher & Tipper, 2004; Tian & Yao, 2008; Prime & Jolicoeur, 2009; Satel et al., 2012). Nevertheless, finding P100 modulations that coincide with the behavioural effects observed when using spatially non-informative peripheral cues, is not as common as one might think, especially in the case of the facilitatory effect. There are not too many examples in which significant facilitatory effects are related to enhanced amplitude of the P100 component for cued as compared to uncued trials. Hopfinger and Mangum (1998) reported this result, but only at SOAs shorter than 234 ms; for longer SOAs, the P100 modulation was still observed, but associated to a non-significant behavioural effect (see Hopfinger et al, 2000, for similar results). Therefore, the P100 modulation associated to significant facilitatory effects is usually related to short SOAs (although see Prime & Jolicoeur, 2009; and Van der Lubbe, Vogel, & Postma, 2005; for two examples of P100 modulation and facilitation at SOAs longer than 500 ms[14]). After a long enough SOA, either no modulations of the P100 amplitude are observed, or P100 is reduced for cued as compared to uncued locations (see Chica & Lupiáñez, 2009; Eimer 1994; Hillyard et al, 1994; Hopfinger & Mangum, 1998, Hopfinger et al, 2000).

A similar result is usually observed when IOR is behaviourally measured. Hopfinger and Mangun (2001) reported a significant IOR effect but not significant P100 amplitude modulations, and a significant P100 reduction for cued as compared to uncued trials but not significant IOR effect (see also Eimer, 1994). This might suggest that the IOR effect is also dissociable from the P100 modulation (see also Tian, et al., 2011). Importantly, significant behavioural facilitatory effects have been observed, associated to a reduced amplitude of the P100 component for cued as compared to uncued trials (Chica & Lupiáñez, 2009; Wascher & Tipper, 2004).

In the present study, the target-locked P100 component was reduced for cued as compared to uncued trials, independently on the presence/absence of an intervening event, and therefore, when

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[14] Note that differences in the experimental paradigms might be crucialto understand these results. For example, in Prime and Jolicoeur (2009), the cue was presented 200 ms whereas in most ERPs studies cue duration is shorter than 50 ms(see e.g., Chica & Lupiáñez, 2009; Hopfinger & Mangum, 1998; McDonald et al., 1999). Indeed, some studies have provided evidence that long cue durations could be crucial for observing behavioural facilitation (see e.g., Berger, Dori & Henik, 1999; Collie et al., 2000). Thus, although this facilitation may not have been reflected in behaviour in Prime and Jolicoeur’s (2009) study due to the long SOA, it could have been in the electrophysiological activity of early visual regions.

either significant facilitation or IOR were behaviourally observed. This result is therefore consistent with previous literature demonstrating that the P100 modulation is not a direct correlate of the behavioural effects evoked by spatially non-informative cues. We therefore reckon that in light with the present results, and the above-reviewed studies, it can been concluded that perceptual processing is impaired or target saliency is reduced, for cued as compared to uncued targets (as reflected by the P100 modulations) any time a peripheral cue is presented and a long enough SOA is provided, no matter the behavioural result that is observed.

Differential modulations for behavioural facilitation vs. IOR were observed in later components, namely the N100, N2pc, Nd, and P300. The amplitude of the N100 component was enhanced for cued trials as compared to uncued trials when the intervening event was absent and a significant behavioural facilitatory effect was observed. Moreover, no modulation of the N100 component was found in the intervening event present condition, in which a significant IOR effect was observed (see Hopfinger & Magnum, 2001; Wascher & Tipper, 2004; McDonald et al., 1999; for similar results). This result is consistent with studies proposing that N100 modulations are related to a benefit for correctly allocating attentional resources, facilitating further perceptual processing of stimuli, which is therefore associated to behavioural facilitatory effects (Luck, Hillyard, Mouloua, Woldorff, Clark, & Hawkins, 1994; Luck, et al., 2000; Vogel & Luck, 2000[15]). The Nd component (Eimer, 1994; McDonald et al., 1999) has been interpreted in terms of selection or enhanced sensory processing of attended locations, thus indicating an enhanced processing of attended stimuli (Eimer, 1993; 1994). In the present study, cued targets elicited an enhanced Nd component as compared to uncued targets in the intervening event absent condition, while no modulations of the Nd component were observed when the intervening event was presented (see also Wascher & Tipper, 2004). A similar result was observed for the P300 component; it was only modulated in the intervening event absent condition, while no modulations of the P300 component were observed when the intervening event was presented. The P300 component is thought to reflect processes involved in stimulus evaluation. Indeed, P300 is usually considered as an index of the neural processing associated with task-relevant information (Luck et al., 1994; Polich, Ellerson, & Cohen, 1996; Polich, 2007). The absence of modulations of the P300 amplitude when

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[15] These authors assume that the N100 component reflects a discrimination mechanism that enhances the processing of attended spatial locations.

IOR was observed is coherent with previous studies (see e.g., Prime & Ward, 2004; McDonald et al., 1999; Prime & Jolicoeur, 2009).

The only ERP component reflecting opposite and significant modulations associated to the behavioural effect (facilitation and IOR depending on the absence/presence of the intervening event) was the N2pc. This component has been related to the attentional selection when processing visual stimuli (McDonald et al., 2009; Yang et al., 2012). In the current study, the amplitude of the N2pc component was enhanced for cued trials as compared to uncued trials when the intervening event was absent and a significant behavioural facilitatory effect was observed, while it was reduced for cued trials as compared to uncued trials when the intervening event was presented and a significant behavioural IOR effect was observed. On the basis of this component, our results suggest that more attentional resources (i.e., more attentional selection) were deployed to targets at cued trials as compared to uncued trials when behavioural facilitation was observed; but attentional selection was hindered when targets appeared at a recently cued location when the IOR effect was measured (or otherwise, more attentional selection was deployed to targets at uncued locations when the IOR effect was observed) (see also McDonald et al., 2009).

To summarise, the ERPs components measured in the present experiment might be separated into different subgroups, namely, the modulation of early perceptual or sensory correlates (i.e., P100 and N100[16] components) of attentional information processing (see also Eimer, 1994; Luck, 1995), the modulation related to attentional selection associated to the N2pc (Luck, 2005), and other post-perceptual correlates (i.e., Nd and P300 components) of resource allocation (Eimer, 1999). The present results demonstrate that changes in the amplitude of early occipital ERP components associated to facilitation and IOR do not support hypotheses proposing that both facilitation and IOR can be explained by the same mechanism, namely, the orienting of attention (see e.g., Prime & Ward, 2004; Prime & Jolicoeur, 2009). Instead, perceptual processing is impaired for cued as compared to uncued trials when a long enough cue–target SOA is used (i.e., ~500 ms), and independently on whether the behavioural effect measured is either facilitation or IOR (see Chica and Lupiáñez, 2009; Hillyard et al., 1994, for similar results). This might indicate a cost in detecting new attention-capturing information (i.e., the target) at a previously cued

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[16] Although the visual N100 is an early perceptual component, it also reflects a benefit for correctly allocating attentional resources (Vogel & Luck, 2000).

location, reducing saliency of subsequent targets presented at this spatial location (as a consequence of the target being less new at the cued location; see e.g., Lupiáñez, 2010).

This observation is consistent with what has been assumed by other researchers. For example, McDonald and colleagues (McDonald et al., 1999) suggested that the P100 reduction for cued as compared to uncued locations might reflect sensory refractoriness, understood as a reduction of ERP components that occur when the component's generator is in a refractory state (see Eimer, 1994, for similar conclusions). These authors argued that peripheral cues sometimes appear to reduce the amplitude of the P100 component and some other times appear to lead to a cued-uncued difference that lasts longer than the P100 component, depending on the strength of cue–target sensory interactions. Importantly, this result is also consistent with the original approach assumed by Posner and Cohen (1984). They proposed that the inhibition "does not arise from attentional orienting but from the energy change present at the cued position", and therefore that "the origin of this spatially selective inhibitory effect is sensory rather than attentional" (p. 539). More recently, Berlucchi (2006) established similar assumptions, suggesting that "the RTs inhibition may result because the response of the visual system to the target is reduced by the previous stimulation from the cue, independent of orienting, and this is a bottom-up, sensory effect" (p. 1066). Dukewich (2009) has also offered a conception of the IOR effect in terms of habituation, in which the presence of a similar preceding event (the cue), at the same spatial location, leads to a weakened orienting response to the target. Similarly, the detection cost hypothesis proposed by Lupiáñez (2010), hypothesizes that the appearance of IOR is related to a lost of novelty, or a detection cost, for targets presented at a previously stimulated location. All the above-mentioned interpretations of the IOR effect assume that targets presented at previously cued locations elicit a weaker perceptual response as compared to targets presented at non-previously cued (i.e., newer) locations. This impaired perceptual processing can be the cause of the IOR effect, independently of other attentional mechanisms (see also Chica et al., 2006; Chica & Lupiáñez, 2009; Martín-Arévalo, Kingstone, & Lupiáñez, 2013), which, in the present study, might rather be indexed by the N2pc component.

It seems therefore clear that the IOR effect has to be the result of some sort of reduced perceptual reactivity (either cognitive or neural, see also e.g., Dorris, Klein, Everling, & Munoz, 2002) at previously cued locations. As just stated above, several researchers have provided an explanation of the IOR effect in this line. However, it remains to be explained why this impaired perceptual processing, which seems to be independent of attentional orienting (Lupiáñez et al., 2013), task set

(Chica & Lupiáñez, 2009), and whether an intervening event is presented between the cue and the target (as shown in the present paper), is sometimes related to behavioural IOR, whereas in other situations it coexists with behavioural facilitation (as in the intervening event absent condition of the present experiment; see also Chica and Lupiáñez, 2009; Wascher and Tipper, 2004). According to Lupiáñez and colleagues (Lupiáñez, 2010; Lupiáñez et al, 2013), cueing produces effects at multiple stages of processing, namely it produces a detection cost (hindering perceptual processing at spatial locations that have already been inspected), but it also leads to cue-target integration processes that would facilitate target discrimination (i.e., leading to a benefit in the target's spatial selection). Thus, whereas cueing would always produce a perceptual "detection cost" that is measured in early components (reduced amplitude of the P100 component for cued as compared to uncued locations), it also affects other later-stage ERP components (in our case N100, Nd, and P300). Importantly, both modulations seem to be independent; for example, in the intervening event absent condition, P100 was impaired at the cued location, while the modulation of later components (N100, Nd, and P300) demonstrated an enhanced processing of the cued location. Moreover, the intervening event manipulation, leading to behavioural facilitation or IOR, also modulated attentional selection process (indexed in the N2pc), reflecting whether the cued or uncued location was selected for further processing, and leading to the behavioural effect.

Taken all this evidence together, it suggests that cueing effects are related to a perceptual detection costs (more directly related to IOR), and modulations on later post-perceptual components, beside an enhanced/reduced probability of attentional selection to recently attended locations (for facilitation and IOR, respectively). When an intervening event was presented, its appearance seems to interrupt the modulation of later components (N100, Nd, P300), and therefore, the behavioural effect (i.e., IOR) only reflected the detection costs measured in the P100 component. However, when no intervening event was presented (and facilitation was measured), the contribution of later-stage components could override and mask the detection cost observed in the P100 component (Chica & Lupiáñez, 2009; Waschler & Tipper, 2004).

These results therefore confirm the hypothesis that attentional cueing is composed of multiple mechanisms (perceptual, attentional, and post-perceptual). Early perceptual processes (as reflected by the P100) are always impaired when the SOA is long enough, and the behavioural effect that is measured depends on other late-perceptual (N100), attentional selection (N2pc and Nd), and decision processes (P300).

Finally, we also analysed cue-related activations during the time interval between cue and target onset (see Tian et al, 2011; see also Chica et al., 2010, 2012) in order to determine whether the intervening event manipulation might have created a different task-set to orient attention before the target was presented. Results demonstrated that this was in fact the case. When the intervening event was presented, the peripheral cue was processed faster than when it was not (as indicated by the mean latency of the P100 cue-locked component[17]). We proposed a perceptual-attentional capture basis for this faster processing of the peripheral cue when the IOR effect is observed (see Tian et al, 2011, for similar conclusion). The presence of the intervening event may have created an attentional set to rapidly and efficiently process the peripheral cue before the intervening event was presented, which might be related to the appearance of behavioural IOR. It is important to note that most researchers propose that the intervening event increases the magnitude of IOR by attracting attention back to the centre before the target is presented. However, our results clearly suggest that, at least when the presence or absence of intervening events is manipulated in different groups of participants, the presence of an intervening event affects how the peripheral cue itself is processed, even before the intervening event is presented. This makes us hypothesize that other variables modulating peripheral cue processing might affect cueing effects (facilitation and IOR) similarly to the presentation of intervening events (see for example Gabay et al., 2012).

Conclusion:

The major contribution of this paper is to have provided electrophysiological evidence for differential contributions of ERP components to cuing effects (i.e., facilitation and IOR). We demonstrate that peripheral cues always produce a detection cost (reflected in reduced amplitude of the P100 component for cued as compared to uncued trials) when a long enough SOA is provided. This perceptual detection cost is observed independently of the behavioural effect that is measured. The measured behavioural effect (facilitation or IOR) is related to the added modulation of peripheral cueing on later-stage components (namely N100, Nd, and P300) and to the changes

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[17] Although there was a tendency for the amplitude of the P100 component to be modulated by the presentation of an intervening event, with enhanced amplitude of the component for intervening event absent conditions as compared to the intervening event present condition, these modulation did not reach significance; perhaps to obtain sufficient statistical power, a within-participants manipulation might have been recommended. However, pilot un-published work in our lab has shown that this manipulation produces strong cross-over effects, being difficult to find significant facilitation and IOR effects within the same experiment.

in attentional selection process (reflected in the N2pc component). While facilitation is associated to modulations of cueing in these components, the IOR effect is related to lack of modulations on the later-stage components (i.e., N100, Nd, and P300), so that the detection cost observed in the P100 component is the main contribution to cueing. The N2pc component seems to indicate whether the cued or the uncued location is selected for further processing, correlating with the measured behavioural effect. The IOR effect can therefore be considered a measure of the first detection cost reflected in the P100 component which reduces the probability of attentional selection (measured in the N2pc component) to recently attended locations. Our data challenge the reorienting hypothesis about IOR, leading to an alternative explanation of cuing effects that goes beyond orienting of attention (Berlucchi, 2006; Dukewich, 2009; Lupiáñez, 2010). Spatial attention can therefore operate at different processing stages, and probably within different cognitive subsystems and cortical areas.

