UNIVERSIDAD
DE GRANADA

TESIS DOCTORAL

Investigating the expression of the acoustic intensity effect in cognitive tasks involving perceptual and visuomotor control

Doctoranda

Paola Cappucci

Directores

Juan Lupiáñez Castillo

Ángel Correa Torres

Departamento de Psicología Experimental

Programa de Doctorado en Psicología

Enero 2021

Editor: Universidad de Granada. Tesis Doctorales
Autor: Paola Cappucci
ISBN: 978-84-1306-779-7
URI: http://hdl.handle.net/10481/66742

Ai miei genitori.

Acknowledgments

First, I would like to thank my tutors, Juan and Ángel, for giving me the opportunity to study this topic, for encouraging me and for the positive attitude towards our project. Without you, this thesis would not exist, and my life would not be the same. Thank you so much!

Thank you to all the research groups of the UGR, who have shared courses, talks, and helped me to grow and understand how beautiful it can be to do research.

I would also like to thank the people who have welcomed me into their laboratories during the past years and have contributed to my scientific training. A special thanks to Rico Fischer, for those four months at the Dresden University, and for having taught me how interesting it can be to study human behaviour. Thank you also to Torsten, for your friendly reception in Berlin and your support.

A big thank you goes to my old colleagues from Granada: Dafina, Maryem, Ana, Mauro, Alberto, Fabiano, Elisa, Bea, Raúl, Lina, Conchi, Francesco, Quique, Mariagrazia y Paul. Without you, my years in Granada would not be full of precious memories. I will keep you in my heart for the rest of my life.

I want to thank my people in Berlin, who in the last years supported me endlessly and made this long journey of knowledge a really nice walk. To Ilaria and Martina, for always being so nice. To Alessandra and Luigi, for being the living proof that the world of research is full of wonderful people. To Radek, who taught me to believe in my dreams, despite everything and everyone. To my past and present colleagues of NobleProg and Auto1 Fintech, who invested in me and give me a new purpose.

Dulcis in fundo: thanks to my parents, to my sister Roberta and my brother Giacomo, for the unconditional support in everything I do, wherever I am. Grazie!

Finally, a special thanks to Antti, for your patience, love and, above all, for believing in me.

Thank you from the bottom of my heart to all of you.

Paola

CONTENTS

TABLES AND FIGURES

CHAPTER 1. INTRODUCTION

CHAPTER 3. EXPERIMENTAL SERIES I

CHAPTER 4. EXPERIMENTAL SERIES II

CHAPTER 5. EXPERIMENTAL SERIES III

ABSTRACTS

ABSTRACT

An important function of attention is the ability to prepare and maintain a state of alert to process high-priority signals coming from the environment (Petersen & Posner, 2012). At the behavioural level, response preparation is observable through reaction times, which are usually faster in conditions where the imperative stimulus (target) occurs after an abrupt warning signal (WS) than in conditions without WS.

The temporal, spatial, motor and perceptual characteristics of these effects have been the subject of research in order to study how warning mechanisms can influence performance during a cognitive demand task (Callejas, Lupiàñez and Tudela, 2004; Fischer, Plessow and Kiesel, 2012; Weinbach and Henik, 2012). By controlling the probability of appearance of the target during a specific time window, it is possible to increase or flexibly modulate the preparatory state for the execution of motor response (Correa, Lupiáñez, Milliken, & Tudela, 2004; Correa, Lupiáñez, Madrid, & Tudela, 2006a). In the case of acoustic WS, the warning effect produced by a WS is strongly influenced by some characteristics which, despite being considered accessory and irrelevant, cause a more automatic responses activation, that is, a pure alerting effect. For example, it is known that reaction times are shorter when the intensity of an auditory WS increases. This phenomenon, which is usually called intensity effect, has been attributed to the influence, direct or indirect, on the earlier processes of response execution.

The main objective of our research project was to understand which mechanisms are triggered by the accessory characteristics of an acoustic WS, in particular its intensity, and the temporal information provided by the presentation of a WS, and how these mechanisms can modulate the processing of target and the response motor preparation. For this reason, we designed three experimental series, which allowed us to investigate in an optimal way the influences of the characteristics of WSs on the attentional mechanisms of alertness and cognitive control, as well as on the visual search for the target.

To investigate the role of response preparation (derived from the temporal information provided by the WS) and to understand the impact of the WS intensity level were our main objectives of the Experimental Series 1. Our main idea was that the WS could influence response times because of the temporal information about the presentation of the target, of an automatic acceleration of the response due to the intensity effect, or of the influence of both mechanisms. We studied these two factors by manipulating on the one hand the simultaneity between WS and target, and on the other hand the intensity of the WS. Knowing that a very intense sound can trigger a defensive motor response, called startle reflex (Carlsen, 2011), we differentiated between trials with a startle response and those without a startle response. We also study whether the intensity effect is influenced by the level of control demand of the task.

The results of Experimental Series I highlighted the importance of the level of task control in the expression of the intensity effect and suggested that the acceleration of response times, related to the temporal information provided by the WS, is also modulated by the level of task control. Thus, the response acceleration effect for higher intensity WS (when there was no startle reflex) was only observed in conditions of high preparation and readiness to respond. Another important result of the series was that, in the case of an automatic startling response, this response was not modulated at all by the level of task control and response preparation. The idea that the behavioural advantage derived from increased intensity depends on whether a state of response preparation is active after a WS was verified in the last experiment of the experimental series, where participants used the temporal information from WS and activated response-preparatory mechanisms. Therefore, we conclude that, although response preparation and sound intensity are dissociable and separate mechanisms, they can interact depending on the task.

The Experimental Series II was aimed at understanding the importance of WS intensity manipulation during imperative stimulus selection during visuo-spatial interference conditions. Weinbach and Henik (2012a) presented the idea that, in conditions of alerting, the attentional focus is broadened, which entails a prioritisation of peripheral information. Therefore, the alertness would be affected by the control processes when the interference increases, but only in conditions where the distracting stimuli are presented in the periphery, separated from the stimulus. In order to verify Weinbach and Henik's (2012a) hypotheses, we decided to test whether the alerting effect was reflected in the modulation of Simon task (perceptual-motor interference) and spatial Stroop task (perceptual interference). The visuospatial interferences were manipulated in a between-trials and a between-blocks experimental design. On the other hand, we wanted to dissociate the impact from the preparation mechanisms due to the intensity effect and in both experiments we manipulated the intensity of WS and the preparation effect by alternating presence-absence of WS.

In addition to the classical effects of congruence (Simon and Stroop) and alertness, our results confirmed that Simon-type perceptual-motor interference is modulated by the presence of WS and its acoustic intensity. However, Stroop-type perceptual interference was not modulated in any case by the presence/absence of WS, or by its intensity. The modulation of Simon interference, observed as a decrease or increase of the congruency effect, depending on the experimental design, was the proof of the possibility of dissociating response preparation and pure alertness mechanisms in the resolution of visuospatial interference. Since in our paradigm the targets (the direction of an arrow) and the distracting spatial characteristics (the position on the screen) were integrated in the same visual stimulus, the results did not confirm Weinbach and Henik's theory, according to which the distracting information should be separated from the target in order to observe the modulating action of the WS. Rather, the results point to the idea that, under certain conditions, attention can

increase spatial interference by inducing a stronger association with response motor execution centres (Fischer et al., 2012). From this, it derived the exclusive modulation of the Simon (perceptual-motor) interference, but not of the Stroop (perceptual) interference.

In the Experimental Series III, we try to clarify whether the behavioural advantage derived from the increase of the WS intensity affects the target selection during visual search tasks. Presenting Feature search and Conjunction search paradigms, we expected that the latter would be less efficient: since the target and distractors shared some of the characteristics, target selection would be more complicated, response times slower and directly proportional to the increase of the set size. The results confirmed our hypothesis, showing slower response times with the increase of the number of distracters in the visual scene (only in the Conjunction search task) and a higher response speed in conditions of higher WS sound intensity. Finally, the separate analysis of the search slope (the average increase in the reaction times, RT, for each element added into the set size) and the intercept (theoretic RT for the minimum level of set size) showed both positive and negative effects of WS intensity: an increase of search slope values in conditions of higher WS intensity (increased impact of the number of distracters by the highest WS intensity) and a lower intercept values (accelerated response in conditions of minimum distraction by the WS intensity).

Through the three experimental series, it was possible to draw important conclusions about the mechanisms that regulate the development and impact of accessory characteristics of an acoustic WS (i.e. temporal information on the appearance of the target and its intensity). These two characteristics of a WS are dissociable, but they may occasionally interact, depending on the control demand of the task. Moreover, in a context of Simon and spatial Stroop interference, we were able to dissociate the behavioural expression from the effect of intensity, through the activation of pure alertness mechanisms during visuo-spatial conflict

resolution. In particular, we showed that the presentation of a WS is accompanied by a modulation of the effect of perceptual-motor interference, or Simon, depending on the level of intensity of the WS, but not on the perceptual interference, or Stroop. Finally, we learned that an increase in WS intensity can lead to a faster execution of visual search tasks, however, with an increase of the impact of distracters.

All this leads us to conclude that the pure alerting effect leads to an automatic acceleration of the direct response of target stimuli. This results in an acceleration of responses, but especially when there is only one target, and when the direct and automatic response to it is the correct one. However, in conditions where it is not clear which stimulus is the target, or when it appears between distracting information, or the correct response to the target is not the most automatic and direct one, the increased intensity of the WS has a negative effect, by facilitating the automatic distracting response, or the selection of a distracter instead of the target. In these situations, the activated response, or the initial selection, must be inhibited, which finally leads to a loss of the initial alerting advantage, or even to a detrimental effect, that lead to a slower response.

RESUMEN

Una función importante de la atención es la capacidad de preparar y mantener un estado de alerta para procesar las señales de alta prioridad que llegan desde el ambiente (Petersen & Posner, 2012). A nivel de comportamiento, la preparación de la respuesta es observable por medio de los tiempos de reacción, que suelen ser más rápidos en condiciones donde el estímulo imperativo (target) se presenta después de una señal de alerta abrupta (warning signal, WS) que en las condiciones sin WS.

Las características temporales, espaciales, motrices y perceptivas de estos efectos han sido objeto de muchas investigaciones para estudiar cómo los mecanismos de alerta pueden influenciar la ejecución durante una tarea de demanda cognitiva (Callejas, Lupiàñez y Tudela, 2004; Fischer, Plessow y Kiesel, 2012; Weinbach y Henik, 2012a). Controlando la probabilidad de aparición del target durante una ventana temporal específica, es posible aumentar o modular de manera flexible el estado preparatorio para la ejecución de la respuesta motora (Correa, Lupiáñez, Milliken, & Tudela, 2004; Correa, Lupiáñez, Madrid, & Tudela, 2006a). En el caso de WS acústicas, el efecto de alerta producido por una WS está fuertemente influenciado por algunas características que, a pesar de ser consideradas accesorias e irrelevantes, provocan una activación más automática de las respuestas, es decir un efecto de alerta puro. Por ejemplo, es sabido que los tiempos de reacción se acortan al aumentar la intensidad de las WSs auditivas. Este fenómeno, que se suele denominar efecto de intensidad, se ha atribuido a la influencia, directa o indirecta, en los procesos de ejecución de la respuesta más tempranos.

El principal objetivo de nuestro proyecto de investigación era comprender qué mecanismos se desencadenan por las características accesorias de una WS acústica, en particular su intensidad y la información temporal proporcionada por la presentación de una WS, y cómo estos mecanismos pueden modular el procesamiento del target y la preparación motora de la respuesta. Por esta razón diseñamos tres series experimentales, que nos permitieron investigar de manera óptima las influencias de las características de los WS en los mecanismos atencionales de alerta y control cognitivo, así como en la búsqueda visual del target.

Indagar sobre el papel de la preparación de la respuesta (derivada por la información temporal proporcionada por la WS) y comprender el impacto del nivel de intensidad del WS eran nuestros objetivos principales para la Serie Experimental 1. Nuestra idea principal era que la WS podría influir en los tiempos de respuestas debido a la información temporal sobre la presentación del target, a una aceleración automática de la respuesta debida al efecto de intensidad, o a la influencia mutua de ambos mecanismos. Estudiamos estos dos factores manipulando por un lado la simultaneidad entre WS y target, y por otro la intensidad de la WS. Sabiendo que un sonido muy intenso, puede desencadenar una respuesta motora defensiva, llamada reflejo de sobresalto (Carlsen, 2011), diferenciamos entre los ensayos con una respuesta de sobresalto y aquellos sin respuesta de sobresalto. También estudiamos si el efecto de intensidad se ve influido por el nivel de demanda de control establecido por la tarea.