Experimental Series 4

Electrophysiological modulations of exogenous orienting depend on task demands

The content of this chapter is in preparation:
Martín-Arévalo, E., Chica, A.B, & Lupiáñez, J. Electrophysiological modulations of exogenous orienting depend on task demands.

Abstract

In the present study we investigated electrophysiological modulations produced by peripheral cueing leading to inhibition of return –IOR, when intervening events were either presented between the cue and target or absent. Participants were to detect the target, and this tasks led to an IOR effect in both conditions. Peripheral cues always produced a perceptual detection cost (reflected in a reduced amplitude of the P100 component for cued as compared to uncued trials) and an enhanced and slowed processing for cued trials as compared to uncued trials (reflected in the decisional P300 component). Results from the current detection task are compared to those obtained with a discrimination task (Martín-Arévalo et al., submitted), using a very similar paradigm. Possible mechanisms for cueing modulations depending on task demands are discussed in light of cue-target integration processes (Lupiáñez, 2010).

Introduction

Attention mechanisms bias information processing in the brain, leading to a selective perception of a small subset of the vast amount of information continually inundating our senses (Hopfinger & West, 2006). Attention is thought to include both *endogenous* mechanisms, where attentional processing is exerted in a top-down manner, and *exogenous* mechanisms, where attentional processing is exerted in a bottom-up manner (Jonides, 1981). These two types of attentional orienting have been extensively examined in studies using the Posnerian cuing paradigm (Posner, 1980), and are proposed to be supported by two separate attentional systems (e.g., Corbetta & Shulman, 2002; Chica, Bartolomeo, & Valero-Cabré, 2011; Chica, Bartolomeo, & Lupiáñez, 2013).

In the Posner paradigm, spatially non-predictive peripheral cues, which trigger an exogenous attentional capture (Ruz & Lupiáñez, 2002), produce two distinct effects on target processing. At short cue-target stimulus onset asynchronies (SOAs), reaction times (RTs) are usually faster for targets appearing at the same location than the peripheral cue (i.e., the cued location) as compared to RTs for targets presented at the opposite location (i.e., the uncued location), i.e., a facilitatory effect is observed. At longer SOAs, however, the effect reverses, and RTs are shorter for targets appearing at the uncued location as compared to the cued location. This latter effect, initially described by Posner and Cohen (1984), is named *inhibition of return* (IOR; Posner, Rafal, Choate, and Vaughan, 1985), reflecting the theory initially proposed to explain the effect: IOR is believed to be the consequence of an impaired ability to return attention to a previously attended location (Klein, 2000). However, although other explanations for the IOR effect have been currently considered, such as a detection cost or habituation for targets presented at a previously stimulated location (Lupiáñez, 2010; see also Berlucchi, 2006; Dukewich, 2009; Gabay, Chica, Charras, Funes, & Henik, 2012), the mechanism/s and process/es underlying the IOR effect still remain highly debated. However, several researchers have proposed that the IOR effect might arise from multiple mechanisms, such as perceptual, attentional, or motor, and from multiples stages of processing (e.g., Kingstone & Pratt, 1999; Taylor & Klein, 2000; Hunt & Kingstone, 2003; Berlucchi, 2006; Lupiáñez, 2010).

Table 1- Predictions about target-locked cuing modulations of the attentional and perceptual theories of IOR.

Hypotheses	Effect	P1	N1	N2pc	LRP	Nd	P300
Attentional	Facilitation	Enhancement	Enhancement	Enhancement	Enhancement	No agreement	Enhancement
	IOR	Reduction	Reduction	Reduction	Reduction		Reduction
Perceptual: *Habituation hypothesis*	Facilitation	Enhancement	No predictions	No effect	No predictions		
	IOR	Reduction					
Perceptual: *event integration-segregation hypothesis*	Facilitation	Reduction	Enhancement	No effect	No predictions	Enhancement	Enhancement
	IOR		No effect			No effect	Enhancement or no effect*

Reduction: Smaller peak amplitude for cued than uncued trials; Enhancement: Larger peak amplitude for cued than uncued trials; * Depending on the task

Of particular relevance to our current aims, Table 1 represents the hypotheses put forward by the attentional and perceptual theories about IOR in relation to the electrophysiological modulations that both facilitation and IOR should produce. According to the *attentional hypotheses* (assumed by many researchers in the field; see e.g., Klein, 2000; Prime & Jolicoeur, 2009), three main processes occur during attentional orienting: 1) An attentional orienting to the cued location (most likely reflected in a cue-locked P100 or N2pc component); 2) An attentional re-orienting to the centre, which happens at long enough SOAs, and is enhanced or accelerated by the presence of an intervening event[18] (see e.g., Martín-Arévalo, Chica, & Lupiáñez, 2013; for a review of modulations by intervening events); and 3) An inhibited attentional orienting if the target is presented at the cued location as compared to the uncued location. This inhibited re-orienting to the target could produce effects at different stages of processing: perceptual (reflected in the target-locked P100 and N100 components), attentional selection (reflected in the target-locked N2pc component), motor (indexed by the target-locked lateralized readiness potential, LRP component), and in other post-perceptual correlates of resource allocation and/or decisional processing (reflected in the target-locked Nd, and P300 component, respectively; see for example Martín-Arévalo, Chica, & Lupiáñez, submitted-a).

According to this attentional hypothesis, the IOR effect has been associated to a reduction in the amplitude of the visual target-locked P100 component (originated in the human extrastriate cortex, see e.g., Mangun, Hillyard, & Luck, 1993; Mangun, Hopfinger, Kussmaul, Fletcher, & Heinze, 1997; Martinez, Anllo-Vento, Sereno, Frank, Dubowitz, Wong, Heinze, & Hillyard, 1999; Di Russo, Martinez, & Hillyard, 2003) for cued as compared to uncued locations (Eimer, 1994; Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999; Prime & Ward, 2004; Doallo, Lorenzo-Lopez, Vizoso, Holguin, Amenedo, & Bara, 2004; Prime, Visser, & Ward, 2006; Wascher & Tipper, 2004; Tian & Yao, 2008; Prime & Jolicoeur, 2009). It has also been related to a target-locked N2pc modulation, suggesting that the inhibitory process/es underlying the IOR effect impair the probability of target selection at recently attended locations (McDonald, Hickey, Green, & Whitman, 2009; Yang, Yao, Ding, Qi, & Lei, 2012; Martín-Arévalo et al., submitted). Previous studies have also associated IOR to the Nd component (e.g., McDonald et al., 1999;

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[18] The presence of an intervening event favours the appearance of the IOR effect in some experimental situations in which no IOR would otherwise be observed (see e.g., Pratt & Fischer, 2002; Prime & Ward, 2004; Lupiáñez, Martín-Arévalo, & Chica, 2013).

Prime & Ward, 2004, 2006), although its involvement in the generation of IOR has not been proved in other studies (see e.g., Wascher & Tipper, 2004; Prime & Jolicoeur, 2009; Martín-Arévalo et al, submitted; see also Eimer, 1993; 1994). Other effects in motor and decisional processes have also been reported (see e.g., Prime & Ward, 2004; 2006; for motor processes; and Hopfinger & Mangun, 1998; 2001; Chica & Lupiáñez, 2009; for decisional processes).

Contrary to the attentional hypothesis, *perceptual hypotheses* about IOR (see e.g., Handy, Jha, & Mangun, 1999; Berlucchi, 2006; Spalek & Di Lollo, 2007; Dukewich, 2009; Lupiáñez, 2010) only postulate two processes underlying the IOR effect: 1) An attentional orienting to the cued location (most likely reflected in a cue-locked P100 or N2pc components); and 2) A habituated attentional orienting or detection cost if the target is presented at the cued location as compared to the uncued location (reflected in reduced amplitude of the target-locked P100 or N2pc component for cued as compared to uncued trials). Note that these perceptual theories do not consider attentional re-orienting as a necessary condition to observe IOR (see e.g. Chica & Lupiáñez, 2009; Berlucchi, 2006, for a review). Indeed, Berlucchi (2006) suggests an interpretation of the IOR effect in sensory terms, where the response of the visual system to the target would be reduced by the previous stimulation at the same spatial location, independently of orienting. As it can be observed in Table 1, while the habituation hypothesis (Dukewich, 2009; see also Berlucchi, 2006, for similar assumptions) postulates that the early target perceptual processing (reflected in the P100 modulation) will only be measured if IOR were behaviourally observed, the cue-target event integration-segregation hypothesis (Lupiáñez, 2010; see also Lupiáñez et al., 2013) postulates that perceptual processing is always impaired by the very appearance of the cue when a long enough SOA is presented. The final behavioural effect observed might depend on other processes related to attentional selection (reflected in the target-locked N2pc component), motor preparation (target-locked LRP component), and other post-perceptual correlates of resource allocation and/or decisional processes (reflected in the target-locked Nd and P300 component, respectively). Moreover, another important conceptual difference between attentional and perceptual theories is that while the attentional theory predicts that the attentional capture by the target should always be inhibited at the cued location (which is reflected in the N2pc component), perceptual theories do not make such prediction.

In particular, the detection cost theory of IOR, on the basis of cue-target event integration-segregation processes (Lupiáñez, 2010; see also Lupiáñez et al., 2013), makes an explicit prediction involving task set: while some tasks are mainly affected by the contribution of the "*detection cost*" to performance (such as detection tasks, where the most relevant process for the task at hand is to detect the appearance of the target), other tasks require the contribution of what is called "*spatial selection benefits*". For example, in the case of discrimination tasks, spatial selection is important to further analyze the critical features to be discriminated. Therefore, this hypothesis clearly predicts that in discrimination tasks, a long enough SOA will always be related to a detection cost, which might be associated to a reduced P100 for cued as compared to uncued targets. However, the spatial selection benefit would be related to neural processes associated to attentional selection of a spatial location for further processing (measured in the N2pc component), and higher level perceptual processing (related to N100 and Nd modulations). In discrimination tasks, the presence of this spatial selection benefit (associated to N100, Nd, and N2pc modulations) could counteract the detection cost that is always present given a long-enough SOA, and measured in the P100 component. This hypothesis was tested and confirmed in a previous ERP study (Martín-Arévalo et al., submitted) using a paradigm in which the presence/absence of an intervening event produced opposite effects on RTs: facilitation in the absence of an intervening event, and IOR when the intervening event was presented (see also Experiment 2; Martín-Arévalo et al., 2013). Results demonstrated that the P100 component was reduced for cued as compared to uncued targets both when the intervening event was present and when it was absent; therefore, perceptual processing was impaired independently of the behavioural result that was measured (see also Hopfinger & Mangum, 1998; Chica & Lupiáñez, 2009; Satel, Wang, Hilchey, & Klein, 2012, for similar results). Moreover, peripheral cues only modulated later components (namely N100, N2pc, Nd, and P300) when no intervening event was presented and facilitation was behavioural observed (see e.g., Hopfinger & Magnum, 2001; Wascher & Tipper, 2004; McDonald et al., 1999; for similar results in some of these components).

Thus, as predicted by the event integration-segregation theory (Lupiáñez, 2010; Lupiáñez et al., 2013), the intervening event eliminated the contribution of selection benefits to performance, therefore eliminating the modulation of later ERP components, consequently leading to the behaviorally observed IOR effect. The present paper aims at testing another important prediction of the cue-target event integration-segregation theory regarding the electrophysiological modulations of IOR. If discrimination tasks call for the contribution of spatial selection processes and these are indexed by the observed later-stage ERP modulations (i.e., N100, Nd, and N2pc), no modulation on these later components should be observed in detection tasks, as such processes arenot involved in these tasks. In detection tasks, detecting the target onset is sufficient for correctly performing the task, and therefore, only the detection cost process will contribute to performance. If this were true, the P100 component should always be reduced for cued as compared to uncued targets, while no modulations associated to attentional selection of spatial locations for further processing (measured in the N2pc component), and/or higher level perceptual processing (related to N100 and Nd modulations) should be observed.

In order to test this prediction, we used a paradigm in which the presence/absence of an intervening event was manipulated between groups of participants (see also Martín-Arévalo et al., 2013; submitted). Instead of using a discrimination task, as in our previous study (Martín-Arévalo et al., submitted), a detection task was used in the present experiment. If the cue-target event integration-segregation hypothesis were correct, P100 should be reduced for cued as compared to uncued trials always, no matter whether the intervening event is present or absent. Moreover, two observations might be possible: 1) There could be similar modulations of later-stage components (concretely, N100, N2pc, Nd, and P300), than those produced in discrimination tasks (Martín-Arévalo et al., submitted), but IOR would be behaviorally observed because the detection costs (indexed by a reduced amplitude of the P100 component for cued as compared to uncued trials) has a stronger weight in detection task than discrimination tasks. 2) No modulations of these later-stage components might occur, because these components are related to spatial selection benefits that are not required for the detection task at hand.

Methods

Participants

A total of thirty-two healthy volunteers participated in this experiment (all right-handed, 21 women, mean age of 22 years, SD=3.55). All participants were naïve students from the University of Granada, who participated in the experiment for course credits. They reported having normal or corrected to normal vision. The experiment was conducted in accordance with the ethical guidelines laid down by the Department of Experimental Psychology, University of Granada, in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Apparatus and Stimuli

The experiment was run on a computer with a 1GHz Pentium III processor, connected to a 15-inch color VGA monitor. E-primer software (Schneider, Eschman, & Zuccolotto, 2002) controlled the presentation of stimuli and the acquisition of data throughout the experiment. Two placeholder boxes were presented, one on each side of the fixation point. Each box was 20 mm in width by 20 mm in height (subtending 2.0 and 2.0 degrees of visual angle at a viewing distance of 57 cm). The boxes were positioned 25 mm away from central fixation along the horizontal plane, as measured from the center of the bottom edges of each placeholder to the center of the screen (fixation point), and positioned 10 mm above the central fixation along the vertical plane, as measured from the center of the inner lateral edges of each placeholder to the center of the screen. Peripheral cues were created by thickening the outline of one of two placeholder boxes. The intervening event was created by presenting a smaller box around the fixation cue (10 mm in width by 10 mm in height). The target was either the letter “X” or “O” (2 mm), although participants were not to discriminate the letters, but to detect its appearance.