Los resultados de la Serie Experimental I destacaron la importancia del nivel de control de la tarea en la expresión del efecto de intensidad y sugirieron que la aceleración de los tiempos de respuesta, relacionada con la información temporal proporcionada por el WS, también se ve modulada por el nivel de control de la tarea. Así, el efecto de aceleración de la respuesta para las WS de mayor intensidad (cuando no se producía reflejo de sobresalto) sólo se observaba en condiciones de alta preparación y predisposición a lo respuesta. Otro importante resultado de la serie fue, al contrario, en el caso de una respuesta automática de sobresalto ésta no se vio modulada en absoluto por el nivel de control de tareas y preparación de la respuesta. La idea que la ventaja comportamental derivada del aumento de la intensidad depende de si se activa un estado de preparación de la respuesta después de la WS se ha verificado en el último experimento de la serie experimental, en que los participantes utilizaron la información temporal de la WS y activaron mecanismos preparatorios de la respuesta. Por lo tanto, concluimos que, a pesar de que la preparación de la respuesta y la intensidad acústica son mecanismos disociables y separados, pueden interactuar en función de la tarea.

La Serie Experimental II estaba dirigida a comprender la importancia de la manipulación de la intensidad de la WS durante la selección del estímulo imperativo en condiciones de interferencia visuoespacial. Weinbach y Henik (2012a) presentaron la idea de que en condiciones de alerta se amplía el foco de atención, lo que conlleva una priorización de la información periférica. Por tanto, la alerta los procesos de control se vería afectados por la alerta al incrementarse la interferencia, pero solo en condiciones donde se presentan los estímulos distractores en la periferia, separados del estímulo. Para verificar las hipótesis de Weinbach y Henik (2012a), decidimos comprobar si el efecto de alerta se reflejaba en modulaciones de la interferencia de tipo Simon (interferencia perceptivo-motora) y Stroop espacial (interferencia perceptiva). Las interferencias visuoespaciales se manipularon en un diseño experimental entre ensayos y entre bloques. Por otra parte, quisimos disociar la intervención de los mecanismos de preparación del efecto de intensidad y en ambos experimentos manipulamos la intensidad de la WS y el efecto de preparación alternando presencia-ausencia de la WS.

Además del clásico efecto de congruencia (Simon y Stroop) y de la alerta, nuestros resultados confirmaron que la interferencia perceptivo-motora de tipo Simon se ve modulada por la presencia de la WS y la intensidad acústica. Sin embargo, la interferencia perceptiva de tipo Stroop no se vio modulada en ningún caso ni por la presencia/ausencia de la WS ni por su intensidad. La modulación de la interferencia Simon, observada como una disminución o incremento del efecto de congruencia, dependiendo del diseño experimental, fue la prueba de la posibilidad de disociar los mecanismos de preparación de la respuesta y de la alerta pura en la resolución de interferencias visuoespaciales. Ya que en nuestro paradigma los targets (la dirección de una flecha) y las características espaciales distractoras (la posición que ocupa en la pantalla) estaban integrada en el mismo estímulo visual, los resultados no confirmaron la tesis de Weinbach y Henik según la cual la información distractora debería estar separadas del target para observar la acción moduladora de la WS. Más bien, los resultados apuntan a la idea de que, bajo ciertas condiciones, la atención puede aumentar la interferencia espacial induciendo una asociación más fuerte con los centros de ejecución motora de la respuesta (Fischer et al., 2012). De ahí la modulación exclusiva sobre la interferencia Simon (perceptivo-motora), pero no de la interferencia Stroop (perceptiva).

En la Serie Experimental III intentamos aclarar si la ventaja comportamental derivada por el aumento de la intensidad de la WS afecta a la selección del target durante tareas de búsqueda visual. Presentando tareas de búsqueda de rasgos y búsqueda conjuntiva, esperamos que esta última fuera menos eficiente: dado que el target y los distractores compartían algunas de las características, la selección del target sería más complicada y los tiempos de respuesta más lentos y directamente proporcional al aumento del tamaño del conjunto de búsqueda. Los resultados confirmaron nuestras hipótesis, mostrando tiempos de respuestas más lentos con el aumento del número de distractores en la escena visual (sólo en la tarea de búsqueda conjuntiva) y una mayor velocidad de la respuesta en condiciones de mayor intensidad acústica de las WS. Finalmente, el análisis por separado de la pendiente de búsqueda (el incremento medio en el TR por cada elemento añadido al conjunto de búsqueda) y el intercepto (el TR teórico para un mínimo conjunto de búsqueda) mostró efectos positivos y negativos de la intensidad de las WS: un incremento de la pendiente de búsqueda en condiciones de mayor intensidad de la WS (el impacto del número de distractores se vio entonces aumentado por la alta intensidad acústica de la WS) al tiempo que un menor intercepto (la intensidad de la WS acelerando la respuesta en condiciones de mínima distracción).

A través de las tres series experimentales, fue posible sacar importantes conclusiones acerca de los mecanismos que regulan la elaboración y el impacto de características accesorias de una WS acústica (es decir, la información temporal sobre la aparición del target y su intensidad). Estas dos características de la WS son disociables, pero ocasionalmente pueden interactuar, dependiendo de la demanda de control de la tarea. Además, en un contexto de interferencia de tipo Simon y Stroop espacial, pudimos disociar la expresión comportamental del efecto de la intensidad desde la activación de mecanismos de alerta pura durante la resolución de conflicto visuoespacial. En particular, demostramos que la presentación del WS se acompaña de una modulación del efecto de incongruencia perceptivo-motora o tipo Simon, dependiendo del nivel de intensidad del WS, pero no de la interferencia perceptiva o tipo Stroop. Finalmente, aprendimos que el aumento de la intensidad del WS puede conducir a una mayor rapidez de ejecución de tareas de búsqueda visual, sin embargo, con un incremento del impacto de los distractores.

Todo ello nos lleva a concluir que los efectos puros de alerta conllevan una aceleración automática de la respuesta directa de los estímulos target. Ello tiene como consecuencia una aceleración de las respuestas, pero especialmente cuando sólo existe un solo target, y cuando la respuesta directa y automática al mismo es la respuesta correcta. Sin embargo, en condiciones en las que no está claro qué estímulo es el target, al presentarse entre información distractora, o la respuesta correcta al target no es la más automática y directa, el incremento de intensidad de la WS conllevará un efecto negativo al facilitar la respuesta automática distractora, o la selección de un distractor en lugar de un target. En esas situaciones se debe inhibir la respuesta activada, o la selección realizada inicialmente, lo que conlleva finalmente una pérdida del beneficio inicial de la alerta, o incluso un perjuicio que se manifieste en un enlentecimiento final de la respuesta.

CHAPTER 1.

INTRODUCTION

Several theoretical frameworks have tried to explain the organization and functioning of selective attention. In particular, the Posner´s theoretical framework (Posner and Petersen, 1990; Petersen & Posner, 2012), distinguishing between functional and neuroanatomical networks, has been the starting point for many studies and has helped to increase enormously the knowledge about the human attention system. In this chapter, we present the findings about the selective attention most relevant for the current dissertation, especially focusing on the domain of Alerting and Executive Control mechanisms, although also making some references to spatial orienting. These mechanisms play a fundamental role in the elaboration of the relevant information in the environment, in the inhibition of irrelevant or potentially distracting information, and in the selection and execution of the appropriate motor responses.

The importance of understanding not only how each of these mechanisms work, but also how they interact with each other, will be outlined within the four main sections of this chapter.

1. The theoretical framework of selective attention

To safely navigate the environment, survive, and reproduce, animals and people must rapidly select sensory information that are most relevant for their goals (Corbetta, Patel & Shulman, 2008). Given the limitations of the available resources, the cognitive systems need to establish a fixed representation of the environment and selectively process relevant information. This idea of a limited capacity has been a central feature of the views of how the human attentional system is organized (Broadbent, 1977; Lavie 1995; Treisman, 1960; Posner & Petersen, 1990).

The cognitive system that helps to select relevant incoming stimuli, make decisions, and produce outputs, is called selective attention. The selective attention system gates which visual and acoustic information is processed. It is implemented in a complex network of anatomical areas to carry out its functions (Petersen & Posner, 2012). The common goal of the theories dedicated to the description of attentional processes is to identify the mechanism of selection put in place when relevant and irrelevant information are mixed and presented simultaneously. Despite the action of the selective attention is considered as general, there are several theoretical models that focused on explaining its functioning through its specific application. Some of them focused the taxonomy of selective attention mainly on the stage of information processing, at which the selection occurs, either earlier or later in the processing sequence. One example is the Broadbent's early selection theory (Broadbent, 1958), where it was proposed that all the information in the environment are transferred to specific selective filters, which identify what it is supposed to be attended on an early stage, via its physical characteristics. On the other hand, Deutsch and Deutsch held a late selection view, where all sensory messages which impinge the organism are perceptually analysed at the highest level (Deutsch & Deutsch, 1963). According to this approach, the selection only occurs late in the process, after the full perception, in order to provide the relevant response.

These two views collided in the mixed model proposed by Treisman (1960), called attenuation theory of selective attention, where the selective filters were found between the early and late selection. In accordance with the attenuation theory, the information coming from the unattended channel is not elaborated unless it shows to be unexpectedly important. When this occurs, the attention is reoriented on the unattended channel, and the channel that was previously attended get unattended (Treisman, 1960). The load theory (Lavie & Tsal, 1994; Lavie 1995; Lavie & Dalton, 2014) was also proposed as a model that resolves the early versus late selection debate. The load theory postulated that perceptual load is the necessary condition for early selection and the perceptual processing becomes selective only when the limits of perceptual capacity is reached. If a task imposes sufficient demand to exceed capacity, the task-irrelevant information is not processed and can therefore be successfully ignored (early selection). By contrast, if a task imposes only a low perceptual demand, the remaining capacity is automatically allocated to the processing of task-irrelevant information, which may then cause distraction (late selection) (Lavie & Dalton, 2014).

An alternative to theories focused on the attentional selection stages were capacity theories, which identify the allocation of attention as more flexible and able to be distributed on different activities as required by the task demand. One example is the theory of attention proposed by Kahneman (1973), which identify the attention as a general pool of limited capacity or "mental effort" (Kimchi, 1982), controlled by task demand and a complex feedback mechanism for the performance control and coordination of combined demands from the environment and the task (Kahneman, 1973). Other models, such as the supervisory attentional system proposed by Norman and Shallice (1980), consider that behaviour is composed by sets of automatic actions, or schemas, and given a particular environmental situation, several possible schemas may be activated. The existence of these automatic schemas eliminates the possibility of having limitations on the processing capacity, however, the problem for the attentional functions lies in monitoring the selection between the different response alternatives, mainly under the responsibility of cognitive control functions.

1.1. The three attentional network theory

All the previous theories admit that attention must, in some cases, be divided, or redirected, in order to process the relevant information effectively. However, there is one theoretical framework that preferred to focus the taxonomy on the distinction between specific functional areas, or networks. This theory, named as three attentional networks theory (Posner & Petersen, 1990: Petersen & Posner, 2012) has the advantage to present an integrated view that combines all the previous partial models in a unitary global model.

In their three attentional networks theory, Posner and Petersen (1990) localized the main attentional functions not in a single brain area, but as a network of interconnected areas. They assumed the existence of three attentional networks, each of these defined by specific functions and neuroanatomical areas (Fan, Gu, Liu, Fossella, Wang & Posner, 2009), and named as Orienting network, Executive-control network, and Alerting network.

- The Orienting network is characterized by the ability of attention to shift between positions to attend relevant stimuli. This system is also focused on the ability to prioritize sensory input, by selecting the more appropriate modality or location, and have been implicated in some forms of sensory stimuli processing, not only restricted to orienting movements.
- The Executive Control network has been related to the control of goal directed behaviour, target detection, error detection, conflict resolution and inhibition of automatic responses. This network can monitor for targets in many processing streams, however the moment of target detection may produce interference across the system, slowing the detection of another target, depending also on the modulatory activities of the other two networks.
- The Alerting network is defined by a network of areas involved in establishing on producing and maintaining optimal vigilance and readiness to react during tasks. While the Orienting network is focused on information about where a target occurs, this network is mainly focused in detect when a target occurs.

1.2. The orienting mechanisms

The Orienting network is involved in knowing which point of space to attend, allowing to shift the attention to the right location and save a large amount of time. We know that orienting attention to the location where an imperative stimulus will occur produces faster motor responses. However, once engaged at a specific location, the reorienting of the attention also negatively affects the time to detect an imperative stimulus presented in an unattended location (Posner, 2008).

The attentional selection accomplished by the orienting mechanisms involves one of two functionally different types of attention. The first one, the Exogenous orienting attention, refers to a mostly automatic mechanism in which salient stimuli capture involuntarily attention. In a famous work, Posner presented a method to the study the exogenous orienting attention in the visual field (Posner, 1980), called as cueing method. The subject had to response by pressing a single key when an asterisk appeared, while looking at a central stimulus flanked on each side by a box. One of these boxes after an interval would change in luminance. A change in the luminance of the box was the cue for attention to move to the target and thus the time needed to shift attention to the cued location could be measured. If the cue indicated that the target would occur at the cued location with high probability, the target was facilitated in comparison with other location, and the facilitation remained as though attention remained at the cue (Posner, 1980; 2016).

The second type, the endogenous orienting attention, refers to a voluntary mode of orienting that keeps the attention directed at locations where a relevant event is expected, regardless of the actual presence of stimuli (Posner, Snyder, & Davidson, 1980). Moreover, in some cases it can be interesting to analyse the performance when the target needs to be selected from two or more visual stimuli. In those cases, we move from the visual discrimination into the domain of search. An optimal tool to investigate the endogenous orienting attention is a visual search paradigm. Visual search tasks are often used as a framework to study many aspects of cognitive and visual function and represents an optimal paradigm to study the impact of the number of stimuli in a display (Davis & Palmer, 2004). In tasks as the visual search, where a target is usually accompanied by one or more distracters, the target detection is difficult, especially when target and distracters share some characteristics (e.g., the colour or the shape). Usually, the performance during this task depends greatly on the set size, i.e., the number of task-irrelevant distracters (Treisman & Gelade, 1980; Treisman 1998; Treisman, 1993; Wolfe, 1998). Depending on the nature of the visual stimuli, the search can be framed as Feature search (where a fast processing of visual information is required, with all features being processed in parallel and therefore responses being independent on set size), and Conjunction search (where the target identification happens among distracters, that share one or more features with the target, and requires a serial processing). Beside of simple RT and accuracy rate, the indexes of performance for the visual search task are two parameters of the search function, the slope and the intercept. The slope of the search function represents the cost in RT of adding each visual element item to the search display (for a reference, see Wolfe, 2016). On the other side, the intercept represents the RT needed to respond to a display with a minimum set size and it informs about processes needed to respond, independently of the searching time. Depending on the type of visual search, these parameters will vary. As an example, during a Feature visual search paradigm, the values for the slope of the search function are close to zero, regardless of the number of distracters, because the processing of visual stimuli occurs in parallel and the target defining feature pops out, automatically capturing attention. On the other hand, during a Conjunction search the values for the slope will depend on the similarity between target and distracters, with the time required to find the target linearly increasing with their amount in the visual scene.

Despite the initial evidence suggested the independence between the orienting function and the other systems (Fan, Mc Candliss, Sommer, Raz & Posner, 2002; Fernandez-Duque & Posner, 1997), these systems usually work together in most real-world situations and it is difficult to imagine a complete independence. The three attentional networks theory has been an important conceptual framework of reference for the current work. Indeed, Callejas and colleagues (Callejas, Lupiáñez, & Tudela, 2004; Callejas, Lupiáñez, Funes, & Tudela, 2005), have consistently shown that attentional orienting interacts with cognitive control, and that alertness modulate cognitive control and attentional orienting. For the purpose of this dissertation, we decided to mainly focus on the Alerting network and its modulation over the Executive Control network, and in their interdependence. In fact, the contribution of the Executive Control and Alerting mechanisms is especially important during a cognitive task for 1) the identification of task-relevant information about the relevant stimuli; 2) the inhibition of irrelevant information, which could waste cognitive resources or impede the execution of the task; 3) the preparation and execution of the response. Therefore, the observation of these two attentional systems in action is fundamental to reach a good understanding of the selective attention processes during tasks requiring visuomotor control.

2. The cognitive control mechanisms

The Executive Control Network accomplishes complex mental operations responsible of inhibiting distractive information and selecting responses to relevant, to-be-attended stimuli (Fan, McCandiss, Sommer, Raz & Posner, 2002). These cognitive control mechanisms are based on a hierarchy of specific brain areas located mainly in the frontal-parietal network (Corbetta, Shulman, Miezin & Petersen, 1995; Nobre, Sebestyen, Gitelman, Frith & Mesulam, 2002), which provide mainly top-down control to other brain areas (Miller & Buschman, 2014).

The understanding of cognitive control addresses how the selection of relevant and irrelevant information is possible, and in which moment of the currently performed tasks this selection is done. This is studied through behavioural parameters like response accuracy (e.g., the number of commission errors) and reaction time (RT), defined as the interval between the onset of a target stimulus and the subject’s response. By introducing specific manipulations (e.g., the degree of response inhibition to a visual stimulus), it is possible to provide an objective measure of the participant´s ability to perform a conflict task (e.g., inhibit an automatic response). In particular, the ability to resolve conflicts is often measured by tasks that require to control 1) the response execution, that is associated with an imperative stimulus (target), or with some of its features; 2) the response competition due to specific features of the target or other competitive stimuli distracters, that are incompatible and task-irrelevant but automatically associated with the response.

A common paradigm used for measuring the response execution inhibition is the Go/No go task (White, 1981), where participants are required to respond as rapidly as possible to certain “Go” stimuli and refrain from responding to other “No go” stimuli. The amount of commission errors is an index of the level of inhibitory control applied to respond and allows to understand how well participants may inhibit the execution of automatic but incorrect responses. In a similar way, the interference tasks allow to study the response competition from task-irrelevant target features. One of the most known interference tasks is the Stroop task (Stroop, 1935), where participants are required to name the ink colour in which the words of colour names are displayed. RTs are slower when the name of the printed word is inconsistent with its colour (incongruent condition - e.g., the word “green” printed in red ink) with respect to when word and colour are congruent (congruent condition - e. g., the word “green” printed in green ink). This difference in performance, defined as congruence effect, provides a measure of the time taken to resolve the interference. Another classic interference task is Eriksen's flanker task (Eriksen & Eriksen, 1974). This task is characterized by a target presented centrally and surrounded by target-like distracters. Those distracters might be associated to either the same response (congruent condition) or the opposite response (incongruent condition).

As previously explained, the resolution of conflict tasks and visuospatial interferences involves control functions. However, not all these tasks necessarily involve the same control mechanisms. In the dimensional overlap model (Kornblum, Hasbroucq & Osman, 1990), it was proposed that the stimulus and the response dimension manipulated withing a task can be relevant or irrelevant for the task itself and this distinction can be used to differentiate between types of interference and mechanisms involved in their resolution. Following this taxonomy, an interference has a task-relevant stimulus (S) dimension, a task- irrelevant stimulus dimension and a response (R) dimension. The resolution of the conflict can occur independently between any of these two components. As an example, during the resolution of a Stroop interference task, or a Flanker task, the conflict is located at several levels of stimulus (S) and stimulus-response (S-R) conflict, due to the overlap between of the relevant and the irrelevant stimulus dimension and the response.

However, the analysis of specific dimensions of stimulus and response, either relevant or irrelevant for the task, is also possible. In the spatial version of the Stroop task (Lu & Proctor, 1995), participants are asked to respond to a target-arrow´s direction, that can match or not its location (e.g., the arrow pointing up or down, presented either in the upper or lower visual hemifield) (see Figure 1). In this type of interference, participants tend to perform more quickly when the position of the arrow matches the arrow´s direction (congruent condition), than when they do not (incongruent condition). During the spatial Stroop interference, the conflict is considered stimulus-stimulus (S-S), as the overlap between of the relevant and irrelevant dimension is only at the level of the stimulus. Differently, in a Simon task the conflict is stimulus-response (S-R), as the interference is caused by the overlap between the irrelevant stimulus dimension and the response (Kornblum, Hasbroucq & Osman, 1990). In the Simon's conflict task (Simon & Small, 1969), in which participants respond to a stimulus whose irrelevant spatial position may be congruent or incongruent with the hand associated to the corresponding response (e.g., the target is presented to the left or the right visual hemifield, and the response is associated with either with the left or right hand). Participants usually respond more quickly when the position of the target matches the hand associated to the response (congruent condition), than when it does not (incongruent condition).

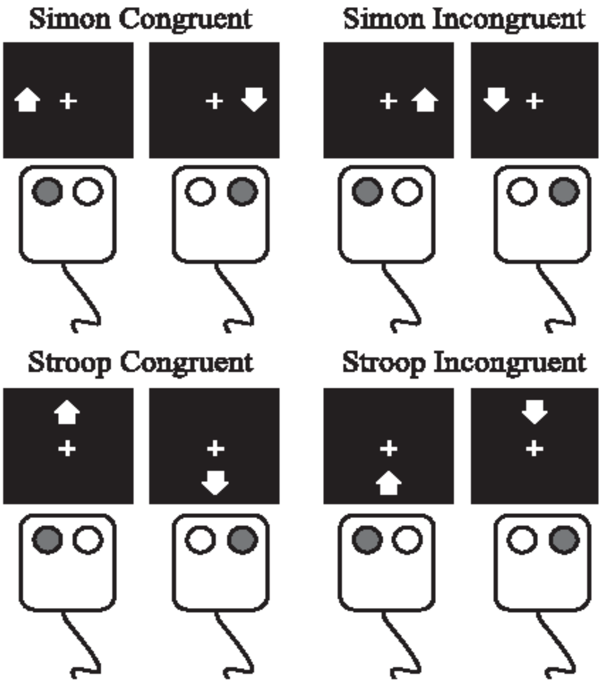


FIGURE 1. Examples of the Simon effect (upper part of the figure) and the spatial Stroop effect (lower part of the figure). For the Simon task conditions, the target arrow appears on each trial in at the left/right to the fixation point. For the spatial Stroop task conditions, the target arrow appears below/above the fixation point. Keypress responses are to be based on the relevant stimulus dimension, which is unrelated to the irrelevant target location in both Simon and spatial Stroop tasks (e.g., the arrow location as in the example) but also has a location property (e.g., the direction of the arrow). In Simon task conditions, if the left keypress response is to be made to a specific stimulus direction, responses are usually faster when the target occurs in the left location (Simon congruent) than when it occurs in the right location (Simon incongruent). In spatial Stroop task conditions, if the target arrow appears in a specific location (in this case, below the fixation point), responses are usually faster when the target arrow points down (spatial Stroop congruent) than when it points up (spatial Stroop incongruent). Adapted from Liu, Banich, Jacobson & Tanabe (2004).

Since the conflicts S-S and S-R involve different types of information, it was hypothesized that the mechanisms underlying their resolution may be different. Evidences from behavioural studies have been supporting the independence (Correa, Cappucci, Nobre, & Lupiañez, 2010; Egner, Delano, Hirsch, 2007; Liu, Park, Gu, & Fan, 2010). However, it emerged also that the cognitive control mechanisms are able to adapt flexibly to the circumstances, and the combination of Simon and spatial Stroop interference may lead to an additive interference effect (Hommel, 1998; Kornblum, 1994).

Considering everything that has been said so far, it seems clear that the control mechanisms, equipped with rather limited resources, need to enhance the attentional elaboration on relevant rather than irrelevant information. For this reason, the involvement of alerting mechanisms is critical for optimal performance in tasks involving higher cognitive functions, as favourite the processing of high priority signals (Posner, 2008). Therefore, it is fundamental to know how these mechanisms works in collaboration with the cognitive control functions, especially during the perceptual elaboration and response preparation.

3. The phasic alerting mechanisms

As mentioned before, the alerting mechanisms provide the capacity to increase vigilance to an impending stimulus, supplying and supporting the processing of high priority signals (Posner, 2008; Petersen & Posner, 2012). The mechanisms of alertness provide people with the ability to sustain attention and enable direct attention to one or more sources of information over a continuous and relatively long period of time. The vigilance is the ability to maintain attention over a prolonged time interval, during which infrequent response-demanding events occur, as expression of sustained attention (Mackworth, 1964; Davies and Parasuraman, 1982), and its assessment allows to indicate disturbances of sustained attention, by the deterioration, the change or the fluctuation of performance over time (Mackworth, 1964).

In general, the alertness is considered an autonomic network. Nevertheless, it is not a unitary system, and it can be distinguished between tonic and phasic alertness (Posner, 2008). While tonic alertness is responsible for wakefulness and the endogenous maintenance of a general arousal state across time on task, the phasic alertness represents the ability to increase response readiness to a target, usually after an external unexpected warning stimulus (WS), e.g., a sound presented before the target onset. There are a variety of changes in heart rate and brain oscillatory activities that follow the presentation of a WS, reflecting a suppression of ongoing activity thought to prepare the system for a rapid response (Posner, 2008), possibly with the goal of inhibit other competing activities (Fan et al., 2009). In particular, to provide temporal information on the target presentation represents an important function of the WS, as illustrated in the next section.

3.1. The impact of warning signal on response preparation and pure alertness

In some paradigms, the WS can be associated with an event, as the target that is about to occur, and provides information about the moment of its appearance. It is well known that visual and acoustic WSs, conveying information about the forthcoming target, facilitate the target response (Driver & Spence, 1998; Eimer & Schröger, 1998). Moreover, when a constant interval between WS and target (i.e., the target always appears following the same duration in a block of trials), participants get ready in advance for the response and RTs are faster, if compared to trials with a random interval duration (Niemi & Näätänen, 1981). The WS seems to have the greater impact within an interval of 500 ms prior the target appearance and in most studies involving phasic alerting are used intervals that range roughly between 100–800 ms (Weinback & Henik, 2012b).