Procedure

The stimuli used, and the sequence of events in each trial, are illustrated in Figure 1. The procedure, stimuli, and material were exactly the same as those used in Martín-Arévalo et al. (submitted) except that participants had to detect the target instead of discriminating it, and target duration was reduced to 50 ms in order to further enhance the contribution of the detection cost to performance[19].Each trial began with the presentation of the fixation display (containing the fixation point, and the two boxes), with a duration varying randomly between 1000 and 1500 ms. Participants were required to keep their eyes on the fixation point throughout the experiment. The peripheral cue was presented in one of the two possible locations with equal probability for 50 ms. After the peripheral cue had disappeared, the fixation display was presented again for a duration varying randomly between 200 and 300 ms. Next, the intervening event was presented for 50 ms. In the group with intervening event absent, the fixation display was maintained on the screen for these 50 ms, keeping a constant SOA for both groups. After the offset of the intervening event (or the 50 ms fixation display in the group with intervening event absent), another fixation display of random variable duration (200-300 ms) was presented. The target was displayed for 50 ms in one of the two peripheral boxes with equal probability. Participants were instructed to detect the appearance of any of the two letters by pressing the appropriate response key on the keyboard as fast as possible (half of the participants pressed the “Z” key, whereas the other half pressed

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[19] Note that short target durations (i.e., 50 ms) could emphasize target detection, increasing the need to rapidly detect the target, leading to a larger IOR effect (Martín-Arévalo et al., 2013).

the“M” key). On 15% of the trials (catch trials), no target was presented and no response was required. The inter-trial interval, in which the screen remained black, was 2000 ms in duration. An auditory feedback was presented for wrong, missing, or premature responses (shorter than 200 ms).

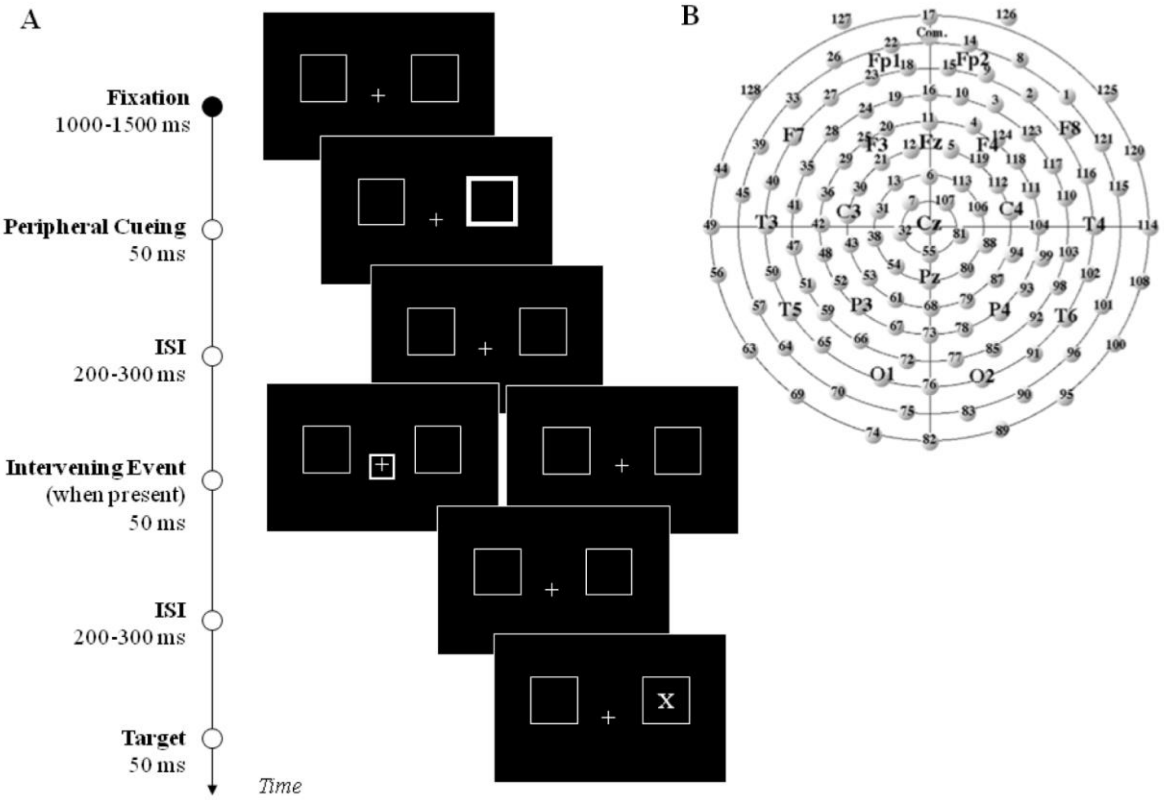

Figure 1. A) Sequence of events in a given trial. B) Sketch of the electrodes distribution around the scalp as viewed from above (the top of the figure represents the frontal area). Additional sites according to the 10–20 International system are shown for further reference.

Design

The experiment consisted of a two-factor design. Peripheral cueing was manipulated within participants, while Intervening event was manipulated between participants. Peripheral cueing had two levels: cued and uncued location trials; Intervening event had also two levels: intervening event absent and present. The experiment consisted of 20 practice trials, which were not further analyzed, followed by 392 experimental trials (7 blocks of 56 trials each; 24 cued location, 24 uncued location trials, and 8 catch trials).

EEG experiment: 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 recording and were averaged re-referenced offline. The EEG was amplified with a band pass of .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. For the cue analysis, epochs were segmented from 200 ms before cue appearance to 300 ms after the cue presentation. For the target analysis, epochs were segmented from 200 ms before target appearance to 700 ms after its presentation. All trials containing eye movements, blinks, or artifacts, as well as trials with anticipatory responses were rejected. An average of 26.43 % and 16.39 % of the trials were excluded in the cue and target analysis, respectively. A 200 ms segment previous to the cue or the target presentation was used to calculate the baseline. A minimum of 40 trials per condition was required to ensure a sufficient signal-to-noise ratio.

Results

Behavioral results

Participants missed the target (i.e., no response was made) on 0.28 % of the trials, which were not further analyzed. False alarms (i.e., responses to catch trials) accounted for 1.56 % of the trials in this experiment. Responses faster than 200 ms (1.41 %) were also excluded from the RT analysis as outliers.

Mean correct RT data were submitted to a 2 (Peripheral cueing: cued vs. uncued) and 2 (Intervening event: absent vs. present) mixed analysis of variance (ANOVA) with the second factor as a between participant variable. Table 2 shows the mean RTs and percentage of errors for each experimental condition. The analysis revealed a highly significant main effect of Peripheral cueing, $F(1, 30)=69.69$, $MSE=261$, $p<.0001$, $\eta 2=0.63$, showing that RT was overall slower when the target appeared in a position previously occupied by the cue as compared to the uncued location (i.e., an IOR effect was observed). Neither the main effect of Intervening event, nor the interaction between Peripheral cueing and Intervening event, $Fs<1$, were significant.

The results of the present experiment indicate that in the detection task used in the present experiment, IOR was always observed, independently on the presence/absence of the intervening event (see Pratt & Fischer, 2002; Prime, Visser, & Ward, 2006). This result is typically found in detection tasks, in which IOR appears even at short SOAs, being unsusual to observe facilitatory effects (see e.g., Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994; Collie, Maruff, Yucel, Danckert, & Currie, 2000; Mele, Savazzi, Marzi, & Berlucchi, 2008; Martín-Arévalo et al., 2013).

Table 2- Mean RTs (in ms) for each condition of Peripheral cueing and Intervening event. Mean percentage of misses (no response to the targets) are presented in parenthesis.

	Intervening Event	Cueing		Cueing Effect (Uncued - Cued)
		Cued	Uncued	
EEG experiment	Absent	366 (0.33%)	333 (0.07%)	-33
	Present	373 (0.44%)	347 (0.29%)	-26

ERP results

Event-related potentials (ERPs) locked to the appearance of the cue and target were analyzed. Visual inspection[20] of cue-related ERPs revealed only one component during the cue period; this was the N2pc, peaking at ~200 ms, and observed in the lateral occipital electrodes. Visual inspection of target-related ERPs revealed two main components during the target period. The first component was the P100, peaking at ~170 ms, observed in parieto-occipital electrodes, and larger for ipsilateral than contralateral electrodes. This component was directly followed by the P300 component, peaking at ~350 ms at central and at midline electrodes. Importantly, in contrast with previous results (Martín-Arévalo et al., submitted), in which three other components were observed in a discrimination task (a parieto-occipital negativity -N100- peaking at ~200 ms at PO7-PO8 electrodes, a N2pc component peaking at ~220 ms at PO7-PO8 electrodes, and a Negative difference component -Nd- around ~220-280 ms at midline electrodes, namely Cz and

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[20] The visual inspection was based on the grand average waveforms, according to previous literature. Visual inspection of topographic maps was also carried out.

Pz), no other components were observed in the current detection task (see Figure 2 for a comparison between tasks[21]). Moreover, given the relevance of the absence of components to our aims, we submitted to a mixed analysis of variance (ANOVA) each event related response at the same time-window and electrodes that were analyzed in the discrimination task, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes to the presentation of the target) as factors (Martín-Arévalo et al., submitted). Neither the N100 component nor the N2pc yield any significant main effects or interactions (all ps>.0702[22]). However, we found a significant main effect of the Peripheral cueing in the time window related to the Nd component, F(1, 30)=11.97, MSE=0.4208, p=.0011, η2=.28, showing an enhancement amplitude of the wave for cued trials as compared to uncued trials. None of the other effects were significant (all ps>.1555). Nevertheless, as it can be observed in the Figure 2, this component represents an earlier appearance of the P300 component for uncued trials as compared to cued trials rather than the Nd component found at the same time window in the discrimination task. The implications of this result are discussed in the General Discussion.

For cue-locked analysis, we calculated the mean amplitude of the N2pc component (time window from 100 to 300 ms after cue onset), for each participant in a sample of representative electrodes covering the scalp (PO7/PO8, P3/P4, T5/T6, Pz/Cz, electrodes 12/5 representing Fz, F7/F8, Fp1/Fp2; see Fig. 1B; see Chica et al. 2012; Martín-Arévalo et al., submitted, for a similar analysis). For target-locked analyses, we calculated the mean amplitude of the P100 component (time window from 100 to 200 ms after target onset), and P300 (time window from 200 to 400 ms), for each participant in the same sample of representative electrodes covering the scalp. In order to determine the scalp location where each component was maximally elicited, we performed a one-way ANOVA for each component, with Electrode as a factor.

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[21] It could be argued that these later-stage component were not generated in the current detection task because target duration was short. However, Chica & Lupiáñez (2009) used a short target duration (100 ms) and observed these later components in a discrimination task. Therefore, we argue in favor to task-demands, rather than target duration, as responsible of generating (or not) these components.

[22] This closed to significance effect (p=.0702) is related to the interaction between Laterality and Cueing, demonstrating a smaller positivity for cued trials as compared to uncued trials at contralateral electrodes. However, as it can be observed in the Figures 2 and 3 (200 ms), this effect does not reflect a N100 component, being the voltage positive in all conditions. The remaining interactions or main effects were far of the significance (all ps>.1194).

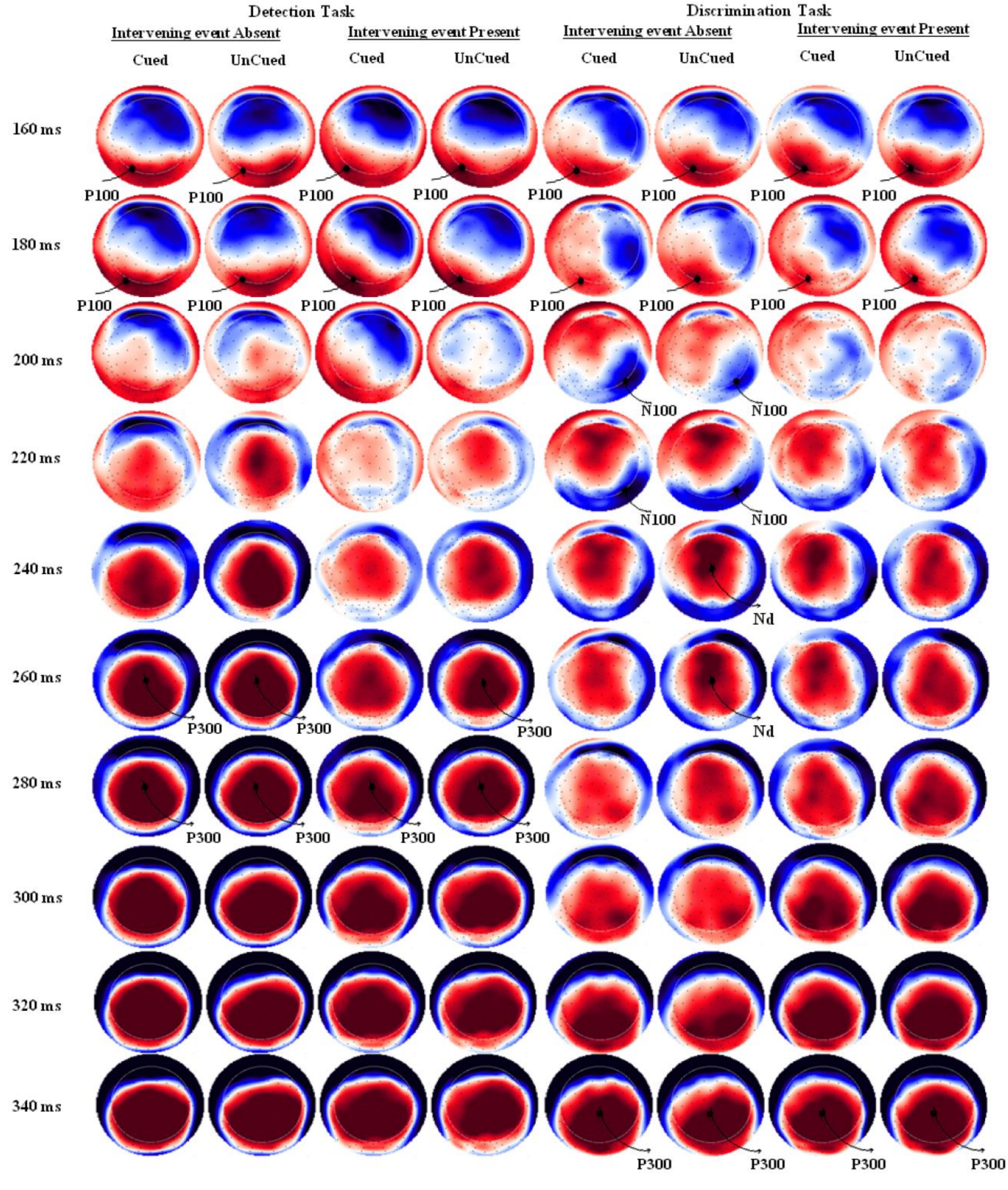

Figure 2. Scalp topographic voltage maps (each 20 ms) between 160 and 340 ms after target onset, in which P100, N100, N2pc, Nd, and P300 should be observed. Topographic maps are shown for each task condition (the detection task of the present paper vs. the discrimination task presented in Martín-Arévalo et al., submitted), Peripheral cueing, and Intervening event. Left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral electrodes, respectively. Note that

between 200 and 220 ms, where the N100 component was significatively observed in the discrimination task, no negativity was even observed in the detection task. Between 240 and 260 ms, the Nd component was observed in the discrimination task while the P300 was already peaking in the detection task, which presented its maximal amplitude at 340 ms. In the discrimination task, the P300 component was not observed until 340 ms.