In addition to that, an abrupt sound can be used as WS, when presented during a visual task, may trigger a rather automatic attentional capture. At a behavioural level, the presentation of a WS usually enhances the response readiness and shortens reaction times (RT). In experimental paradigms where the alerting effect is manipulated across trials, WS conditions have a behavioural advantage over conditions without WS, even when the WS provides little or no information about where or when a target will occur (Coull, Nobre, & Frith, 2001; Posner, 1978; Posner & Petersen, 1990). Even in case the WS elaboration is irrelevant, it leads to an automatic, pure alertness state and accelerates RTs. It is important to note that other characteristics of the responses, rather than RT, can be also altered by an acoustic WS. For instance, auditory WSs seem to increase pupillary responses (Petersen, Petersen, Bundesen, Vangkilde, Habekost, 2017), finger flexion force (Miller, Franz, & Ulrich, 1999; Stahl & Rammsayer, 2005; Watanabe, Koyama, Tanabe, & Nojiba, 2015; Włodarczyk, Jaśkowski, & Nowik, 2002), detectability of a visual stimulus and influence temporal order judgement (McDonald, Teder-Sälejärvi, Di Russo, & Hillyard, 2005).

An important question is whether the effect of the WS is attributable to motor preparation, or rather, on early perceptual and response selection processing stages. In several studies, the impact of WS on reaction times has been linked to an improved perceptual efficiency. For instance, an enhanced alerting state seems to have positive impact to the global perceptual processing of the target (Matthias, Bublak, Müller, Schneider, Krummenacher & Finke, 2010; Kusnir, Chica, Mitsumasu & Bartolomeo, 2011; Seibold & Rolke, 2014; Weinbach and Henik, 2012b) and increases the activity in regions involved in perception and processes of stimulus encoding (Böckler, Alpay & Stürmer, 2011; Hackley and Valle-Inclán, 1998; Thiel, Zilles, and Fink, 2004). Nevertheless, other studies questioned the beneficial effect of WSs during the perceptual processing and debate the idea whether the WS might facilitate motor execution (see Hackley & Valle-Inclán, 2003) or rather locate the WS impact in the visuo-motor response facilitation (Fischer, Plessow & Kiesel, 2012).

The intrinsic characteristics of the sound used as WS, as its frequency in time of and its intensity, can modulate the capacity of WS to alert the participant about the target presentation and speed the response. Depending on the task utilized, opposing effects of the pure alertness on the performance have been reported, in some instances leading to distraction (i.e., longer RT) rather than facilitation (San Miguel, Morgan, Klein, Linden & Escera, 2010). In the next paragraph, it will be focused on the impact of the accessory characteristics of an acoustic WS.

3.2. The impact of accessory characteristics of warning signals

When the intensity of a stimulus is manipulated, RTs are usually shorter for higher intensities (Kohfield, 1971; Angel, 1973), even when the intensity dimension was task irrelevant (Jaskowsky, Rybarczyk, & Jaroszyk, 1994; Kohfield, 1971; Miller, Franz, & Ulrich, 1999; Ulrich, Rinkenauer, & Miller, 1998). The intensity of a sound is commonly measured within the decibel scale. Decibels measure the ratio of a given intensity to the threshold of hearing intensity, so that the hearing threshold takes the value 0 decibels (0 dB). The threshold varies only slightly across individuals and the inter-subject variability for white noises is below 2 dB (standard deviation of 1.92 dB; see Hawley, Sherlock & Formby, 2017).

Previous studies have been investigating the effect of phasic auditory alertness on early visual perception (Petersen, Petersen, Bundesen, Vangkilde, Habekost, 2017), by presenting a temporally uninformative acoustic WSs of 40 dB or 85 dB in 50% of the trials. The remaining 50% of the trials had no WS prior to the target. By performing a discrimination task (i. e., to report the identity of a target letter presented in two possible locations of the screen), participants reported an increased processing speed of the target in conditions with the highest WS intensities (i. e., higher processing speed in 85 dB versus 40 dB WS trials). The authors concluded that there is direct correspondence between levels of WS intensity and the processing speed (Petersen et al., 2017).

Nevertheless, the use of particularly intense WSs to raise the pure alerting effect presents some inconveniences. For instance, if an extremely high, an acoustic stimulation might trigger an automatic defensive response, commonly known in the literature as startle reflex (Davis, 1984; Valls-Solé, Kofler, Kumru, Castellote, & Sanegre, 2005). The startle reflex is formed by a complex sequence of muscular defensives responses, which have been reported within different paradigms (Blumenthal, Cuthbert, Filion, Hackley, Lipp, & van Boxtel, 2005; Carlsen, Chua, Inglis, Sanderson, & Franks, 2004; Carlsen, Chua, Inglis, Sanderson, & Franks, 2007; Carlsen, Maslovat, Lam, Chua, & Franks, 2011). An overt automatic expression of startle has often been associated with faster RT, attributed to a quicker trigger of response selection and motor programming (Carlsen et al., 2011). Importantly, the RT shortening due to the pure alerting effect and the startling response speediness, can be overlapped in experimental paradigms where high intense WSs are manipulated. Nevertheless, the differentiation between the effects of startle responses and the pure alerting effect is crucial to understand the impact of WS in visual control tasks.

The importance of more or less automatic components of phasic alerting has been already highlighted (see also Weinback & Henik, 2012b) and the behavioural consequences of manipulating the level of intensity of WS, also as expression of pure alerting effect, has been already the object of several investigations (Carlsen et al., 2011; Lipp, Kaplan, & Purkis, 2006; Washington & Blumenthal, 2015; Petersen, et al., 2017). Nevertheless, the distinction of response preparation and pure alertness components is, in some cases, overlooked. Possibly for this reason, which stage of perceptual encoding and response preparation is mostly impacted by the acoustic WS remains under debate (Correa et al., 2006; Weinbach & Henik, 2012b). But to understand the impact of acoustic WSs on tasks requiring some form of cognitive control is not possible without distinguish their behavioural and functional effects, and this dissertation, taking distinction of response preparation and pure alertness components into account, aims to fill some gaps in knowledge about the effects of the accessory features of acoustic WS, as its intensity.

4. Studying the interaction between alerting and cognitive control mechanisms

In recent years, many studies have corroborated the idea that alerting mechanisms may influence the resolution of visuospatial interference and suggested a great (but not complete) deal of independence between alertness and cognitive control mechanisms (Fan et al., 2002; Fernandez-Duque & Posner, 1997; Posner, 2008). On the other hand, the WS seems to activate brain areas associated to executive control processes (Coull, 2004; Fan, Mc Candliss, et al., 2005; Hackley, et al., 2009; Raz & Buhle, 2006). The interdependence between alerting and cognitive control mechanisms was supported by evidences in shared lateral and medial frontal lobe areas, as the anterior cingulate cortex, involved in both response anticipation (alerting) and conflict resolution (Wager, Jonides & Reading, 2004; Posner, 2008). Evoked potential studies confirmed further the overlap of its involvement with alerting and control functions (Cohen, Semple, Gross, Holcomb, et al., 1988), as well as studies of neurogenetic (Fossella, Sommer, Fan, Wu, Swanson, Pfaff & Posner, 2002).

In the next two sections, we will illustrate which behavioural paradigms have been used to examine this interaction and which are the more recent explanatory frameworks.

4.1. The impact of warning signals in the cognitive control mechanisms

One of the first attempts to study all three attentional networks in a unique paradigm was the attention network task (ANT) (Fan, Mc Candliss, Sommer, Raz & Posner, 2002). The ANT paradigm has been widely employed in brain functional, developmental, genetic, and psychiatric investigations (Wang, Cui, Liu, Huo, Lu & Chen, 2014). The ANT combined the Posner's cueing task (Posner, 1980) and a classic interference task (Eriksen's flanker task; Eriksen & Eriksen, 1974) to independently measure attention components in one single paradigm. This paradigm showed a relative independence of the networks, while other studies apported evidence showing that the alerting mechanisms may inhibit the executive control.

Callejas and collaborators investigated more closely their interdependence with the ANTI, a variation of the ANT that provides independent measures of the phasic alertness and orienting functions, by including an acoustic WS instead of a visual cue to independently assess phasic alertness. A larger spatial orienting effect was observed under conditions of high alertness, together with larger interference, which can be considered as an index of reduced cognitive control. These findings suggested a general inhibitory action of the alerting mechanisms in the cognitive control mechanisms and a facilitation action of the response activation and attentional orienting (Callejas, et al., 2004; Callejas, et al., 2005). Indeed, more recently, in a study aimed to investigate whether auditory-induced arousal could facilitate visual attention in a search task (Asutay & Västfjäll, 2017), it was found that search times decreased with the presentation of affectively arousing auditory WSs, while searching for a visual target. Their findings represented an evidence that exposure to affectively sounds can facilitate visual attention and search efficiency in a subsequent visual search. In fact, the auditory system is involved in detection and identification of significant events in our surroundings and help people to orient by guiding the visual system (Arnott, & Alain, 2011). Therefore, the exposure to arousing sounds could increase the pure alertness and vigilance, which in turn facilitate crossmodal information processing and attention. The authors argued that these findings were primarily due to the overall attentive facilitation in the presence of affectively arousing WSs, which may impact the visual attention either by influencing the speed of subsequent pre-attentive visual processing, or by decreasing the response thresholds (Asutay & Västfjäll, 2017). The current doctoral thesis has further explored this topic and answered to this question during the Experimental Series III (**Chapter 5**).

4.2. The impact of warning signal on visuospatial interference

The analysis of above mentioned interaction between alertness and cognitive control observed with the flanker task of he ANTI, can be more focused with the use of visuospatial interference tasks. By specifically measuring the spatial Stroop interference and the Simon interference, the use of these tasks can help to study the interaction between pure alertness, response preparation and cognitive control. Fischer and collaborators observed an increased Simon interference in concomitance with the presentation of WS and suggested that WS does not impact the general state of response readiness but rather the strength of automatic response activation, speeded up by the warning signal itself (Fischer, Plessow, & Kiesel, 2010). In particular, they suggested that WSs speed the translation of the visual stimulus code and the transmission of the relevant/irrelevant information into the associated motor code. This facilitation led not only to faster responses, but also to a larger interference effect, as the WS facilitates the activation of automatic response tendencies, based on a direct transmission of visual information into corresponding motor codes processing (Fischer, Plessow & Kiesel, 2012).

In contrast, Weinbach and Henik (2012a) found no modulation of WSs in the classic Stroop interference, but a larger interference effect in a Flanker task when the WS was presented. As they reported larger interference with alertness but only when the conflicting distracters were close but separated from the stimulus target, they concluded that a WS increases the attentional spotlight. This enhanced spotlight by alertness causes a general accessibility of spatial information therefore driving the interaction only in those cases where relevant and spatial irrelevant characteristics are separated (Weinbach & Henik, 2012a). Nevertheless, these findings where not confirmed by Seibold (2018), who reported no differences between the attentional focus size in trials with and without WS. Finally, more recently it has been argued that alertness increases interference, but only when the distracters and the task set have a spatial component (Schneider, 2019; 2020).

Indeed, it is possible to conclude that several aspects of a task involving control heavily influence the interaction between alerting and cognitive control mechanisms. The impact of some of task set features (i.e., the level of response control requested by the task; the type of interference to control; the interval between the WS and the target presentation; the amount of features shared between the target and distracters; the internal characteristics of the WS, as its intensity in case of an acoustic WS) have been diffusely studied with various experimental paradigms (Coull, Jones, Egan, Frith, & Maze, 2004; Hackley & Valle-Inclàn, 2003; Weinbach & Henik, 2012a; 2012b), but there is still a lack of consensus regarding the conditions and the specific processes involved in the interaction between alerting and cognitive control and the discussion concerning the nature of the interaction is not concluded.

In sum, temporal, spatial, motor and perceptual features have been subjects of many studies devoted to understanding how alerting mechanisms influence performance in the attentional paradigms. In the last years, several pieces of evidence about the involvement of the alerting network in the visual selection process during conflictive tasks have been generated (Callejas et al., 2004; Fischer et al., 2010; 2012; Weinbach & Henik, 2012). However, the literature reported discordant opinions about the impact of warning signals. For instance, accordingly to Weinbach & Henik (2012a), the interaction might, or might not, take place depending on the separation of the visuospatial information about relevant (target) and spatial irrelevant information. But according to Fischer and colleagues (2010), the separation between the target and the irrelevant spatial information is not the most decisive aspect, for the warning signals to speed up congruent responses at cost of a larger interferences. To confirm or reject these assumptions is crucial to comprehend the true nature of phasic alertness.

Finally, even though a task might not require a conscious elaboration of WS features, the time window between WS and target presentation, and its intensity, may influence the impact and the magnitude of these behavioural changes, even when they are considerate accessory and irrelevant features. A good understanding of how accessory features of a WS influence human performance and interact with other attentional processes is crucial to fully comprehend the nature of all phasic alerting manipulations involving acoustic warning signals. In our opinion, it is extremely relevant to study the modulation of WSs, by distinguish and comparing its component of response preparation and pure alerting effect. The current doctoral thesis was dedicated to deepening this knowledge.