For the cue-locked components, the main effect of Electrode was significant (p<.0001). The largest mean amplitude of the N2pc component was observed at P3/P4 electrodes (M=−0.27µ), followed by T5/T6 electrodes (M=−.24µ), and by PO7/PO8 electrodes (M=−.20µ). None of these amplitudes were statistically different (planned comparison, p=0.5881). For the target-locked components, the main effect of Electrode was also significant (all ps<.05). The largest mean amplitude of the P100 component was observed at PO7/PO8 electrodes (M=1.65µ), followed by P3/P4 electrodes (M=1.31µ). These two amplitudes were statistically different (planned comparison, p=0.0004). Finally, the largest mean amplitude of the P300 component was observed in the Pz electrode (M=4.44µ), followed by Cz electrode (M=4.14µ), and P3/P4 electrodes (M=3.55µ). None of these amplitudes were statistically different (planned comparison, p=0.4328).

We subsequently analyzed the modulation of each component (i.e, cue-locked and target-locked) when the intervening event was present or absent by calculating its adaptive mean amplitude (20 ms before and after the higher peak) at those electrodes where the components were maximally elicited based on the previous analyses (PO7/PO8, P3/P4, and T5/T6 for the cue-locked N2pc component, PO7/PO8 for the target-locked P100 component, and Pz, Cz, and P3/P4 electrodes for the target-locked P300 component). Moreover, the latency associated to the maximum peak was analyzed for each component within the same temporal window and electrodes sites as those used for the mean amplitude analysis.

Cue-locked N2pc component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the cue-locked N2pc component, considering Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes[23] to the presentation of the cue) as factors.

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[23] Note that the data from PO7/PO8, P3/P4 and T5/T6 were collapsed because the first analysis did not show signigicant differences between these electrodes, p=0.5881.

Note that Peripheral cueing (cued vs. uncued conditions) was not introduced as a factor in this analysis because trials cannot be considered as cued or uncued until the target is presented.

The mean amplitude analysis demonstrated that the amplitude of the N2pc was maximal at electrodes contralateral to the cue, F(1, 30)=18.52, MSE=.1758, p=.0001, η2=.38. The analysis of the mean amplitude demonstrated that neither main effect of Intervening event nor the interaction between Intervening event and Laterality reached significance, both Fs<1.

The mean latency analysis demonstrated a marginally significant main effect of Laterality, F(1, 30)=3.73, MSE=612, p=.0626, η2=.11, showing an earlier peak at contralateral electrodes (M=200 ms) as compared to ipsilateral electrodes to the cue (M=212 ms). Neither the main effect of Intervening event nor the interaction between Intervening event and Laterality were significant, all ps>.1984.

Target-locked components

P100 component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the P100 component, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral vs. Contralateral lateral-occipital electrodes to the presentation of the target) as factors. The mean amplitude analysis demonstrated that the P100 component was maximally elicited at ipsilateral electrodes to the target, F(1, 30)=13.19, MSE=0.4012, p=.0010, η2=.13, but laterality did not interact neither with Intervening event nor with Peripheral Cueing, F(1, 30)=1.35, MSE=0.4012, p=.2531, η2=.04 and F(1, 30)=1.19, MSE=0.1207, p=.2070, η2=.05, respectively (see Figure 3). The main effect of the Peripheral cueing was significant, F(1, 30)=5.18, MSE=0.2335, p=.0300, η2=.14, showing a reduced P100 amplitude when the target appeared in a position previously occupied by the cue (cued position, M=1.56μ) than at an uncued position (M=1.76μ). Importantly, this reduced P100 amplitude for cued as compared to uncued trials was similarly observed when the intervening event was present or absent (F(1, 30)=2.49, MSE=0.2335, p=.1249, η2=.07, for the interaction between Peripheral cueing and Intervening event). Neither the main effect of Intervening event, F<1, nor the interaction between all three factors, F(1, 30)=1.66, MSE=0.1207, p=.2070, η2=0.05, were significant.

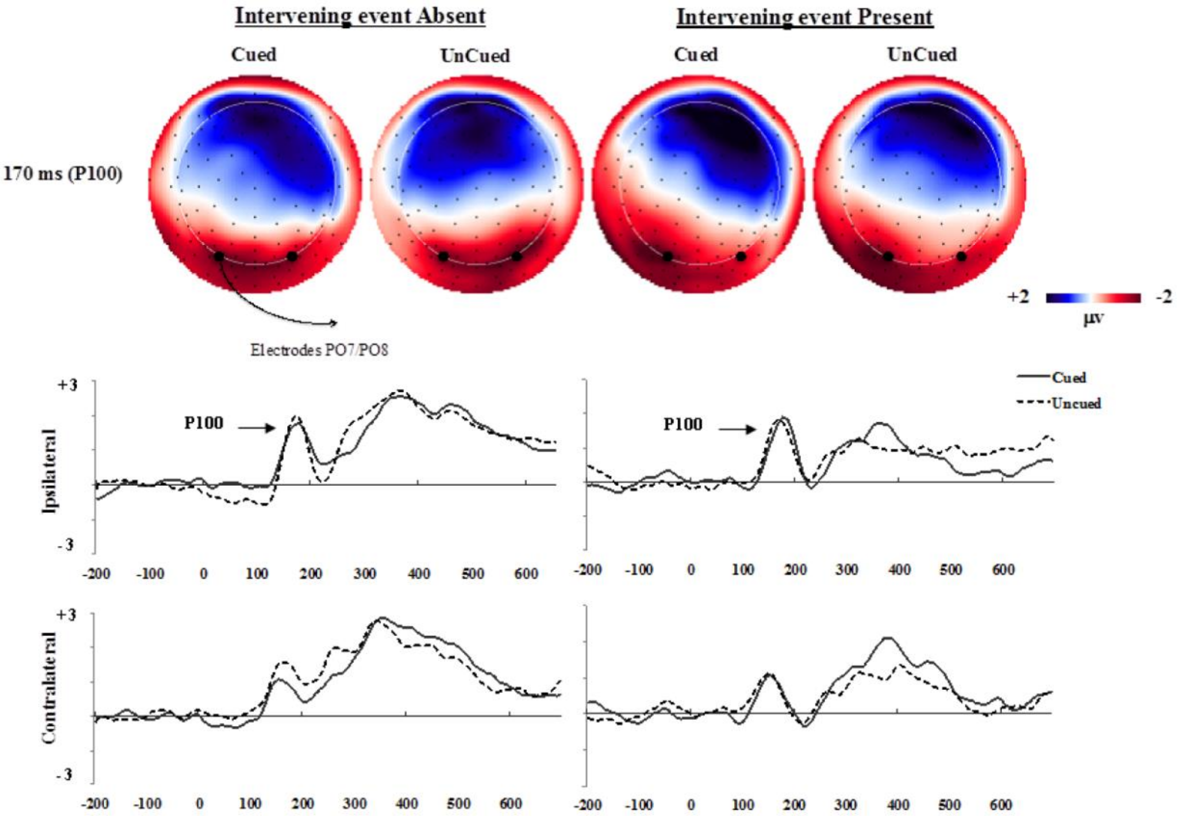

Figure 3. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the target-locked P100 (170 ms) component. Topographic maps are shown for each condition of Peripheral cueing and Intervening event (left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral electrodes, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean target-locked ERPs waveforms for the P100 analysis for each condition of Peripheral cueing and Intervening event.

The mean latency analysis demonstrated a significant main effect of Peripheral cueing, F(1, 30)=38.30, MSE=103, p<.0001, η2=.56, showing an earlier peak at uncued trials (M=160 ms) as compared to cued trials (M=171 ms). Peripheral cueing significantly interacted with the Laterality factor, F(1, 30)=5.95, MSE=184, p=.0208, η2=.16, demonstrating that this P100 modulation was only observed at ipsilateral electrodes to the target (planned comparison, p<.0001). For contralateral electrodes, similar latencies were observed for cued as compared to uncued trials (planned comparison, p=.1131). The interaction between the Peripheral cueing and Intervening event was significant, F(1, 30)=7.49, MSE=103, p=.0103, η2=.19, revealing that, although an earlier peak for uncued trials as compared to cued trials was observed for both intervening event conditions (p<.0001 and p<.0207, for intervening event present and absent, respectively), this difference was larger in the former (-16 ms) that in the latter (-7 ms). Neither the main effect of the intervening event, F(1, 30)=1.07, MSE=468, p=.3075, η2=.03, nor any of the other main effects or interactions were significant, all Fs<1.

To summarize, results indicate that perceptual processing is impaired for cued as compared to uncued targets (as indicated in the mean amplitude analyses; see Chica & Lupiáñez, 2009, for similar results; see also Martín-Arévalo et al., submitted) both when the intervening event is absent and when it is presented. Moreover, perceptual processing is also slowed at the cued location as compared to the uncued location, especially when an intervening event was presented between the peripheral cue and the target.

P300 component

Separate mixed-design ANOVAs were conducted on the mean amplitude and latency of the P300 component, considering Peripheral cueing (cued vs. uncued conditions), Intervening event (absent vs. present), and Laterality (Ipsilateral, contralateral or central[24] electrodes) as factors. The mean amplitude analysis demonstrated that the P300 component was maximally elicited at central electrodes, F(2, 60)=8.11, MSE=2.492, p=.0007, η2=.21, but laterality did not interact neither with Intervening event, F<1, nor with Peripheral Cueing, F(2, 60)=1.73, MSE=.172, p=.1851, η2=.05 (see Figure 4). The main effect of Intervening event was significant, F(1, 30)=5.63, MSE=11.450, p=.0242, η2=.15, showing a larger P300 component when the intervening event was absent (M=4.24μ) as compared to when the intervening event was presented (M=3.08μ). The main effect of Peripheral cueing was also significant, F(1, 30)=11.68, MSE=0.661, p=.0018, η2=.28, showing that the amplitude of the P300 component was enhanced for cued as compared to uncued conditions. Importantly, this enhanced P300 amplitude for cued as compared to uncued trials was similarly observed when the intervening event was present or absent (F<1, for the interaction between Peripheral cueing and Intervening event). The interaction between all three factors was not significant, F(2, 60)=1.10, MSE=.172 p=.3371, η2=.05.

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[24] Note that the data from Cz and Fz were collapsed because the first analysis did not show differences between these two electrodes, p=0.2503.

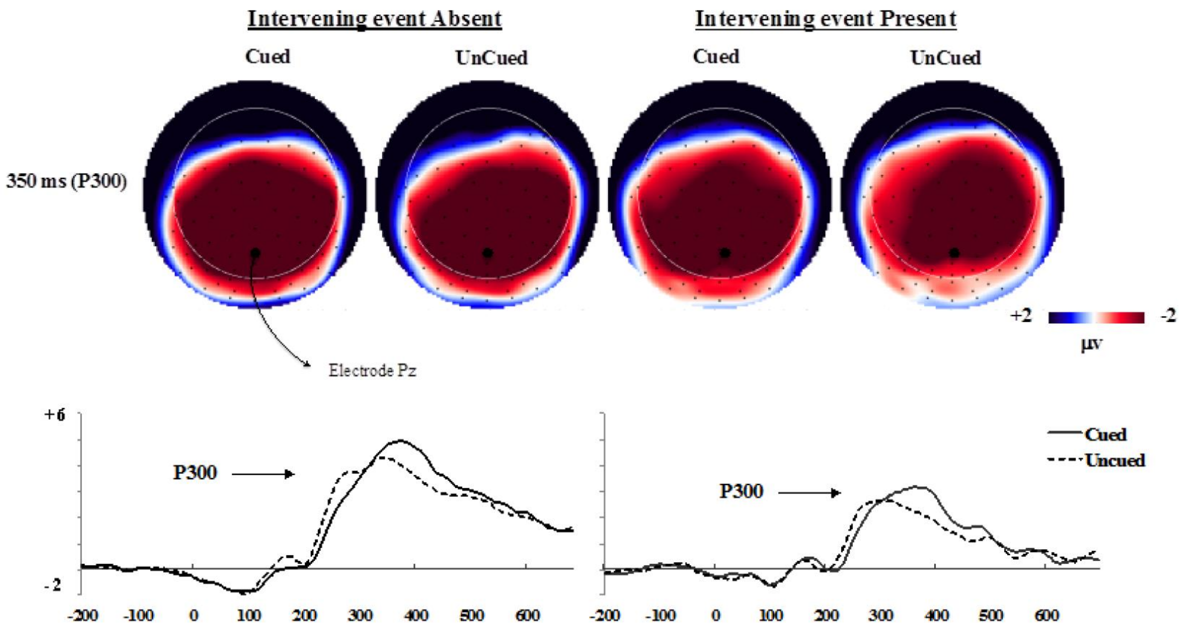

Figure 4. Top panel: Scalp topographic voltage maps at the moment of maximal amplitude for the P300 component (350 ms). Topographic maps are shown for each condition of Peripheral cueing and Intervening event (left targets are represented as an example; thus, the left and right sides of the head represent ipsilateral and contralateral electrodes, respectively). The small black dots on each topographic map indicate the location of the represented electrodes. Bottom panel: Mean target-locked ERPs waveforms for the P300 analysis for each condition of Peripheral cueing and Intervening event.

The mean latency analysis demonstrated a main effect of Peripheral cueing, F(1, 30)=18.26, MSE=1150, p=.0001, η2=.37, showing an earlier peak for uncued targets (M=326 ms) as compared to cued targets (M=347 ms). The interaction between all three factors (Peripheral cueing x Laterality x Intervening event) was significant, F(2, 60)=3.66, MSE=337, p=.0314, η2=.10. Planned comparisons demonstrated that when the intervening event was absent, P300 peaked earlier for uncued trials as compared to cued trials both at contralateral and central electrodes to the target location (p=.0101 and p=.0002, respectively), but not at ipsilateral electrodes (p=.1808). When the intervening event was presented, this effect was found both at ipsilateral and central electrodes to the target location (p=.0047 and p=.0241, respectively), but not at contralateral electrodes (p=.3084). None of the other main effects or interactions were significant, all ps>.1499.

At central electrodes, where the P300 component was maximally elicited, the enhanced but slowed amplitude of the P300 component for cued as compared to uncued trials, was similarly observedwhen the intervening event was present or absent. The implications of this result are discussed below.

General Discussion

The current study aimed at testing one of the predictions of the event integration-segregation theory concerning the effects of detection-task demands on IOR: although IOR should always be related to detection costs, reflected in a reduced amplitude of the P100 component for cued as compared to uncued trials, no modulation on later-stage components should be observed, because they reflect spatial selection processes that are not required for detection tasks (Lupiáñez, 2010; see also Lupiáñez et al., 2013). Concretely, in the present design, a detection task was used, combined with a short target duration, in order to enhance the contribution of the detection cost to performance. We hypothesized that under this condition, the P100 component should always be reduced for cued as compared to uncued targets, while no modulations associated to attentional selection of spatial locations for further processing (as indexed by the N2pc component), and/or higher level perceptual processing (related to N100 and Nd modulations) would be observed.

According to our hypothesis, the target-locked P100 component was reduced for cued as compared to uncued trials, independently on the presence/absence of an intervening event. This result is consistent with previous literature demonstrating that, after a long enough SOA, early perceptual or sensory correlates (indexed by P100 modulations) are impaired for cued as compared to uncued trials, no matter whether the behavioural effect measured is either IOR or facilitation (see Hopfinger & Mangum, 1998, Hopfinger et al, 2000; Wascher & Tipper, 2004; Chica & Lupiáñez, 2009; Martín-Arévalo et al., submitted). As it can be observed in Table 3, enhancements of P100 amplitude for cued as compared to uncued trials are only observed at short SOAs (see e.g., Hopfinger & Mangun, 1998; 2001). After a long enough SOA (i.e., ~500 ms), the P100 component is either reduced for cued as compared to uncued locations or no modulations are observed; this observation is true for both detection and discrimination tasks (see e.g., Chica & Lupiáñez, 2009; Eimer 1994; Hillyard et al, 1994; Hopfinger & Mangum, 1998; 2000; Martín-

Arévalo, et al., submitted; although see Van der Lubbe, Vogel, and Postma, 2005[25], for significant enhanced P100 for cued trials vs. uncued trials at SOAs longer than 500 ms).

In the current detection task, P100 was always reduced for cued as compared to uncued trials, independently of the presence/absence of the intervening event. However, the latency of the P100 component was accelerated for cued as compared to uncued trials when the intervening event was presented. This latency modulation was not observed in our previous study where participants performed a discrimination task (Martín-Arévalo et al., submitted). This result is consistent with previous work reporting that intervening events accelerate the onset of IOR, being the effect observed at SOAs where no cueing effects or facilitation would be otherwise observed (Faust & Balota, 1997; MacPherson, Klein, & Moore, 2003).

The target-locked P300 component was enhanced (and presented a longer peak latency) for cued as compared to uncued trials, and this was similarly observed when the intervening event was present or absent. This result supports the role of IOR in decreasing the expectation of target appearance at the cued location (Danziger and Rafal, 2009; Spalek, 2007). As it can be observed in Table 3, this result (enhanced P300 for cued as compared to uncued trials) is coherent with most previous studies (see e.g., McDonald et al., 1999; Prime & Jolicoeur, 2009; Chica & Lupiáñez, 2009). Moreover, the accelerated processing for uncued trials as compared to cued trials observed in the present detection task fits with the conception of the P300 component as linked to a person's reaction to a stimulus, rather than to the physical attributes themselves (see e.g., Polich, 2007). It is consistent with the behavioural IOR observed (i.e., faster responses for uncued as compared to cued trials), and fits into the possibility that P300 might be originating from the neural linkage between stimulus perception and its associated response (Verleger, Jaskowskis, Wascher, 2005).

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[25] This paper reported an unusual behavioural facilitatory effect at a long, 940 ms SOA. Note that the range of SOAs can modulate the cueing effect (Cheal & Chastain, 2002, Milliken, B., Lupiáñez, J., Roberts, M., & Stevanovski, 2003). In this study, five different SOAs (144, 188, 236, 588, and 940 msec), composed of mostly short SOAs, were employed. The range of SOAs strongly modulate cueing effects: at the same SOA, IOR or facilitation are respectively measured depending on whether a long or short range of SOAs are employed (Cheal & Chastain, 2002, Milliken et al., 2003).

Table 3- Summary of event-related potential effects in the present and previous studies.

Type Task	Study	Task Conditions	SOA (in ms)	Cueing Effect (Uncued-Cued)	P1	N1	Nd	P300
Detection	Current Study	IE Present IE Absent	500-700	-26 -33	Reduction	Not Observed		Enhancement
	McDonald, Ward, & Kiehl, 1999	Exp 1 Exp 2	500–700 900–1100 100-300 500–700	-13 -17 6 (n.s) -13	Called Nd n.s Called Nd Reduction	None n.s None n.s	Reduction n.s	n.s
	Hopfinger & Mangun, 2001		34-234 566-766	8 -14	Enhancement n.s	IIN None?	Not reported	Enhancement None
	Prime & Ward, 2006		900-1200	-36		Reduction	Reduction	Not reported
	Wascher & Tipper, 2004	Transient Cue Sustained Cue	350 900 350 900	-20 -31 1 (n.s) 12 (n.s)	Reduction	None n.s None n.s	None Reduction None Reduction	
	Van der Lubbe, Vogel, & Potmal, 2005		588 940	-46 -43		n.s n.s	Not reported	
	Chica & Lupiánez, 2009	Predictive Cue Counter-Predictive Cue	1000	0 -44		None? None?	Reduction? None	Reduction Ipsilateral Enhancement
Discrimination	Hopfinger & Mangun, 1998		34-234 566-766	16 - 2 (n.s)	Enhancement Reduction	None? Enhancement?	Not reported	Enhancement None
	Eimer, 1994	Predictive Cue Nonpredictive Cue	700	13 - 2 (n.s)	n.s Reduction Ipsilateral	Enhancement	Reduction	Reduction
	Prime & Ward, 2004		900-1200	-21	Reduction	Reduction		Not reported
	Prime & Jolicoeur, 2009	IE Present IE Absent	800-1100	-14 - 1 (n.s)	n.s	n.s	None Reduction	Enhancement n.s
	Van der Lubbe, Vogel, & Potmal, 2005		588 940	8 (n.s) 19*	n.s Enhancement	n.s n.s	Not reported	
	Chica & Lupiánez, 2009	Predictive Cue Counter-Predictive Cue	1000	18 -27	Reduction	Enhancement? None?	None Reduction?	Reduction Ipsilateral None
	Martín-Arévalo, Chica, & Lupiánez, submitted	IE Present IE Absent	500-700	-11 10		None Enhancement	None Reduction	Enhancement

Reduction: Smaller peak on cued trials; Enhancement: Larger peak on cued trials; None: No effect; SOA: Stimulus onset asynchrony between cues and targets; ?: Effect observed but not subjected to a statistical test; n.s.: effect not significant; IE: Intervening event; IIN: Ipsilateral Invalid Negativity. Grey background indicates facilitation effects.*See footnote 6 on the manuscript.

Therefore, the present results observed with a detection task have demonstrated that when behavioural IOR is observed (in conditions with or without intervening events), target processing is modulated at two stages of processing: perceptual (P100 component), showing a detection cost for cued trials as compared to uncued trials, and decisional (P300 component), showing an enhanced but slowed processing for cued trials as compared to uncued trials.

Of particular relevance to our aims, we predicted that in a detection task, in which the detection cost process (indexed by the P100 component) constitutes the main contribution to performance, no modulations associated to attentional selection of spatial locations for further processing (as measured in the N2pc component), and/or higher level perceptual processing (related to N100 and Nd modulations) should be observed. Importantly, in the current detection task, none of these components were even generated (see Figure 2).

Concretely, both the N100 component and the Nd component have been considered to be related to benefits for allocating attentional resources, indicating an enhanced processing of attended locations, and being associated to behavioural facilitatory effects (Eimer, 1993; 1994; Vogel & Luck, 2000). As it can be observed in the Table 3, the appearance (or significant modulations) of the N100 component are not as usual as one could think, and if any, its observation depends on some variables such as the task at hand. Concretely, the modulations of the N100 component in detection tasks reporting IOR effects have been non-significant, not shown, or not subjected to statistical tests (see e.g., McDonald et al., 1999; Hopfinger & Magnun, 1998; 2001; Wascher & Tipper, 2004; Van der Lubbe et al., 2005; Chica & Lupiáñez, 2009; although see Prime & Ward, 2006, reporting a significant N100 modulation and significant IOR effect). In contrast, a significant enhancement of the N100 component for cued as compared to uncued trials has been associated to facilitation effects observed with discrimination tasks (see Eimer, 1994; Martín-Arévalo et al., submitted). Indeed, Eimer (1994) reported significant N100 amplitude modulations when a discrimination task was performed (and either significant facilitation or non-significant IOR were behaviourally observed) as compared to a detection task, where the modulations were not significant. This result is consistent with our previous work (Martín-Arévalo et al., submitted), showing modulations (contralateral to the target position) of the N100 component in discrimination tasks, but only when significant behavioural facilitation was measured. The exception in the above-reviewed studies is found in some of the Prime and colleagues' studies (Prime & Ward, 2006; Prime & Jolicoeur, 2009), demonstrating significant reductions of the N100 component for cued as compared to uncued trials, accompanied by a significant IOR effect. Note that the modulations associated with the N100 component are more likely to be contralateral or bilateral to the target position (see e.g., Hopfinger & Magnun, 1998; McDonald et al., 1999; Wascher & Tipper, 2004; Van der Lubbe et al., 2005; Chica & Lupiáñez, 2009); however, in most of the Prime et al.'s experiments, the N100 component was associated the left or right hemisphere, but not related to target position. Thus, although it is still unclear whether different manipulations can give rise to a different lateralization of the effect, differences in the experimental paradigm could be crucial for understanding these different results.

Inspection of Table 3 also reveals that an Nd component was observed in most experiments, no matter the task at hand or the behavioural effect that was measured. However, the neural origin and functional significance of this component are unclear, and its meaning, latency, and topography are not consistent between studies. Thus, while Eimer (1993; 1994) found this component at midline electrodes, and interpreted it in terms of selection or enhanced sensory processing of attended locations, related to facilitation effects (see Martín-Arévalo et al, submitted, for similar finding and interpretations), other authors related the component to a early sensory refractoriness (McDonald et al., 1999). Concretely, McDonald et al. (1999) showed that peripheral cues sometimes appeared to reduce the amplitude of the P100 component and some other times appeared to lead to a cued-uncued difference that lasted longer than the P100 component (which they called Nd; see also Prime & Ward, 2004; 2006; Prime & Jolicoeur, 2009). Moreover, Wascher and Tipper (2004) associated the parietal Nd component to the activity of a facilitatory process that might be compensating for earlier perceptual inhibition on cued locations. Taken all this evidence together, the available data seem to allow no firm conclusions about this component, requiring additional research.

The N2pc component is related to attentional selection of the target location, and is a crucial component to prove or refute attentional versus perceptual theories about IOR. While the attentional theory presumes that attentional selection will always be impaired at the cued location (as reflected by the target-locked N2pc component), perceptual theories do not make such prediction, being the most relevant process underlying IOR the perceptual impairment at cued locations as compared to uncued locations (reflected on the P100 component modulation, and associated to a detection cost according to the event integration-segregation hypothesis, Lupiáñez, 2010, or to an habituated response according to the habituation theory, Dukewich, 2009; see also Berlucchi, 2006, for a review). A review of the literature demonstrates that the N2pc component is not always associated to IOR. The component is only reported in localization (see McDonald et al., 1999; Yang et al., 2009) or discrimination tasks (Martín-Arévalo et al., submitted), in which target spatial selection is a necessary process for correct performance. However, in the present detection task, target spatial selection is not necessary, as detecting the target onset is sufficient for correctly performing the task. This speculative interpretation, in which the N2pc component would only be observed if target spatial selection is necessary, could explain the absence of this component in the present study (i.e., detection task) and its appearance in the previous ones (i.e., location and/or discrimination tasks).

Finally, cue-related activations did not show significant differences in the modulation of the N2pc component when the intervening event was present or absent, leading to the same attentional selection-set before target appearance, and even before the onset of the intervening event, according to the behavioural IOR effect that was measured in both conditions.

Conclusion

The present results clearly suggest that early perceptual processes (as reflected by the P100 component modulations) are always impaired by the very appearance of the cue at long SOAs, no matter the conditions at which it is measured (i.e., detection or discrimination tasks) and no matter the behavioural effect observed (see e.g., Posner & Cohen, 1984; McDonald et al., 1999; Berlucchi, 2006; Chica & Lupiáñez, 2009; for consistent explanations about this effect). In detection tasks, the IOR effect could be related to the perceptualdetection cost reflected on the P100 component. In discrimination tasks, the behavioural effect that is measured (i.e., facilitation or IOR), seems to be related to the added modulation of peripheral cueing on later-stage components (namely N100, Nd; such as it is summarized in the Table 3), and to the changes in attentional selection process (as reflected in the N2pc component) (see Martín-Arévalo et al., submitted). Thus, the appearance of some of these components (namely N100, N2pc, and Nd) seem to be dependent on the task at hand: in the detection tasks, where the occurrence of early facilitation is difficult to observe (see e.g., Collie, Maruff, Yucel, Danckert, & Currie, 2000; Mele, Savazzi, Marzi, & Berlucchi, 2008), these components are usually not generated, because they are related to spatial selection benefits that are not required for detection tasks, but highly relevant for discrimination tasks.