CHAPTER 2. OVERVIEW OF THE RESEARCH AND GENERAL AIMS

The main aim of this dissertation was to evaluate the effects of acoustic warning signals (WS) on early (i. e., visual processing of stimuli) and late (target selection and response execution) processes. Specific aims are detailed as follows.

1. General aims

The general aim is focused on two specific goals:

- To investigate whether response preparation and the intensity effect are controlled by independent mechanisms of phasic alertness. In particular, it was crucial to understand whether WS influences response speediness either because of the temporal information about the target onset, the automatically triggered acceleration of perceptual elaboration and motor execution, or by a combination of both elements. The initial objective was to see how alertness impacts the ability to select relevant features and to control the intrusive effect of irrelevant features during the target selection and response execution. Our main hypothesis was that the increase of intensity lead to a general faster motor execution at the cost of impaired target selection. For this reason, it was important to manipulate both the temporal information about the target presentation, which allows to prepare in advance, and the effect of accessory characteristics of WS (i. e., its acoustic intensity), which could affect perceptual elaboration of targets and motor execution, in a combined experimental paradigm.
- To differentiate between positive and detrimental effects of task-irrelevant, accessory characteristics of WS. The effects of those accessory characteristics are related to response preparation in time and pure alerting effects and may be differentiated by the release of involuntary and nearly instantaneous movement in response to an intense stimulus, as the eye startle reflex.

These specific goals were accomplished by three Experimental Series (**Chapters 3**, **4** and **5**).

2. Aims of the Experimental Series I: Response preparation and intensity effect.

In **Chapter 3**, we examined the interaction between the attentional mechanisms related to response preparation and the pure alerting effect triggered by the task-irrelevant acoustic intensity of WS. We designed a simple detection task (Experiment 1) in which we manipulated the presence of a WS, with the alternation of two conditions: with a time interval between the warning and the target (expecting participants to take advantage of the temporal information), and without a time interval, presenting the warning signal and the target simultaneously. We also manipulated the level of intensity of the acoustic warning signal, using as WS a white noise of three levels of intensity (53 dB, 83 dB and 113 dB), and we expected the shorter RT for the highest WS intensity, as previously reported in the literature (Jaskowsky, Rybarczyk, & Jaroszyk, 1994; Miller, Franz, & Ulrich, 1999).

Based on Carlsen and collaborator´s (2004) findings, a sound of 113 dB should produce a startle reflex (Carlsen, Chua, Inglis, Sanderson, & Franks, 2004). Thus, we expected startling responses to be elicited by the WS, at least in the highest intensity conditions. For this reason, we recorded the orbicularis oculi muscle contraction and differentiated between trials with a startle response from those without a startle response. In trials in which the orbicularis oculi activity was categorized as startle response we expected to detect behavioural changes in response readiness in comparisons to trials without startle response. This effect was expected to be independent of temporal preparation and task set.

As we intended to analyse the influence of several levels of response control on both the preparation in time and the pure alerting effect, in Experiment 2 we maintained the intensity manipulation used in Experiment 1 (simple detection task), but incremented the response control by adding a proportion of catch trials, which usually induces a “dispreparation” state and impacts performance (see Correa, Lupiáñez, Madrid, & Tudela, 2006). Finally, in the Experiment 3, catch trials were substituted by NoGo targets, for which no response was required. This Go-NoGo discrimination task allowed to investigate the possible role of the inhibitory processes caused by the NoGo targets and, as the response control required was higher, we expected to encourage participants to prepare in time when possible (i. e., in conditions with a time interval between the warning and the target).

The results of this Experimental Series pointed to a dissociation between different possible mechanisms of phasic alerting in combination with the different levels of intensity, the provided temporal information and response control required by the task. The speed of responses was influenced by the temporal information about the target appearance and the task-irrelevant intensity of the WS. However, the task set determined the direction of the interaction between response preparation and the pure alerting effect induced by the WS intensity. In contrast, the effect of the startle response seemed to be independent from the response preparation and task set manipulations.

A single target presented at fixation was presented in all experiments of this experimental series therefore facilitating target selection. In the following experimental series, we examined the impact of response preparation and pure alerting effects when target and response selection was hindered by employing visuospatial interference paradigms in which target location and target direction were in conflict.

3. Aims of the Experimental Series II: Executive control and intensity effect of WS.

In **Chapter 4**, we manipulated the relevant and irrelevant visuospatial information, within a double interference paradigm, to investigate the modulation of alertness on perceptual and response related conflict. As it was crucial to distinguish between the effect of response preparation in time and the intensity effect of WS, we manipulated in the same paradigm the presence of a WS, its acoustic intensity, and target and task-irrelevant visuospatial information in the same visual object (i.e., Simon interference task), which, according to Weinbach & Henik (2012), should lead to no modulation of WSs over the conflict resolution mechanisms.

In Experiment 1, we set up a task suitable to measure Simon and spatial Stroop interference within the same trial. The impact of phasic alerting mechanisms on response preparation was tested with the presentation of the WS only in 2/3 of conditions. The warning signal manipulated was the same white noise used during the first Experimental Series (**Chapter 3**), in two levels of intensity. The largest intensity level was not used in this series to avoid startle responses. As the intensity seems to increase the response automaticity (Miller, Franz & Ulrich, 1999), we expected the manipulation of the WS acoustic intensity to negatively affect the Simon interference, with an increase of the interference from the spatially irrelevant information. We did not expect a modulation of the spatial Stroop interference (i.e., stimulus related conflict), as the effect of the WS was expected at the level of response selection. Results from Experiment 1 showed that temporal preparation modulated Simon and spatial Stroop interferences differently. Therefore, in Experiment 2, we tested whether the effect of the acoustic intensity was interference specific, and whether the reported WS-driven modulation on Simon interference reported in Experiment 1, was mainly caused by co-occurrence of two competitive interferences. Therefore, Simon and spatial Stroop interferences were manipulated in distinct trials in the second experiment, and further grouped into Simon and spatial Stroop blocks.

For Experiment 2, we again reported an interaction between alerting and conflict resolution mechanisms, and more importantly, we observed one more time different results for the Simon and spatial Stroop interferences, in line to what was observed in the first experiment. In particular, the temporal information following the presentation of a WS seems to have a detrimental effect, increasing the interference on Simon, but not on spatial Stroop interference conditions. Also, the pure alerting effect impacted the Simon but not spatial Stroop interference. This dissociative effect of WS on Simon and Spatial Stroop seems important to differentiate between different theories about the alerting effects of WS (Fischer et al., 2010; Fischer et al., 2012).

These findings assessed whether the intensity manipulation would lead to a pure alerting effect in a context of visuospatial interference, and whether this automatism was additive or independent from the response preparation induced by phasic alerting manipulations. However, only one visual stimulus at a time was presented as target in the visual field. Therefore, it was still unclear whether and how the intensity of WS affects performance when the target needs to be selected from distracters. For this reason, in the following experimental series we used a visual search paradigm.

4. Aims of the Experimental Series III: visual search and intensity effect.

In **Chapter 5** we investigated whether the impact of the WS intensity was also dissociable from the impact of response preparation during the detection of a visual target among distracters in visual search. It was also relevant to test whether the presence of a WS and the manipulation of its accessory characteristics (i. e., the acoustic intensity) affects target selection, either by leading to a faster motor execution, and or by affecting impact in the target search and selection from the distracters. The usual linear increase in RT for larger display sizes was expected. To analyse the performance, we measured intercept and slope coefficients of the search function, in order to differentiate between the effects of the WS intensity over the overall speed of responses (indexed by the intercept) and over the search efficiency (indexed by the search slope).

In Experiment 1, participants performed a visual search task of either small (3 distracter and 1 target), medium (7 distracters and 1 target) and large (11 distracters and 1 target) set sizes. The target was presented in 50% of the trials. We designed a Feature search paradigm, characterized by a stimulus target defined by the feature colour (e.g., a red L surrounded by green Ts and Ls). On the other hand, in a Conjunction search paradigm the target was defined as a conjunction of two features (shape and colour, e.g., searching for a green T), among distractors sharing either the same shape or the same colour with the target. As in **Chapter 3** and **Chapter 4**, we tested whether the presentation of a WS and its acoustic intensity facilitates or hinders target selection during a visual search task. For both search tasks, we expected to observe overall faster RTs (i.e., lower intercept coefficients) in the condition with the acoustic WS preceding the target. Concerning the search slope coefficient, in the case of Feature search it was expected to have values close to 0. In the case of Conjunction search, the impact of distracters on RT is larger, and a higher slope search index would reflect a sequential analysis of items across the search display. We also expected an impact of WS intensity on the search slope, depending on the set size manipulation. For the smallest set size condition, we expected faster responses after the WS, and even faster for the highest intense WS. For the largest set size conditions, we could expect either that WSs would broaden the attentional spotlight (Weinbach & Henik, 2012), leading to faster RTs WS and flatter slopes, especially for trials with the more intense WS; or alternatively, that the WS accelerate the automatic responses to the target (Fischer, et al., 2010; 2012), resulting in either the absence of the WS effect or a negative effect (i.e., steeper slopes for the more intense WS), as the automatic response to the target need to be inhibited during the search.

In Experiments 2 and 3, we used a Conjunction search as for Experiment 1, but we increased the task complexity by asking participants to discriminate the orientation of the target (canonical or inverted), which was presented in 100% of the trials. Moreover, we focused on the pure alerting effect, by presenting the WS in 100% of the trials with two levels of intensity (53 and 83 dB). In Experiment 3, we further increased the difficulty of target selection with a higher number of distracters, from 7 to 11 (medium set size) and from 11 to 35 (large set size). For both Experiments 2 and 3, we again expected faster overall RT for trials with higher intensity WS, in line with previous literature (see **Chapter 3** and **4**), despite having slower RT/larger intercept in these experiments compared to Experiment 1, due to the increased complexity of the task.

In general, this Experimental Series supported the conclusion that the pure alerting effects of WS might lead to the dissociation between the beneficial effect on motor execution of responses (overall RT or intercept of the search function) and the detrimental effect on processes involved in perceptual elaboration and target selection (steeper slope of the search function). We also clarified the impact of an increased intensity of WS in the visual search efficiency, leading to enhance or weaken the performance, depending on the set size.

CHAPTER 3.

EXPERIMENTAL SERIES I

The content of the Experimental Series has been published as:

Cappucci, P, Correa, Á., Guerra, P., Lupiáñez, J (2018). Differential effects of intensity and response preparation components of acoustic warning signals. *Psicológica Journal*, 39 (2), 292-318. IF:0.668 (Q3)

DIFFERENTIAL EFFECTS OF INTENSITY AND RESPONSE PREPARATION COMPONENTS OF ACOUSTIC WARNING SIGNALS

ABSTRACT

It is known that the increase of intensity on a warning signal (WS) usually decreases reaction times to targets and occasionally is accompanied by a startle reflex reaction that influences the speediness of response execution. In a simple detection task (Experiment 1), a detection task with catch trials (Experiment 2) and a Go-NoGo discrimination task (Experiment 3), we studied the relationship between response preparation and alerting mechanisms operating upon the presentation of warning signals. A WS was presented either synchronously with the target (simultaneous condition) or 1400 ms before it (delayed condition). In all three experiments, the intensity of the WS and the simultaneity between WS and target were orthogonally manipulated.

Results confirmed shorter reaction times by increasing the WS intensity. In Experiment 1, all conditions presented a clear acoustic intensity effect. In Experiment 2 we observed shorter reaction times in higher intensity conditions but only when the WS and the target were presented simultaneously. In Experiment 3, the intensity effect was observed only when the WS preceded the target. In all experiments, trials where the WS triggered a startle reflex showed a systematic increase in reaction time, which was independent of response preparation and task demands. In general, our findings suggest that response preparation modulates the alerting mechanisms, as a function of task set, but not the startle reflex. The dissociation between intensity, response preparation and startle supports the interdependence between these mechanisms elicited by the presentation of warning signals.

KEYWORDS: Alertness; warning signal; acoustic intensity; startle reflex; orbicularis oculi; response preparation; task setting.

The alerting system is fundamental for humans to supply and sustain the processing of high priority signals (Posner, 2008; Posner & Petersen, 1990; Sturm & Willmes, 2001). The priority of these signals is established by an internal, general state of wakefulness (tonic alertness) or by a phasic alerting mechanism, usually triggered by an external and abrupt warning signal (WS). In particular, an acoustic WS presented before the imperative stimulus (target) provides information about the moment of its appearance, both modulating the preparatory state before the motor execution and informing about when and whether the target will be presented (Correa, Lupiáñez, Milliken, & Tudela, 2004; Correa, Lupiáñez, Madrid, & Tudela, 2006; Gabay & Henik, 2008; Hackley, 2009; Hackley, & Valle-Inclán, 2003; Mather & Sutherland, 2011). This means that a WS can leads to programing and preparation of the response in advance, thus optimizing response readiness and speeding up reaction times (RT) (Hackley et al., 2003).