Chapter IV

General Discussion

The general aim of this thesis was to investigate the mechanisms and electrophysiological basis of exogenous spatial attention (facilitation and IOR), once discarded the generally accepted hypothesis that the facilitation and IOR effects are simply the consequence of the orienting of attention and the subsequent inhibition of its return to the previously attended location. In particular, we were interested in specifying the stages of processing modulated by intervening events presented between the cue and target, depending on task demands. These variables are known to strongly modulate cueing effects, allowing us to test our alternative explanation (Lupiáñez, 2010; Lupiáñez, Martín-Arévalo, & Chica, 2013), which would lead to a better comprehension of exogenous spatial attention effects. In order to achieve these goals, several experiment series were carried out, which provided important results that will be summarized below.

Furthermore, we will briefly review the main proposed mechanisms underlying cueing effects, in order to make explicit the inconsistencies with the present results. In addition, we will also present the neural basis of the exogenous attention in order to frame our interpretative model on the current neural framework of exogenous attention. Then, we would like to go one step further and relate the present results with the neuromodulators underlying exogenous attention, and end with some speculative ideas about future research.

Summary of the empirical evidence presented in the thesis

In the first study of this thesis (Experimental Series 1; Martín-Arévalo, Kingstone, et al., 2013), we studied the independence of IOR from exogenous spatial orienting. Previous studies had reported dissociations between the endogenous orienting of spatial attention and the IOR effect (see e.g., Berger et al., 2005; Chica et al., 2006); but the question about whether exogenous disengagement might lead to IOR still remained open. To figure out this issue, we created a paradigm in which a peripheral non-predictive cue was fully crossed with a non-predictive central cue (a gazing face or an arrow, stimuli known to generate reflexive orienting), in order to dissociate the effects of automatic spatial cueing (generated by the spatially non-predictive peripheral cue) from automatic spatial orienting (generated by the spatially non-predictive central cue). Importantly, the peripheral cue was presented before the central cue, thus manipulating whether attention was automatically disengaged or not from the peripherally cued location, by the automatic effect generated by the very appearance of the central orienting cue. The results showed a clear dissociation between the IOR effect generated by the non-predictive peripheral cue and the facilitatory automatic orienting effect generated by the central non-predictive cue across three different experiments, in which the type of central orienting cue (i.e., arrow or gaze) was manipulated between participants, between blocks, or randomly within-blocks (Experiment 1, and Experiment 2A and 2B, respectively). These results allowed us to conclude that the IOR effect is not produced by spatial orienting, either endogenous or exogenous, and by extension, it cannot reflect the inhibition of the return of attention to a previously attended location, as it is assumed by the extended reorienting hypothesis about the IOR effect (Klein, 2000).

Once we demonstrated the independence of the IOR effect from spatial orienting, and it being established that cueing effects (facilitation and IOR) cannot be explained by the engagement or disengagement of spatial attention (see also Lupiáñez, 2010; Lupiáñez et al., 2013), a further aim of our research was to explore the function of intervening events, if it is not related to the disengagement of attention. To this purpose, we jointly manipulated the presence of intervening events together with some variables such as target duration and the task at hand (detection, discrimination, and go-no go task), given the importance of the effects of these variables on the presence (or absence) of IOR and facilitatory effects (Experimental Series 2; Martín-Arévalo, Chica, & Lupiáñez, 2013). The results revealed that the IOR and facilitatory effects were modulated by target duration and the presence/absence of intervening events depending on the task at hand. Concretely, when the target was presented until response, the presence of an intervening event made the cueing effect more negative in all tasks, although facilitation in the absence of intervening event was only observed in discrimination and go-no go tasks. When target duration was 50 ms, intervening events only modulated cueing effects in the discrimination and go-no go tasks. Finally, target duration had no effect at all in the discrimination task, but it did in detection and go-no go tasks. In summary, the manipulation of target duration and intervening event, in a general way, produced similar effects; both target duration of 50 ms and the presence of the intervening event led to more negative cueing effects (i.e., IOR and/or less facilitation effect), while target duration until response and intervening event absent led to more positive cueing effects (i.e., facilitation and/or IOR effect), although the modulations depended on the task at hand. These findings are in good agreement with the "*cue-target event integration-segregation hypothesis*" (Lupiáñez, 2010; Lupiáñez et al., 2013), where it is assumed that the IOR effect mainly reflexes the fact that targets at the cued location poorly capture attention, since the presence of the peripheral cue produces a detection cost to detect the appearance of a "new" object in that specific location. Facilitation, on the other hand, mainly reflexes the benefit of the integration of cue and target within the same object file for further discrimination processes. According to this general framework to explain spatial cueing effects, variables that increase the contribution of detection processes to target processing, such as short target durations, detection tasks, and/or the presence of an intervening event, lead to larger IOR; while variables increasing the contribution of integration/discrimination processes to target processing, such as long target durations, discrimination tasks, and/or the absence of an intervening event, would lead to larger facilitatory effects (as it was the case in the Experimental Series 2; Martín-Arévalo, Chica, & Lupiáñez, 2013). The results of this experimental series lead us to conclude that the magnitude, and even the sign (facilitation or IOR), of cueing effects are modulated by target duration and the presence/absence of an intervening event, depending on the task at hand. These data are clearly consistent with other hypotheses (see e.g., Lupiáñez, 2010; Dukewich, 2009) rather than with the classic "reorienting hypothesis" of IOR.

In Experimental Series 3 (Martín-Arévalo et al., submitted-a), we further explored the electrophysiological ERP modulations of exogenous attention by intervening events in situations where they produce the maximum modulation on behavioural effects. In particular, we used a cue-target discrimination paradigm in which the presence/absence of an intervening event produced opposite effects on RTs: facilitation in the absence of the intervening event, and IOR when the intervening event was presented. Thus, the use of this paradigm while recording ERP components was very useful for determining the stages of processing influenced by the intervening event manipulation. Importantly, if both facilitation and IOR effects were explained by the same mechanism (as it is assumed by most researchers in the attentional field according to the reorienting hypothesis), then we would expect a direct relationship between early occipital ERP components and the behavioural effect measured. However, if several mechanisms underlie spatial cueing effects (Lupiáñez, 2010), only some of them would be affected by the presence of the intervening event, whereas other ERP components might be independent of the intervening event manipulation. The results clearly supported this alternative assumption. Peripheral cues always produced a detection cost (reflected in a reduced amplitude of the P100 component for cued as compared to uncued trials), independently of the behavioural effect that was measured. In contrast, facilitation and IOR effects were related to the modulation of later-stage components (namely N100, Nd, and P300), and were also reflected in modulations associated to attentional selection (reflected in the N2pc component). Concretely, facilitation (in the absence of the intervening event) was associated to modulations of all the above-mentioned components, while the IOR effect (when the intervening event was presented) was related to a lack of modulations on the N100, Nd, and P300 components, but it was associated to changes in attentional selection (as revealed by the N2pc). These results reveal that changes in the amplitude of early occipital ERP components associated to facilitation and IOR do not support the hypotheses that both facilitation and IOR can be explained by the same mechanism, namely, the orienting-reorienting of attention (Klein, 2000; Prime & Ward, 2004; Prime & Jolicoeur, 2009). We consider that the P100 reduction for cued as compared to uncued trials is related to the *detection cost* suggested by Lupiáñez's model (2010), and is generated by the very appearance of the cue, which together with a hindered attentional selection (reflected on the N2pc) at the cued location might determine the IOR effect that is measured. The cueing modulation on other later-stage ERP components might be related to the presence/absence of the *spatial selection benefit*, and therefore, determinate the facilitatory effects of cueing. The results of this experimental series lead us to conclude that facilitation and IOR arise from changes at different stages of processing. Again, our results spoke against the reorienting hypothesis of IOR.

Finally, the last aim of the present thesis was to explore whether the modulation of exogenous attention by intervening events, related to both early and late stages of processing, would depend on task demands. Concretely, if the *cue-target event integration-segregation hypothesis* were correct (Lupiáñez, 2010; see also Lupiáñez et al., 2013), in detection tasks, detecting target onset will be sufficient for correctly performing the task, and therefore, the detection cost will mainly contribute to performance. Thus, the P100 component should always be reduced for cued as compared to uncued targets, reflecting the first detection cost, and no modulations associated to higher level perceptual processing (related to N100, Nd, and P300 modulations) and/or related to attentional selection of spatial locations for further processing (indexed in the N2pc component), should be observed. In Experimental Series 4 (Martín-Arévalo et al., submitted-b), we tested this prediction using a detection paradigm in which the presence/absence of an intervening event did not modulate the behavioural cuing effect, leading to IOR when the intervening event was present and when it was absent. The results revealed that the P100 component was reduced for cued as compared to uncued trials independently on the presence/absence of an intervening event. This was consistent with our previous results discussed in Experimental Series 3, demonstrating that, after a long enough SOA (i.e., ~500 ms), early perceptual or sensory processes (indexed by P100 modulations) are impaired for cued as compared to uncued trials, no matter whether the behavioural effect is either IOR or facilitation, and no matter whether intervening events are present or absent. The P300 component was enhanced (but presented a longer peak latency) for cued as compared to uncued trials, and this was similarly observed when the intervening event was present or absent. We hypothesised no modulations associated to higher level perceptual processing (related to N100, Nd, and P300 modulations) and/or related to attentional selection of spatial locations for further processing (indexed in the

N2pc component), and no modulation of these components were observed. These components were not even generated in the present detection task, indicating that the appearance of these later-stage components seem to be dependent on the task at hand. We interpreted these later-stage components as related to *spatial selection benefits* that, not being required for detection tasks, are not even observed.

Taken the four experimental series together, the main results of the present dissertation could be summarized in some highlights:

- Exogenous cueing effects are independent of exogenous orienting-reorienting (disengagement) of attention.
- Facilitation and IOR depend on some relevant variables such as task demands and the presence/absence of intervening events between the cues and target; these variables seem to be related to the contribution of the detection cost and spatial selection benefits to overall performance according to our general framework for understanding exogenous cueing effects (Lupiáñez, 2010).
- Both detection cost and spatial selection benefits, and therefore, respectively, the underlying IOR effect and facilitation effects, are reflected on different stages of processing. The former would be reflected on modulations of early stages of processing (reflecting the loss of novelty of the target, and therefore its reduced capacity to capture attention), while the later would be reflected on later stages of processing (as a reflect of integration processes).

Proposed mechanisms underlying cueing effects

A variety of accounts have been proposed to explain how cueing effects are generated (see e.g., Taylor & Klein, 1998; 2000, for reviews; see also Gabay, Chica, Charras, Funes, & Henik, 2012). Most of these accounts have been reviewed throughout the different experimental series, and for this reason, only a summarised review will be provided below, being the main goal of this review to underline the consistencies and inconsistences with our main results.

The most influential account to explain cueing effects is based on Posner et al.'s (1985) "reorienting hypothesis". This hypothesis assumes that both the facilitatory and IOR effects are explained by the same mechanism: the orienting and reorienting of attention, respectively. Spatial attention has been associated to modulations of perceptual processing (Luck, 1995), which leads to the assumption that facilitation effects should be associated with an enhancement of perceptual processing at the cued location as compared to uncued locations, while the IOR effect will be related to an impaired perceptual processing at the cued location as compared to the uncued location. Although this inherent assumption has been confirmed by some pieces of evidence (see e.g., Luck, 1995; Prime & Ward, 2004; Prime et al., 2006), the general pattern of data observed in the current thesis and in many other studies (see also Dukewich, 2009; Lupiáñez, 2010; see also Berlucchi, 2006, for a review) clearly argue against it. The fact that the modulation of cueing over the P100 component in the discrimination task (where we observed IOR or facilitation as function of the presence/absence of an intervening event, respectively) was equal in both conditions highly challenges this interpretation. Moreover, the lack of N100 component in the detection task (where IOR was measured) also challenges this interpretation, because it is assumed that a reduction of this component should be observed when IOR is behaviourally observed. Note that the N100 modulation has been associated to attentional benefits, whereas the P100 modulation has been associated to attentional costs (Lasaponara, Chica, Lecce, Lupiáñez, & Doricchi, 2011). Therefore, if IOR were the other side of the attentional orienting coin, the N100 modulation measured when facilitation is observed should be reversed when IOR is instead observed. However, no such results were observed in our Experimental Series 3 and 4.

Other perceptual mechanisms have been postulated to explain the IOR effect (Chica et al., 2006; Milliken, Tipper, Houghton, & Lupiáñez, 2007; Dukewich, 2009; see also Experimental Series 4 for a explanation of these hypotheses). In particular, as it was previously mentioned, Berlucchi (2006) assumed that "the RTs inhibition may result because the response of the visual system to the target is reduced by the previous stimulation from the cue, independent of orienting, and this is a bottom-up, sensory effect" (p. 1066). This implies that the IOR effect is related to sensory rather than attentional mechanisms, as originally assumed by Posner and Cohen (1984). Our results are consistent with the proposal of a perceptual mechanism underlying the cueing effect. However, they are not consistent with the main assumptions from this interpretation framework, where facilitation and the IOR effect should be directly reflected on the modulation of the P100 component.

Non-perceptual effects have also been suggested, assuming that the IOR effect arises from changes in response-related processes (Klein & Taylor, 1994; 1998). The response-related effects can be produced at several stages of processing, such as changes on decisional stages of processing (see Klein & Taylor, 1998, for an explanation in terms of criterion shift; Prinzmetal, Taylor, Barry Myers, & Nguyen-Espino, 2011, for an explanation in terms of an accumulator model), or motor programming, IOR being caused by the inhibition of a previously prepared movement (to the cue), generated by the activation of an oculomotor program (Rafal, Calabresi, Brenen, & Sciolto, 1989; Prime & Ward, 2004; but see Chica, Klein, Rafal, & Hopfinger, 2010). Related to changes on decisional stages, within the context of the Prinzmetal and colleagues' model (2011), where the IOR effect was accounted for as change in the decision threshold (after the cue was presented the threshold is raised at the cued locations), our observation (in the detection task, where IOR was always observed) of an earlier peak in the P300 component for uncued targets as compared to cued targets might reflect this change in the decision threshold. In our view, this could be determined from early stages of processing; concretely, from the P100 modulation that already the detection cost, produced by the previous processing of the same location/object.

Moreover, in relation to the motor programming hypothesis, the oculomotor system seems to have a key role in generating IOR. Taylor and Klein (2000) showed that the IOR effect could affect either attentional/perceptual or motor processes, depending on whether the oculomotor system was in a quiescent (covert attention) or in an active state (overt attention), respectively. Afterwards, Chica, Taylor, Lupiáñez, and Klein (2010) proved that when the oculomotor system was restricted, the IOR effect affected perceptual but not motor processes (see also Hunt & Kingstone, 2003; Prime & Ward, 2004; for consistent results). This evidence provides support for the proposition that at least partly different mechanisms would be responsible for manual and saccadic IOR (Bourgeois, Chica, Migliaccio, Thiebaut de Schotten, & Bartolomeo, 2012; Bourgeois, Chica, Valero-Cabré, & Bartolomeo, 2012), indicating the existence of a functional dissociation between overt and covert attention (e.g. Taylor & Klein, 2000; Hunt & Kingstone, 2003; Sumner, Nachev, Vora, Husain, & Kennard, 2004). Thus, motor programming might account for only "the motoric flavour" of the IOR effect, and this effect might probably involve a multiplicity of different mechanisms. In the present thesis we focused on covert attention paradigms, and therefore, our results do not add much to this discussion.

In summary, several pieces of evidence (some reviewed above) has led several researchers to propose that IOR might arise from multiple mechanisms and from the modulation of multiples stages of processing (e.g. Rafal et al., 1989; Kingstone & Pratt, 1999; Taylor & Klein, 2000; Hunt & Kingstone, 2003; Berlucchi, 2006). In particular, as we have proposed through the present thesis, the model proposed by Lupiáñez (2010; see also Lupiáñez et al., 2013), the "*object file segregation/integration hypothesis*", is a good attempt to accommodate most of the results we observed. It is assumed that peripheral cues trigger exogenous spatial orienting of attention, improving target perception and/or responses to it (being this 'spatial orienting' process almost the only one usually considered for explaining cuing effects in the previous literature). However, a peripheral cue is an event occupying a specific location, which can lead to other effects on the processing of subsequent stimuli appearing at the same location. Targets appearing in close spatiotemporal proximity might be integrated within the same object file (Kahneman, Treisman, & Gibbs, 1992), thus being more easily selected for further analysis. Hence, the cue–target integration process would facilitate processing by helping to select the target location in advance (reflecting the “spatial selection” benefit); but the integration of the target within the cue representation, as part of the same event, (or just the very presence of the cue object file, independently of whether the target is integrated or not in the same file) would also produce a cost in detecting the onset of the target (reflecting the “detection cost”) at this spatial location. In sum, the net facilitation or inhibition of responses to peripherally cued targets that is behaviourally measured would result from the sum of spatial orienting, spatial selection benefits, and the detection cost. This interpretation has been highly consistent with the main results presented throughout the experimental series, being also widely discussed in each of them. In the following we try to accommodate this interpretation within current knowledge about the neural basis of exogenous attention.

Neural basis of exogenous attention

The different processes proposed to be triggered by peripheral cueing might be mediated by different neural systems. Neuroimaging studies, based on functional Magnetic Resonance Imaging (fMRI), have provided evidence for two segregated systems for visual-spatial attention: a *dorsal fronto-parietal network*, bilaterally represented (supporting endogenous, goal-driven attention), and involving dorsal frontal and parietal regions, including parts of the intra-parietal sulcus (IPS), supplementary eye field (SEF), and frontal eye field (FEF); and a *ventral fronto-parietal network*, strongly lateralized to the right hemisphere (supporting exogenous, stimulus-driven attention), and involving the temporo-parietal junction (TPJ), and the inferior and middle ventral frontal cortex (VFC) (Corbetta & Shulman, 2002). The dorsal fronto-parietal network is supposedly pre-activated by the expectation of seeing an object at a particular location or with certain features, by the preparation of a specific response, by the short-term memory of a visual scene, and also involved in linking relevant stimuli to responses, being modulated when people change their motor plan for an object (see Corbetta & Shulman, 2002, for a review). The ventral fronto-parietal network, however, is not activated by expectations or task preparation, but it detects and responds to relevant (specially when unattended) and behaviourally salient stimuli in the environment.

Therefore, Corbetta and Shulman (2002) assumed that endogenous and exogenous attentional orienting would be implemented in the dorsal and the ventral network, respectively. Nevertheless, in their more recent proposal (see Corbetta, Patel, & Shulman, 2008; for a review), they suggested that both endogenous and exogenous attention would be mediated by the dorsal fronto-parietal network, while the ventral fronto-parietal network would be involved in spatial re-reorienting when relevant targets appear at unexpected locations. In particular, when attention is reoriented towards a new source of information (stimulus-driven reorienting), the ventral network would interrupt the ongoing selection of information in the dorsal network (either endogenous or exogenous), acting as a "circuit-breaker", and therefore, shifting attention towards new and potentially relevant objects. Thus, both dorsal and ventral systems dynamically interact during normal perception to determine where and how to attend in order to maintain a coherent behaviour (Corbetta et al., 2008). In particular, some studies have shown that regions related to the dorsal network contain topographic-dimensional maps that allow encoding the saliency of objects, while no such regions have been reported in areas related to the attentional ventral network (see Silver & Kastner, 2009, for a review), supporting, therefore, that dorsal and ventral systems should interact during reorienting responses.

Evidence from right brain-damaged patients and spatial neglect also support this interaction of dorsal and ventral networks during reorienting of attention. Spatial neglect is a multi-component syndrome, associated to right parietal lesions (Brain, 1941; Vallar & Perani, 1986), or right fronto-parietal disconnection (Bartolomeo, Thiebaut de Schotten, & Doricchi, 2007; Bourgeois et al., 2012a). It is characterized by a rightward attentional bias, classically defined by a failure to attend, respond, or orient attention to stimuli appearing in the contralesional hemispace (Heilman & Vanlenstein, 1979). In particular, it is related to attentional orienting impairments concerning mainly exogenous orienting, while endogenous attention seems to be relatively preserved (see Bartolomeo & Chokron, 2002; for a review). Usually, neglect patients demonstrate facilitation instead of the expected IOR effect for repeated right-sided targets (Bartolomeo et al., 1999; Bartolomeo et al., 2001; Bourgeois et al., 2012a). Several results suggest that attentional, rather than motoric mechanisms, are particularly impaired in neglect. In particular, Bourgeois and cols. (2012a) demonstrated that patients with right brain-damage and signs of left visual neglect had impaired manual IOR (showing an abnormal facilitation effect) for right-sided targets (see also Bartolomeo et al., 1999; Bartolomeo et al., 2001; Vivas, Humpheys, & Fuentes, 2003; for similar results), while saccadic IOR was preserved (see also Làdavas, Zeloni, Zaccara, & Gangemi, 1997; for dissociation between mechanisms subserving attentional and saccadic orienting). These results support the previous above-mentioned literature demonstrating two types of IOR (Sumner et al., 2004; Chica et al., 2010; Taylor & Klein, 2000): saccadic IOR, that appears to be mediated by the retino-tectal pathway, with an key contribution of the superior colliculus (SC; intact in neglect patients), and manual IOR, related to fronto-parietal regions (and damaged in neglect patients).

Importantly, the attentional deficits associated to neglect might not depend on local dysfunctions of right parietal areas, but they might rather be mediated by the dysfunction of larger and more widespread attentional networks. The neglect syndrome has been proposed to typically follow right fronto-parietal ventral lesions, while regions of the dorsal attentional networks are usually structurally preserved (see e.g., Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005). Corbetta and colleagues (2005) explored the neural correlates of neglect patients with right hemisphere damage both in subacute and recovered stages. Neglect patients at the acute stage demonstrated decreased activation of structurally intact right dorsal parietal regions (mainly the intraparietal sulcus-IPS, and the superior parietal lobule-SPL), beside substantial activation of homologous regions in the left hemisphere. While recovery was taking place, signs of imbalance between these regions were also disappearing. In fact, it has been assumed that damage to the right ventral network (mainly in the temporo-parietal junction-TPJ) might induce a hyperactivity of the left dorsal fronto-parietal network, leading to a functional imbalance between the left and right dorsal attentional networks. Therefore, this functional imbalance might underline the rightward attentional bias observed in neglect patients (see also He, Snyder, Vincent, Epstei, Shulman, & Corbetta, 2007; He, Shulman, Snyder, & Corbetta, 2007, for similar results).

Studies with non-invasive brain stimulation such as Transcraneal Magnetic Stimulation (TMS) have also provided support for the existence of two segregated systems for visual-spatial attention, with manual IOR relying on fronto-parietal attentional networks of the right hemisphere (Ro, Farne, & Chang, 2003; Bourgeois et al., 2012b). In this context, a recent online TMS study (Chica, Bartolomeo, & Valero-Cabré, 2011) provided causal evidence for the implication of the right IPS in both endogenous and exogenous attentional orienting, while the right TPJ was only causally implicated in exogenous orienting, showing a disturbed manual IOR effect upon stimulation in this area. Moreover, Bourgeois et al. (2012b) systematically compared the role of dorsal and ventral regions under both manual and saccadic responses, reporting consistent results: TMS over right IPS and right TPJ abolished manual but not saccadic IOR for right-sided targets in healthy participants (a result that mimics fairly well the performance patterns found in left neglect patients with damage to the right inferior parietal lobule or its connections to the ipsilateral prefrontal cortex, Bourgeois, et al., 2012b). Left IPS or TPJ stimulation, however, did not affect either manual or saccadic IOR (Bourgeois, Chica, Valero-Cabré, & Bartolomeo, submitted).

Neural support to our interpretation model

The results described above demonstrate that the parietal lobe seems to be specifically relevant for the detection of novel and behaviourally relevant stimuli (Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Indovina & Macaluso, 2007). In particular, Indovina and Macaluso (2007) showed that unattended targets of low perceptual salience (but relevant for task-demands) activated regions in both dorsal and ventral attention networks to a much greater degree than highly salient but irrelevant stimuli. Thus, relevance seems to be a critical factor to activate the reorienting network more than the saliency of stimuli per se. In addition, Kincade et al. (2005) also demonstrated that the right TPJ was strongly modulated by relevant stimuli related to target processing but not by salient but task-irrelevant stimuli.

The absence of manual IOR for right-sided targets after TMS-induced disruption of the right TPJ (and/or injury in neglect patients; Corbetta et al., 2005; Bartolomeo et al., 2007; Bourgeois et al., 2012a; 2012b) suggests a causal association between the IOR effect and TPJ activation. If the appearance of the IOR effect, as we have assumed in the present thesis, is related to a lost of novelty, or a detection cost, for targets presented at a previously stimulated location, and if damage to right hemisphere ventral regions (mainly the TPJ and the ventral frontal cortex) impairs attentional functions such as arousal, reorienting, and detection of novelty/relevance (Corbetta et al., 2005; 2008; Kincade et al., 2005; Indovina & Macaluso, 2007), it could allow us to propose that the IOR effect might reflect the habituation of the reorienting response, mainly implemented in TPJ activation. When TPJ is deactivated (either by a real injury, as it is case of neglect patients, or by the transient inactivation produced by TMS) no covert IOR is observed. Thus, the abolition of manual IOR after right parietal injury could be interpreted as an abnormal processing of novelty (or abnormal habituation to "old" stimuli), which causes attention to be perseveringly oriented to the previously attended location (Downar, Crawley, Mikulis, & Davis, 2000; Asplund, Todd, Snyder, & Marois, 2010).

In a risky-attempt to relate the results of the present thesis with the neural network model predominant in the literature (Corbetta et al., 2008), we propose that the spatial selection benefits proposed by Lupiáñez’s model (2010) might reflect the effects of the ongoing-orienting of attention implemented in the dorsal network (either on the basis of endogenous spatial expectations or, especially in the case of exogenous attention, on the basis of the relevance of external stimuli). On the cue-target exogenous paradigm, target relevance might be mainly dependent on task demands. If the nature of target itself is relevant for the task at hand −as in discrimination tasks−, this relevance would lead to further target processing, being integrated as part of the cue object-file. In this case, these on-going effects might be reflected in late-stage processes (as in our case, N100, Nd, and P300 component modulations in the discrimination task when facilitation is behaviourally observed). If target identity is completely irrelevant, however, as in detection tasks, these processes would not take place, perhaps not even being generated (as we found in the detection task, Experimental Series 4, where an IOR effect was always measured). Importantly, in this context, intervening events might act as a "circuit-breaker", interrupting cue-target integration by the activation of the ventral fronto-parietal network, and leading to a larger contribution of the detection cost to performance. Thus, because the functioning of the ventral system is based on perceptual saliency,, if the target appears at an uncued location, it would be unexpected and "new" for the system, leading to the ventral network activation and therefore, to faster responses; however, if the target appears at a cued location, it would not be as "new", and therefore, the ventral fronto-parietal network will produce a smaller or habituated response, leading to the appearance of the IOR effect. In particular, the *detection cost* might reflect the habituation of the ventral fronto-parietal network (understood as the consequence of its activation) when it has been triggered by a previous event (i.e. the cue in the cue-target procedure). This habituation might be reflected in sensorial activity, as indexed by the reduction on the P100 component for cued trials (i.e., "old events" that have already been processed are considered less novel by the system and therefore, less relevant) as compared to uncued trials (i.e., "new events" that might generate a new attentional capture in the ventral network). In other words, we speculatively link the IOR effect with the activation of TPJ; that is, when an unexpected or irrelevant stimulus is presented (the cue, in a cue-target paradigm), TPJ would be activated in order to process this location. However, when the target appears at the same location than the cue (after a relative long cue–target SOA), it would not be "new"/relevant for the system, and therefore, a smaller activation on TPJ is expected. The IOR effect might be considered as consequence of this hindered (i.e., habituation) TJP response, and it might be reflected on the P100 component modulation. As we observed in our results, the P100 component was always reduced for cued trials as compared to uncued trials, independently of the behavioural effects (and therefore, independently of the task at hand and intervening events), perhaps reflecting this habituation produced by the very appearance of the cue at the same position that the target.