On the other hand, it has been shown that the consequences of acoustic WS presentation vary depending on the accessory characteristics of the stimulus itself. In the case of acoustic WSs, one of the most relevant accessory dimensions is its intensity. When intensity is manipulated, reaction times are usually shorter for higher intensities (Kohfield, 1971; Angel, 1973). This phenomenon, that we call acoustic intensity effect, is usually observed in tasks where the intensity dimension is completely task-irrelevant (Jaskowsky, Rybarczyk, & Jaroszyk, 1994; Kohfield, 1971; Miller, Franz, & Ulrich, 1999; Ulrich, Rinkenauer, & Miller, 1998). These task-irrelevant characteristics can be considered as additional, or more precisely accessory, aspects of the stimulus itself. These characteristics, together with other non-accessory features (i.e., temporal predictiveness), are critical for response execution. It is nevertheless important to clarify whether these two aspects of WSs interact or affect performance independently from each other.

In a series of four experiments, Miller and collaborators examined the effect of the intensity of a pure tone used as WS in simple RT, Go/No-go and choice tasks (Miller, Franz, & Ulrich, 1999). Results showed that high acoustic WSs led to faster RT and stronger finger flexion force. This raised magnitude of the muscular activation was confirmed in later studies with simple and choice RT tasks (Włodarczyk, Jaśkowski, & Nowik, 2002); in choice RT and spatial incongruence stepping tasks (Watanabe, Koyama, Tanabe, & Nojiba, 2015); and in paradigms manipulating the luminance intensity of visual WS (Jaskoswki & Wlodarczyk, 2006). In their fourth series of experiments, Miller et al. (1999) manipulated the temporal interval between WS and target (-400, -50, 50 and 400 ms), the WS intensity and the predictability of target appearance, by not presenting the WS in half of the trials. Increased response force was reported again for the highest WS intensities, although the intensity-related RT shortening was small and not significant. Finally, the authors compared their results with those from studies where the WS always anticipated the target and concluded that the reduced intensity effect was due to the diminished predictability of the WS, which decreased the subject reliance on the warning stimulus as a temporal cue (Miller et al., 1999).

Miller´s study contributed significantly to our knowledge about the impact of temporal expectancy on the acoustic intensity effect. However, the way intensity and preparation were manipulated in their study presents two important limitations. The first one concerns the manipulation of target predictability. In Experiment four, the intensity of the WS was manipulated only in half of the trials, when the WS was presented before or after the target. The authors suggested that the reduced number of trials with WS was the cause of a diminished intensity effect (Miller et al., 1999). Nonetheless, this manipulation did not allow a direct comparison of the intensity effect between conditions with and without response preparation, as the target was presented in all trials and participants were always required to respond. In other words, it is not possible to clarify whether the decreased acoustic intensity effect was due to the specific intervention of response preparation mechanisms, or it was related to a more general coexisting manipulation of temporal expectation. Since the temporal expectation and response preparation following WS are considered separated, dissociable mechanisms (for a review, see Weinbach & Henik, 2012), this distinction is critical in order to understand their influence on the effects produced by the accessory characteristics of WSs.

The second limitation of Miller's study is related to the possibility that intense acoustic stimulations are particularly effective in triggering an automatic defensive response, commonly known in the literature as startle reflex (Davis, 1984; Valls-Solé, Kofler, Kumru, Castellote, & Sanegre, 2005). In mammals, startle responses are a characteristic sequence of muscular responses elicited by a sudden, intense stimulus. Following several studies reporting faster RT associated to overt automatic reflexes, some researchers proposed the idea that the startling motor activation is able to trigger response selection and programming. The startle reflex has been robustly obtained with different paradigms (Carlsen, Chua, Inglis, Sanderson, & Franks, 2004; Carlsen, Chua, Inglis, Sanderson, & Franks, 2007; Carlsen, Maslovat, Lam, Chua, & Franks, 2011; but see Carlsen, Chua, Dakin, Sanderson, Inglis, & Franks, 2008), and different explanations have been proposed to explain it (Lipp & Hardwick, 2003; Lipp, Kaplan, & Purkis, 2006).

Trying to overcome these limitations, the aim of the present work was to investigate whether the intensity effect and response preparation induced by WS represent two independent aspects of alertness, and whether they are modulated by task sets requiring different levels of control. In particular, we intended to clarify the interaction between mechanisms of acoustic intensity and response preparation, while controlling for the presence of the startle reflex likely elicited by the more intense WSs. As explained above, the sound used as a WS may influence the response preparation in several ways: by anticipating the target (as it gives information about the temporal window of target appearance); by its intensity; or by triggering an automatic startle reflex. Despite the frequent use of acoustic WS and the manipulation of this sound dimension in experimental paradigms, the question of whether these behavioural changes rely on single or separate mechanisms is still under debate (Washington & Blumenthal, 2015; Carlsen et al., 2011; Lipp, Kaplan, & Purkis, 2006). In addition, the discrimination between the behavioural contribution of the intensity of the WS and that of the startle reflex is often missed. Nonetheless, understanding how these three mechanisms interact with each other is crucial to fully comprehend the nature of RT changes attributable to the WS manipulation.

With the purpose of exploring the relationship between the intensity effect and response preparation, we manipulated three levels of intensity of the acoustic WS, and expected shorter RT for the highest WS intensity. Moreover, in some conditions there was an interval between WS and target, which would allow participants to prepare in advance for responding to the target. We compared these conditions with those where the anticipatory preparation was not allowed, by presenting the WS simultaneously with the target. If preparatory and intensity effects are the behavioural reflection of independent mechanisms, response preparation should not interact with the intensity manipulation.

Also, we expected the startling response to be elicited by the WS, at least in the highest intensity condition (113 dB). It is worth noting that the startle reflex is a complex sequence of muscular response and there are several methods to record and quantify the electromyographic startling activity (Blumenthal, Filion, Hackley, Lipp, & van Boxtel, 2005; Carlsen et al., 2011). In this study we measured the startle responses by recording the orbicularis oculi (OOc) blink activity, through the identification of a significant increment from baseline of OOc activation. In trials where the OOc activity indicate a startle response manifestation, we expected to detect behavioural changes in response readiness. We did not expect to observe an interaction between the startle reflex and the level of response preparation, following the idea that startle reflexes are controlled by specific and more automatic mechanisms, and it has been previously reported independently of temporal uncertainty (Cressman, Carlsen, Chua, & Franks, 2006).

These hypotheses were tested in three task settings requiring different levels of control. In Experiment 1, we used a simple detection task without catch trials. In Experiment 2, a detection task with catch trials was used instead to investigate the effects of the "dispreparation" state induced by catch trials (Correa, Lupiáñez, Madrid, & Tudela, 2006). Finally, in a third experiment participants performed a Go-NoGo discrimination task, where a response was required to the some targets but not to the NoGo target, in order to investigate the possible role of the inhibitory processes invoked by the presence of NoGo targets.

EXPERIMENT 1

Participants

Thirteen students (mean age: 22.6 years; age range 19-31 years; 3 males) from the University of Granada participated voluntarily. All participants were right-handed, had normal or corrected-to-normal vision and none of them reported neurological disorders. The experiment followed the ethical guidelines for the Department of Experimental Psychology and was conducted in accordance with the ethical standards of the Declaration of Helsinki (1964).

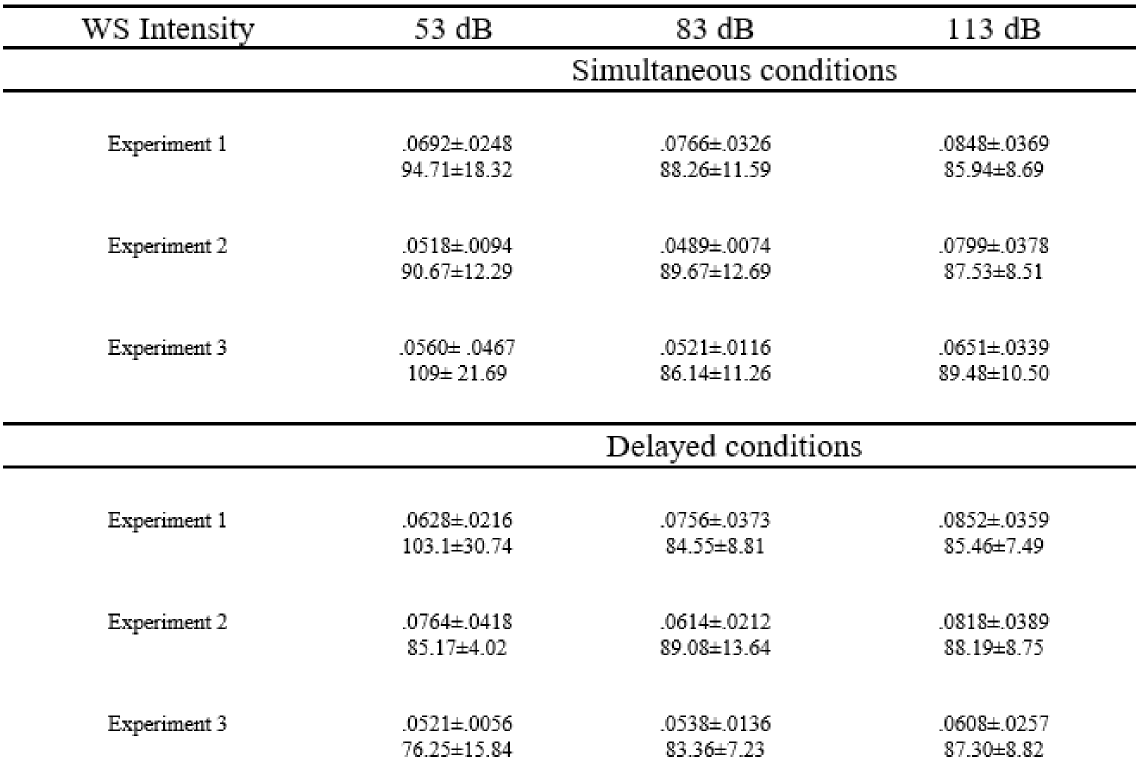
Apparatus and stimuli

Stimulus presentation, timing and behavioural data collection were controlled by a computer running E-prime 2 software (Schneider, Eschman & Zuccolotto, 2002). The target, either a white O or X letter, was used as detection stimulus and was centrally presented for 40 ms in a monitor (BenQ FP731), located at approximately 60 cm from the participant. Responses were recorded by means of a handle joystick button. The warning signal consisted of a 40 ms auditory burst of white noise (virtually instantaneous risetime) presented binaurally. The sound was amplified using a Logitec X-540 sound system and delivered via headphones (Philips SHP 2000), connected to a 220/240 V~ Fender 15 amplifier.

Physiological measurements

The eyeblink is the most persistent component of the startle reflex in humans and is usually measured by electromyography of the orbicularis oculi muscle (OOc) (Bradley & Sabatinelli, 2003). The OOc EMG activity was therefore recorded using an EMG 100G module integrated in the Biopac MP150 system and stored for offline analyses with Acqknowledge 9.3.1 software (Biopac System Inc.). Miniature silver/silver chloride electrodes were placed at the inferior eyelid of the left eye (Blumenthal, Cuthbert, Filion, Hackley, Lipp & van Boxtel, 2005). Frequencies below 28 and above 500 Hz were filtered out. Sampling rates were set at 1000 Hz. The EMG raw signal was then rectified, integrated and finally analyzed using a graphic Matlab program complying with a physiological accepted protocol (Balaban, Losito, Simons & Graham, 1986). The startle responses were measured as the difference between onset and peak µVolts values. Startle always followed a startle probe and stayed within the 21-120 ms window after the probe. The first 20 ms of data were scanned in order to determine whether during the trial onset the eyelid was stable or in motion. Baseline activity (mean: 5.9 ± 1.6 µVolts) was estimated considering the last 10 ms before the WS presentation. Trials were excluded if any eye movement was detected during the baseline recording. Any trial with a noisy baseline, with eye blinks, without a clearly detectable peak, with peak amplitude lasting more than 10 ms, with a peak beyond the 80 ms and with onset-offset duration larger than 100 ms was excluded. If a blink that marked the peak latency was shortly followed by a second one, the trial was also excluded. Table 1 shows the mean amplitude and onset peaks for startle trials as a function of Simultaneity and WS intensity.

TABLE 1. Peak amplitude in Volts and peak latency in millisecond (mean ± standard deviations) in startle trials for each Simultaneity and WS Intensity level.



WS Intensity	53 dB	83 dB	113 dB
		Simultaneous conditions	
Experiment 1	.0692±.0248 94.71±18.32	.0766±.0326 88.26±11.59	.0848±.0369 85.94±8.69
Experiment 2	.0518±.0094 90.67±12.29	.0489±.0074 89.67±12.69	.0799±.0378 87.53±8.51
Experiment 3	.0560± .0467 109± 21.69	.0521±.0116 86.14±11.26	.0651±.0339 89.48±10.50
		Delayed conditions	
Experiment 1	.0628±.0216 103.1±30.74	.0756±.0373 84.55±8.81	.0852±.0359 85.46±7.49
Experiment 2	.0764±.0418 85.17±4.02	.0614±.0212 89.08±13.64	.0818±.0389 88.19±8.75
Experiment 3	.0521±.0056 76.25±15.84	.0538±.0136 83.36±7.23	.0608±.0257 87.30±8.82

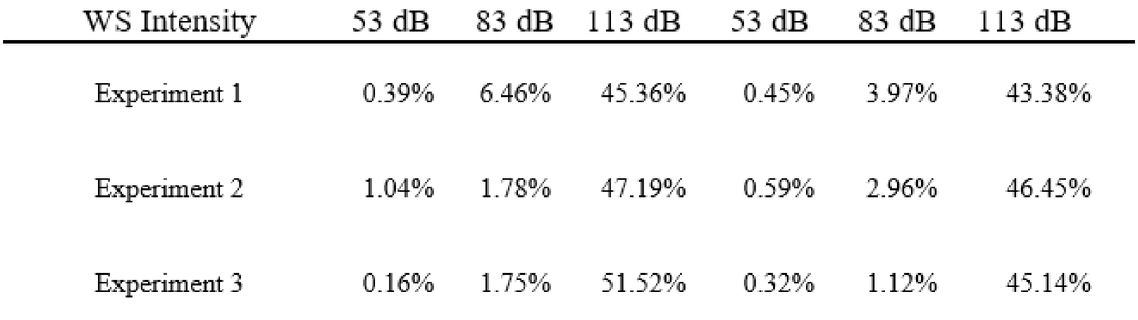
Procedure and design

Participants were asked to detect as soon as possible the target letter by pressing the top button of the joystick with their right thumb. Both targets (a white O or X letter) required the same responses and where randomly presented to the participants to avoid perceptual habituation.

The experiment consisted in a practice block and fifteen experimental blocks, yielding a total of 768 trials. The warning signal lasted 40 ms and was disclosed either synchronously with the target (simultaneous condition) or 1400 ms before the target (delayed condition). We manipulated the intensity of the white noise in three different conditions: 53, 83 and 113 decibels (dB). The levels of WS intensity and Simultaneity were equally presented and crossed in each experimental block. The target was either the letter X (1/2 of trials) or O (1/2 of trials) and lasted for 200 milliseconds. In order to avoid participant's response synchronization, we presented two empty displays at the beginning and at the end of each trial with a variable duration depending on RT, for all trials to have a 5 second duration. The movement required to respond was a button press with the flexion of the right thumb.

In our manipulation the distinction between the effect of Startle and WS intensity in shortening RT is essential. Thus, with the aim of correctly identifying trials with startle response from those without startle response, once the task was concluded, the complete OOc EMG activity was tacked and analysed following the physiological protocol. We selected as valid startle responses any with EMG peak amplitude larger than 0.04 µVolts (within the 21-120 ms window following a startle probe, see Blumenthal et al., 2005). Trials with peak lower than 0.04 µVolts or without peak recorded were considered as no startle trials. Table 2 shows the proportion of startle and no startle trials per condition.

TABLE 2. Percentage of startle trials for each level of Simultaneity and WS Intensity.



	Simultaneous conditions			Delayed conditions		
WS Intensity	53 dB	83 dB	113 dB	53 dB	83 dB	113 dB
Experiment 1	0.39%	6.46%	45.36%	0.45%	3.97%	43.38%
Experiment 2	1.04%	1.78%	47.19%	0.59%	2.96%	46.45%
Experiment 3	0.16%	1.75%	51.52%	0.32%	1.12%	45.14%

Results

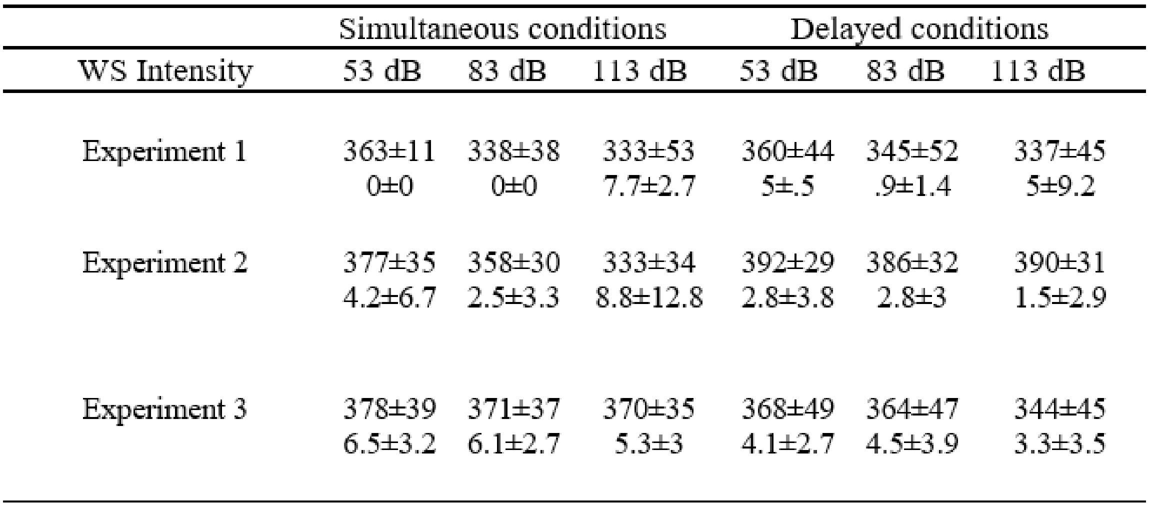
Error analysis

Mean RTs and error rates for each experimental condition are shown in Tables 3 and 4. Due to the low error rate, errors were not further analysed.

RT analysis

Incorrect trials (anticipations: 1.2%; missed responses: 2.1%) and trials with RTs faster than 200 ms or slower than 1000 ms (0.6% of incorrect trials) were excluded from the analysis. The RT filter in the time window 200-1000ms is a procedure widely used in the attentional literature (i.e. Boksem, Meijman, & Lorist, 2005; Correa et al., 2006; Lalor, Kelly, Pearlmutter, Reilly, & Foxe, 2007; Aasen, Håberg, Olsen, Brubakk, Evenseng, Sølsnesg, Skranesg, & Brunner, 2016) and has been reported to include almost all measurable responses for tasks like the one used in our experiments (Ledgeway & Hutchinson, 2008). Trials with EMG peak amplitude categorized as startle response (16.8%) were also excluded. A Simultaneity x WS intensity repeated measures ANOVA was performed on mean reaction times. One participant reported only startle trials in one or more levels of the WS manipulation and the data from this participant was therefore eliminated from analysis. A main effect of WS intensity was found, $F(2,22)= 21.32$, $p<.0001$, $\eta_p^2=.66$, such that RT decreased linearly as the WS intensity increased, $F(1,11)=24.15$, $p=.0005$. The main effect of Simultaneity ($F<1$) and the Simultaneity x WS intensity interaction were not significant, $F(2,22)=1.18$, $p=.3249$, $\eta_p^2=.09$.

TABLE 3. Mean reaction times ± standard deviations (in milliseconds) and errors percentages ± standard deviations in “no startle” trials for Simultaneity and WS Intensity factors. In Experiment 1, percentages of errors include anticipations and missed trials. In Experiment 2, they include anticipations, missed responses in target trials and false alarm response in catch trials. In Experiment 3, they include anticipations, missed responses in “response” trials and false alarms in “no response” trials.



	Simultaneous conditions			Delayed conditions		
WS Intensity	53 dB	83 dB	113 dB	53 dB	83 dB	113 dB
Experiment 1	363±11	338±38	333±53	360±44	345±52	337±45
	0±0	0±0	7.7±2.7	5±.5	.9±1.4	5±9.2
Experiment 2	377±35	358±30	333±34	392±29	386±32	390±31
	4.2±6.7	2.5±3.3	8.8±12.8	2.8±3.8	2.8±3	1.5±2.9
Experiment 3	378±39	371±37	370±35	368±49	364±47	344±45
	6.5±3.2	6.1±2.7	5.3±3	4.1±2.7	4.5±3.9	3.3±3.5

The next analysis focused on the startle response. Due to the small number of startle trials in the 53 and 83 dB conditions (see Table 2), only trials from the 113 dB condition were considered for the Simultaneity (simultaneous vs delayed) X Startle (no startle versus startle) repeated measures ANOVA (see Table 4). With this level of intensity, startle responses indeed occurred in both the simultaneous (45.4% of trials) and the delayed condition (43.4%). The ANOVA showed no significant effect of Simultaneity, F<1, and a marginal effect of Startle, $F(1,11)= 4.12$, $p=.0674$, $\eta_p^2=.27$. On startle trials participants responded slower (mean RT: 353 ms) than on no startle trials (mean RT: 335 ms). This tendency was similar in both the simultaneous and the delayed conditions, as can be observed in Figure 1 and is suggested by the lack of Simultaneity x Startle interaction, $F<1$.

TABLE 4. Mean reaction times ± standard deviations (in milliseconds) and errors percentage ± standard deviations for Simultaneity and Startle factors (only 113 dB conditions included). In Experiment 1 percentages of errors include all anticipations and missed trials. In Experiment 2 they include anticipations, missed responses in target trials and false alarm responses in catch trials. In Experiment 3 they include anticipations, missed responses in Go trials and false alarms in No go trials.

	Simultaneous conditions		Delayed conditions	
Presence of Startle	No startle	Startle	No startle	Startle
Experiment 1	333±53 7.7±2.7	346±50 0±0	337±45 5±9.2	359±75 1±1.3
Experiment 2	329±34 8±6.7	347±28 .6±3.3	392±31 .7±2.9	407±31 .4±3.8
Experiment 3	370±35 5.4±3	391±34 5.1±6	344±45 3.3±3.5	373±37 6.4±7

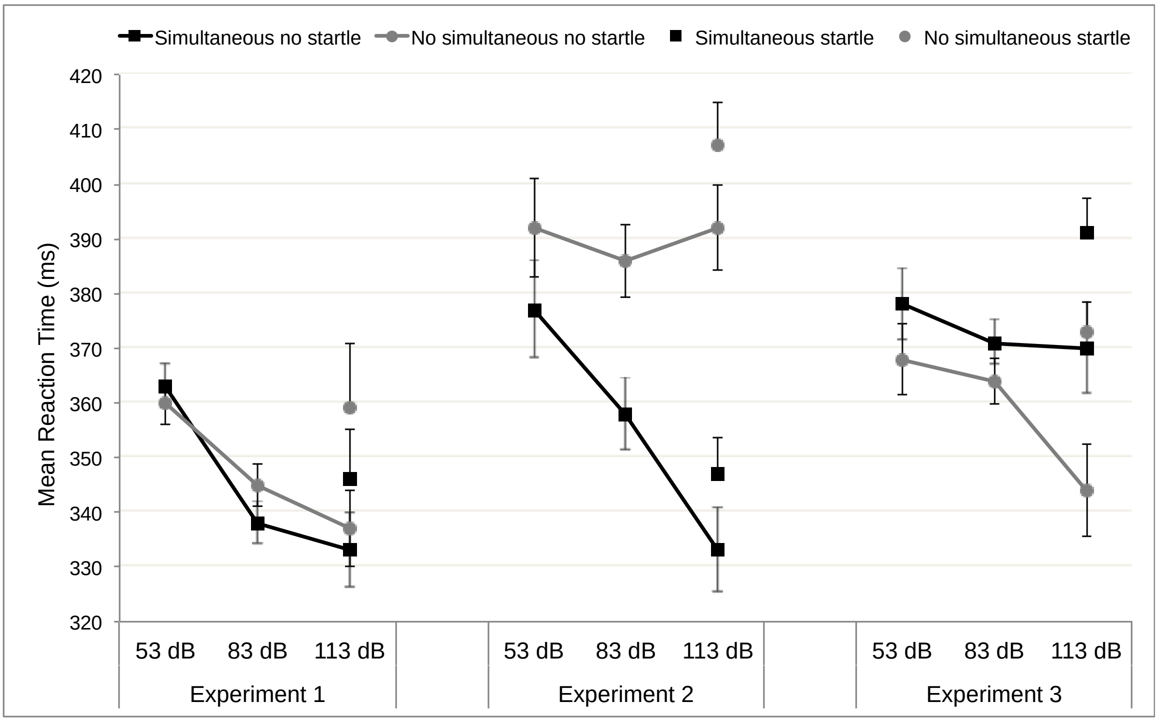


FIGURE 1. Relation between Simultaneity and WS Intensity across all experiments. Mean RT in Experiment 1(detection task), Experiment 2 (detection task with catch trials) and Experiment 3 (Go-NoGo discrimination task) as a function of WS intensities (53, 83 and 113 dB) for each Simultaneity and Startle level. Error bars represent standard error of the mean computed with Cousineau’s (2005) method.