Links between neuromodulators and the reorienting response

Several neuromodulators, such as dopamine (DA) and norepinephrine (NE), have also been linked to the processing and/or detection of unexpected and relevant events (Dayan & Yu, 2006), and their putative function might be similar to that proposed for the ventral attention network (see

Corbetta et al., 2008, for a review). However, while DA appears not to play an important function in reflexive attention using peripheral cues (Ward & Brown, 1996), NE has been highly related to orienting effects (Witte & Marrocco, 1997). Indeed, studies in monkeys have reported evidence for high-density innervations of NE on homologues areas to the human TPJ, as the inferior parietal cortex and the superior temporal gyrus (Morrison & Foote, 1986; Foote & Morrison, 1987).

The majority of brain NE neurons are concentrated in the brainstem nucleus and locus coeruleus (LC), and this NE-LC system exerts a widespread influence on neuronal circuits that are essential substrates of alert waking and state-dependent cognitive processes, such as perceptual, attentional, and memory processes (see Aston-Jones & Cohen, 2005, for a review). In particular, LC neurons fire in two distinct activity modes: *tonic* and *phasic*. Tonic activity is characterized by relatively low-frequency, sustained, and highly regular discharge patterns, and importantly, it is state-dependent: LC neurons display highest discharge rates during waking (associated with enhanced attention and sensitivity to environmental stimuli); discharge rates are lower during slow-wave sleep, and are virtually silent during REM or paradoxical sleep (Foote, Aston-Jones, & Bloom, 1980). Thus, this state-dependent activity enables transitions between them, such as focused alertness, exploratory states, unaroused, and/or sleep-state.

Moreover, within waking (and dependent on this tonic-state), LC neurons also display phasic alterations in discharge rates in response to salient sensory stimuli (Foote et al., 1980; Aston-Jones & Bloom, 1981). ERP studies provide additional support for this assumption. As we mentioned throughout the present dissertation, the P300 component is elicited in response to novel and/or task-related stimuli. Although the origin of the widely-distributed P300 component has not been yet determined (Luck, 2005), some evidence suggests that the LC–NE system, with its anatomical and physiological properties, represents a candidate system for the modulation of this component (Aston-Jones & Cohen, 2005; Nieuwenhuis, Aston-Jones, & Cohen, 2005). For example, inhibition of LC firing and NE release with systemic administration of an agonist, such as clonidine, decreases the amplitude of the P300 component (Swick, Pineda, & Foote, 1994). In addition, bilateral LC lesions in monkeys also led to P300 reductions for infrequent tones (Pineda, Foote, & Neville, 1987). Thus, these results further suggest an important role of the LC–NE system in the modulation of cortical responsiveness to sensory information and the modulation of attentional processes.

Several studies conducted in rodents, monkeys, and humans largely support this hypothesis (see e.g., Oke & Adams, 1978; see also Mehta, Shakian, & Robbins, 2001, for a review). In particular, the LC–NE system seems to be especially sensitive to novel environmental stimuli. Indeed, enhanced LC discharge rates were observed when rats encountered novel stimuli (Vankov, Herve-Minvielle, & Sara, 1995). In addition, pharmacological manipulations that enhance NE release also increased physical contact/interaction with a novel stimulus located within a familiar environment (Devauges & Sara, 1990). Overall, it is also known that LC–NE neurotransmission impacts attentional and other cognitive tasks under conditions associated with high-demand and/or increased arousal (see Mehta et al., 2001). These assumptions seem consistent with our results regarding the modulation of the P300 component observed in the detection task. We speculate that our detection paradigm (where the target had a short duration and, specially, when the intervening event was present) might be a highly demanding situation, where the participant' s arousal might be enhanced by task-demands. We propose that short target durations would emphasize the need for the target to be detected, because it quickly disappears, making the task more demanding (the presence of the previous peripheral cue and the intervening event might further contribute to it). Supporting this proposal, we found that the P300 component peaked earlier for uncued trials as compared to cued trials, consistently reflecting the processing of the unexpected/novel location (as it is the case of the uncued locations on the cue-target paradigm). However, in the discrimination task, where the target was presented until response (allowing the accumulation of information over time, and therefore, making target detection less demanding), such modulation was not found.

Importantly, Corbetta and cols. (2008) have proposed a functional relationship between signals of the LC-NE system and activity in the ventral attention network, both in relation to the transitions between states (related to tonic states) and target detection (related to phasic states). In particular, they established that the decreases in tonic activity during the transitions from high discharge rates (related to the exploratory state) to low discharge rates (related to the task-focused state) might be similar to the deactivations of TPJ when subjects engage in a task (Shulman, McAvoy, Cowan, Astafiev, Tansy, d' Avossa, & Corbetta, 2003); while high tonic activity (related to the exploratory states) might correspond to the ability of any salient stimulus to activate TPJ (Downar, Crawley, Mikulis, & Davis, 2001). We speculate that these relations might support our assumptions related to task-demands; high detection demands (detection task, short target duration, and the presence of intervening events) might be related to phasic activity and TPJ activity, and being more susceptible to habituation, while that low task demands (discrimination task, target duration until response, and the absence of intervening events) might be related to low discharges rates, and therefore, to the possibility of accumulating information over time that is related to the facilitation effect. As mentioned above, this interpretation is consistent with the fact that several brain areas related to the ventral network have strong projections to the LC (see e.g., Corbetta et al., 2008; Foote & Morrison, 1987).

Future research

Understanding the nature and the exact interactions between the brain systems and the behavioural effect that we observe is the main purpose of Cognitive Neuroscience. In our opinion, understanding the roles that the Parvocellular (P) and Magnocellular (M) retino-geniculo-cortical pathways play in spatial processing might shed some light to the relationship between spatial attention and its underlying neural circuits.

P and M cellular channels can be differentiated in terms of their temporal response properties. P cells exhibit slower and sustained responses compared with M cells, which show fast and transient responses (Callaway, 1998; De Valois, Cottaris, Mahon, Elfar, & Wilson, 2000). Moreover, the relatively slow responding of the P-pathway provides the dominant feedforward input to the ventral-temporal system, the so-called "what" stream, which plays an important role in the processing of color, texture, shape, and high spatial frequency (i.e., related to detailed information and/or information related to discrimination processes). The relatively fast responding of the M-pathway provides the dominant feedforward input to the dorsal-parietal system, the so-called "where" stream, playing a relatively greater role in processing location, movement, and low spatial frequency (i.e., lower resolution information and/or information more related to detection processes) (Derrington and Lennie 1984; Lee 1996; Brown & Guenther, 2012). Thus, the M-pathway might be an early entry of visual processing (Bullier 2001, 2006) related to the deployment of visual attention (Vidyasagar, 2005). However, despite the distinction between M/dorsal and P/ventral pathways, it is important to note that there is not a total dichotomy between the two systems, as "neuro-anatomical data indicate that the M-afferents provide the dominant, but not exclusive, inputs to the dorsal ("where") pathway, whereas P-afferents provide the dominant, but not exclusive, inputs to the ventral ("what") pathway” (Breit- Meyer & Ogmen 2006, page 144).

Several studies have examined the influence of spatial (e.g., cue and target spatially overlapped; Collie, Maruff, Yucel, Danckert, & Currie, 2000) and temporal (e.g., cue and target duration; Martín-Arévalo et al., 2013; and/or temporal overlap between cue and target; Collie et al., 2000) parameters on cueing effects, and particularly on the IOR effect. However, only a few have so far manipulated these stimulus parameters to specifically test for the influence of a type of stimulus on the processing on the M and P-cellular channel (e.g., low or high spatial frequency stimulus, respectively) on the IOR effect(e.g., Sumner et al., 2004; Sumner, 2006). Although some studies have explored the relationship between the IOR effect and the information processing related to these information pathways (Sumner 2006; see also Brown & Guenther, 2012, for an illustrative example), further research would be essential for integrating results from different experiments and different approaches. Importantly, on the basis of these observations, it is also possible that the modulation of eccentricity over the IOR effect, shown by some studies (Bao & Pöppel, 2007; Bao, Sander, Trahms, Pöppel, Lei, & Zhou, 2011; Bao, Wang, Liang, Wang, Pöppel, & Li, 2013) were originated from differential implication of cortical mechanisms related to these P and M-pathways. Bao and Pöppel (2005) examined the effect of stimulus eccentricity on IOR. They reported a significant IOR effect for all stimulus eccentricities, but the size of the effect strongly increased at peripheral regions as compared to central and perifoveal regions (see Bao et al., 2011; Bao et al., 2013, for similar results). Several studies (see e.g., Pöppel, von Cramon, & Backmund, 1975; Stoerig & Pöppel, 1986) suggest that the neuronal processing modes for stimuli appearing at central-perifoveal and peripheral regions of the visual field are qualitatively different, and these results might be related to differences in the processing of the the P and M-pathways. As we have mentioned above, low spatial frequency would be mainly processed by the M-pathway, being highly linked to the periphery, where less spatial resolution is assumed by the low density of cones (they are mainly concentrated in the central areas) and by high density of rods, which predominate in peripheral vision. Thus, while visual acuity or spatial resolution is much better with the cones (related to the discrimination carried out by the P-pathway), the rods are better motion sensors and are more efficient to detect changes. This might fit with the type of processing carried out by the M-pathway, and therefore, with the alleged relationship between M-pathway and the IOR effect that we have speculated.

Moreover, given that the amygdala receives M-cellular type visual input and projects to the visual cortex (Amaral, Behniea, & Kelly, 2003), it seems reasonable to assume that the presentation of emotional cues and/or targets would modulate information processing on this M-pathway. This modulation can occur for having to respond to these emotional stimuli, or just because of the task-set generated for the presentation of the emotional events, even if no response to them is required. Concretely, exposure to fearful facial expression has been proved to enhance vision at low spatial frequencies but to impair vision at high spatial frequencies, which can be related to the M and P-pathways processing, respectively (see e.g. Anderson & Phelps, 2001; Phelps, Ling, & Carrasco, 2006). Recently, Bocanegra and Zeelenberg (2009) have also reported results in this line, with enhanced sensitivity for low spatial frequencies targets after exposure to fearful faces. Conversely, perception of disgust has been associated with activations on the anterior insula (Calder, Keane, Mane, Antoun, & Young, 2000), and this structure might active the P-cellular pathway (Adam K. Anderson, at the Lake Ontario Vision Establishment conference in 2012, pointed to this idea). We reckon that the association between fearful stimuli and the M-pathway processing, and the one between disgust and the P-pathway processing, is in good agreement with the meaning of both types of emotions. Namely, fearful emotions are related to sympathetic activation; it is an emotion induced by a perceived threat and it is designed to cause the perceiver to avoid the dangerous situation, requiring fast responses (Ekman, Levenson, & Friesen, 1983). In addition, the fearful emotion, taking into account the previous section, will be related to the LC-NE system, leading to enhancement of NE that might be reflected on faster detection-responses to unexpected/uncued stimuli. Disgust, conversely, involves parasympathetic activation (Levenson, 1992), and is related to a type of aversive reaction that involves withdrawing from a person or object with strong expressions of revulsion, but taking into account the stimulus at hand, in order to increase discrimination process.

Taken together the above assumptions, and from a P and M-pathways perspective, perhaps what it is called *detection cost* and *spatial selection benefit* in the Lupiáñez' s model (2010) might be related to information processing in the early M-pathway (related to target detection) and to information processing in the late P-pathway (related to discrimination processes), respectively. Thus, results such as larger IOR for eccentric as compared to foveal targets (Bao et al., 2007; 2011; 2012), with short vs. long target durations, or with detection task vs. discrimination tasks, are consistent with the processing of the M-pathway; likewise, results such as larger facilitation for long vs. short target durations, or discrimination vs. detection tasks, are also consistent by the processing of the P-pathway. In addition, we can speculate that fearful stimuli, involving the M-processing pathway, might also modulate the detection cost, while disgust stimuli, involving the P-processing pathway, might modulate the spatial selection benefits, because both process are related to detection (requiring a fast response), and to discrimination processes (requiring a further discrimination), respectively.

We have recently started a line of research on this topic in Bernard Hommel' s laboratory. We hypothesised that the presentation of fearful stimuli, where detecting the target is one of the most important processes, might induce a segregation-set between the cue and target, leading to IOR; however, disgust stimuli, where target-discrimination is one of the most important processes, might induce a cue-target integration set, leading to facilitatory effects. Our manipulations will have to disentangle whether the effect of emotional stimuli is produced by the required response to them, or by the task-set that they generate whether or not a response to them is required.

In summary, although the results of the present dissertation provide new insights into the mechanisms underlying exogenous cueing effects, and especially underlying IOR, it is clear that significantly more research is needed. Further research would be essential to understand the brain mechanisms underlying exogenous spatial orienting and IOR. Many questions have been resolved throughout the years in this field, but many other questions still remain unresolved. A better comprehension of exogenous spatial attention, taking into account behavioural, neuropsychological, neuromodulators, and imaging research would be crucial to progress in the knowledge of our interaction with the environment.

Finally, in my opinion, far from simply being a small effect, IOR might be similar to the tip of an iceberg, where at a glance, it might look just as a small chunk of ice, but that hides a whole world underneaththat we cannot directly see, but which can be understood by investigating it.We have demonstrated that IOR is not a simple effect due to the reorienting of attention, as an iceberg is not just a simple piece of ice. Perhaps a better comprehension of this effect will be achieved with a better definition. A good way of expressing it might be by recalling Berlucchi's epilogue (2006), where he re-phrased the Shakespearian dictum "*…a rose by any other name would smell just as sweet. In the same way, by any other (more appropriate) name, IOR-like effects would be equally or more fascinating to study without the passive acceptance of dubious theoretical constraints that in my opinion hinder the understanding of the facts*". I consider these words quite beautiful, more than any words of mine that I could express, to finish the present dissertation and make the reader think about what the IOR effect, a core matter in the current thesis, really represents for the attention, perception and memory literatures.

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