Discussion

In line with our hypothesis, in Experiment 1 we found that responses to trials with high WS intensity were faster. Importantly, the effect was observed in the two Simultaneity conditions. Therefore, we could conclude that both response preparation and accessory characteristics of WS are mediated by independent mechanisms. However, no significant effect of Simultaneity was observed and therefore it seems that participants did not benefit from the temporal information supplied in the delayed condition, where the WS was presented before the target, to prepare their response in advance. One explanation for this lack of beneficial effect is that participants activated an automatic state of response at the beginning of each trial and were able to maintain that level of preparation for the whole trial. Since the target appeared in 100% of trials, in Experiment 1 the probability of making a mistake, besides missing or anticipating the response, was null. Thus, the level of response control applied was extremely low, which might explain the lack of interaction between Simultaneity and WS intensity.

Regarding the startle reflex, data from Experiment 1 showed a clear increase in RT for startle trials. This result contrasted with previous studies reporting RT shortening in conditions of startle reflex (i. e. Carlsen et al., 2004; 2007; 2011). It is important to note that in Experiment 1 participants were asked to respond by pressing a response button with the thumb´s flexion. This response is frequently required in behavioural studies concerning acoustic WSs in visual tasks, but is not usually the case for paradigms involving the startle reflex, where the more often responses are arm extension, wrist displacement and postural adjustments (Carlsen et al., 2004; 2007; 2008; Marinovic & Tresilian, 2016; for a review see Carlsen, 2011). Despite the fact that the type of motor response is usually neglected from the interpretation of startle effects on RT, it is possible that not only the task demand but also the type of response may have an influence on RT when a startle reflex occur, thus explaining why we observed a increase in RT instead of faster responses in this condition.

In any case, no matter the nature of the startle reflex on RT its mere presence allows the possibility to dissociate between the behavioural consequences of the intensity of the WS and the startle reflex. However, it is important to note that the effect was only marginally significant and therefore we cannot exclude the possibility that it might have been spuriously observed. Furthermore, no effect of simultaneity was observed, and therefore it was difficult to extract firm conclusions from this experiment.

EXPERIMENT 2

To test whether simultaneity (i.e., response preparation) and intensity of the WS did not interact because of a low or absent control setting that lead to absent response preparation, we designed a second experiment. In this new experiment, the Simultaneity and WS intensity manipulation remained unvaried from Experiment 1 but we added 1/3 of trials without target (catch trials), which required participants to hold the motor response on some trials. Catch trials intended to avoid the use of an automatic response strategy in order to reduce false alarms and anticipated responses and therefore required more response control. The level of control should be increased mainly after the WS presentation, i.e., in the delayed conditions, in order to avoid responding when no target was presented. Previous studies have also used catch trials to increase task control demands, leading to slower RT in conditions where response preparation is cancelled (Correa et al., 2006; Triviño et al., 2010).

Regarding the startle response, a replication seems necessary to investigate whether the increase in RT we reported for startle trials in Experiment 1 is confirmed in our procedure. Importantly, no matter whether a decrease or increase in RT is observed with startle, we expected the effect to be independent from both WS manipulations, in accordance with our hypotheses and results from Experiment 1.

Participants

Eight students (mean age: 23.5 years; age range 18-30 years; 6 males) from the University of Granada took part voluntarily in Experiment 2. Participants were right-handed and had normal or corrected-to-normal vision.

Apparatus and stimuli

Equipment and stimuli were the same as in Experiment 1.

Physiological measurement

Following the directions stated in Experiment 1, we measured the startle reflex elicitation as the µVolts difference onset-peak and we estimated the baseline (mean: 5.7±2 µVolts) considering 10 ms before WS. Trials with noisy baseline, eye blinks and protocol infringement (1.95 %) were eliminated.

Procedure and design

Stimuli duration and experimental procedure stayed unvaried. As in Experiment 1, three different levels of WS intensity and two levels of Simultaneity were orthogonally manipulated. The difference with the Experiment 1 consisted in the addition of 25% of catch trials, where no target was presented, and participants were instructed to withhold responding until the end of the trial. In the remaining 75% of trials, as in Experiment 1, either the X or O letter was presented together with the WS (simultaneous conditions) or after a 1400 ms interval (delayed conditions).

Results

Means RTs and errors rates for “no startle” and “startle” trials in the 113 dB trials are presented in Table 3 and 4.

Errors analysis

Errors were categorized as “anticipation” trials (0.9% of all trials), in which subjects responded before the target appearance; “false alarm” trials (1.3% of catch trials), in which subjects incorrectly responded to catch trials; and “missed” trials (3.6% of target trials), in which subjects did not respond to the target. The error analysis showed no significant main effect or interaction in false alarm and missed errors.

RT analysis

As in Experiment 1, we excluded from the RT analysis trials with incorrect response and those with responses faster than 200 ms or slower than 1000 ms (0.2% of correct target trials).

A Simultaneity x WS intensity repeated measures ANOVA was performed only considering trials classified as “no startle”. The main effect of Simultaneity was now significant, $F(1,7)= 7.00$, $p= .0331$, $\eta_p^2=.50$, with faster responses for simultaneous than delayed conditions. The main effect of WS intensity was also significant, $F(2,14)= 4.79$, $p= .0260$, $\eta_p^2=.41$, with RT linearly decreasing as intensity raised, $F(1,7)= 7.01$, $p=.0330$. More importantly, the Simultaneity x WS intensity interaction was significant, $F(2,14)= 25.98$, $p<.0001$, $\eta_p^2=.79$: as can be observed in Figure 1, the intensity-related shortening of RT was observed only in the no simultaneous conditions, where the increased noise intensity was accompanied by a linear decrease of RT, $F(1, 7) = 23.14$, $p= .0019$. In contrast, no effect of WS intensity was observed for delayed conditions, $F <1$.

As in Experiment 1, the second ANOVA was performed only for 113 dB trials (see Table 2). One participant was eliminated due to the insufficient number of reported startle trials. The main effect of Simultaneity was significant, $F(1, 6)= 34.13$, $p=.0011$, $\eta_p^2=.85$. Although the main effect of Startle did not reach significance, $F(1, 6)= 2.18$, $p=.1899$, the tendency for slower RT in startle (377 ms) than in No startle trials (361 ms) was observed, as in Experiment 1. Again, the interaction was not significant, $F(1,6)=.19$, $p=.6776$, $\eta_p^2=.31$.

Discussion

In line with our hypotheses, in no startle trials participants were faster as the intensity increased. Furthermore, a main effect of Simultaneity was found, with slower responses for delayed conditions. Furthermore importantly, the intensity effect was only observed for the simultaneous condition, with the no simultaneous condition showing no intensity effect. Previous studies have shown that catch trials modulate attentional orienting in time and in some cases inhibit the normal expression of temporal preparation (see Correa et al., 2004; Triviño, et al., 2010). In particular, catch trials generate target uncertainty and create a state of "dispreparation", which seems to prevent the orienting of attention at longer intervals. In other words, by including catch trials we induced in participants a state of increased response control, which helped to avoid responding before the target was presented. Note that this state of "dispreparation" was unnecessary in Experiment 1, where no catch trials were used and targets were presented in 100% of trials.

On the other hand, in Experiment 2 the pattern of results for the startle effect was similar to that reported in Experiment 1, with RT being slower in trials with a startle reflex response, although not significantly. Furthermore, this tendency to larger RT on startle trials was independent of the Simultaneity manipulation.

EXPERIMENT 3

The third experiment was designed to clarify the role of catch trials in response preparation, and thus further investigate the relationship between response preparation and the intensity and startle reflex effects. In Experiment 3 catch trials were replaced by NoGo targets, in which a number 8 was presented for which no response was required. As the discrimination of the NoGo target from Go targets (either the X or the O, as in Experiment 1 and 2) was necessary, we expected it to encourage participants to prepare in time. Indeed, a visual target-stimulus was always presented and therefore "dispreparation" would lead to either omission or commission errors (i.e., false alarms). Consequently, in Experiment 3 we expected RT to be faster in the delayed than in the simultaneous conditions. Note that to test our hypothesis regarding whether the intensity effect interact or not with other response preparation effects, observing the temporal preparation effect usually observed in the literature (i.e., faster RT when a WS anticipates the target appearance) was crucial.

In Experiment 2 the main effect of Startle was not significant and the interaction was unascertainable. Thus, before drawing any conclusion from this set of results, a further experimental confirmation is necessary. This was the second aim of Experiment 3, in which we expected to confirm the same tendency observed in Experiment 1 and 2.

Participants

Eight students (mean age: 24.6 years; age range 19-33 years; 3 males) from the University of Granada took part in this study. Participants were right-handed, had normal or corrected-to-normal vision and no neurological disorders.

Apparatus, stimuli and physiological measurement

Equipment, stimuli and physiological measurement were the same as in Experiment 2. A display with a central white “8” number was used as NoGo target in substitution of catch trials. When the OOc activation value exceeding an amplitude threshold of 0.04 volts occurred, the trial was considered as startle response. A total of 2.28% of trials violated the reference protocol and were excluded from analyses (see Table 1).

Procedure and design

Participants were required to detect the presence of the X or O letters in the display using the handle grip button, taking care of not responding to NoGo targets, i.e., the “number 8”, which was presented on 25% of trials. As in Experiment 1 and 2, conditions were equally balanced between the three levels of WS intensity and the two levels of Simultaneity.

Results

Error analysis

Error rates on “no startle” trials for the three intensity conditions and on “startle” trials for the 113 dB condition are presented in Table 3 and 4. Errors were categorized as “anticipation” trials (0.1% of all trials) when participants responded before the target appearance, “false alarm” trials (12.5%) when subjects responded to a NoGo target, and “missed” trials (2.7%) when subjects failed to respond to Go targets. Only false alarm and missed errors were further analyzed. The analysis of missed response revealed no significant effects.

The Simultaneity x WS intensity ANOVA carried out on false alarms showed a main effect of Simultaneity, $F(1,7)=7.41$, $p=.0297$, $\eta_p^2=.51$, with fewer false alarms for the delayed condition. The effect of WS Intensity and the interaction were not significant (all p>.1). The analysis of Simultaneity x Startle (in 113 dB trials) showed no significant effects (all p>.1).

RT analysis

As in the previous experiments, incorrect trials and trials with responses faster than 200 ms or slower than 1000 ms (1.3% of correct response trials) were excluded from the RT analysis. Non target trials were also excluded from the analysis.

The Simultaneity x WS intensity ANOVA, where only “no startle” trials were considered, showed a significant main effect of WS intensity, $F(2,14)= 8.46$, $p= .0039$, $\eta_p^2=.55$; one more time, by increasing the WS intensity RT decreased linearly, $F(1,7)= 17.77$, $p= .0040$. Moreover, although the interaction was only marginally significant, $F(2, 14)= 3.42$, $p= .0616$, $\eta_p^2=.33$, the intensity effect was only observed in the delayed condition, $F(1,7)= 40.98$, $p=.0004$, but not in simultaneous conditions, $F(1,7)= 1.73$, p=.2299 (see Figure 1). Although RT was now faster in the delayed conditions (373 ms) than in the simultaneous one (359 ms), as predicted, the main effect of Simultaneity was not significant, $F(1,7)= 2.06$, $p=.1948$.

The second analysis (113 dB conditions only) with Simultaneity x Startle as factors showed a significant main effect of Simultaneity, $F\ (1, 7)=9.70$, $p=.0170$, $\eta_p^2=.58$, with faster RT for the delayed condition. Remarkably, the main effect of Startle was also significant, $F(1,7)=20.34$, $p=.0028$, $\eta_p^2=.74$; once more, participants were slower to respond when trials were categorized as “startle”. This effect was observed in both Simultaneity conditions, as reflected by the lack of Simultaneity x Startle interaction, $F<1$. This result was perfectly in line with the outcomes of Experiment 1 and 2, where RTs increased in case of startle reflex release.

Discussion

As previously observed in Experiments 1 and 2, when a startle reflex response was recorded, in Experiment 3 we reported a significant increase in RT. Importantly, the increase in RT induced by the startle reaction across experiments was independent of response preparation and task. This finding is in line with our original predictions and in sharp contrast with the intensity effect, also produced by the WS, which is quite robust (it was reported in the three experiments) but interacts in a complex way with preparation and the control set induced by task demands.

In line with our expectations, in Experiment 3 response preparation facilitated the behavioural expression of the intensity effect and we confirmed the dissociation between the effect of acoustic intensity and response preparation. Thus, importantly, the intensity effect was significant only in the delayed conditions. Across all three experiments, the task appears to be the key factor to interpret the presence of an interaction between preparatory and acoustic characteristic of the WS. Thus, we conducted an overall analysis including Experiment (1, 2 and 3) as a between-participants factor, in order to clarify the role of the task set on the expression of the WS intensity and WS-target simultaneity effects.

Overall RT analysis

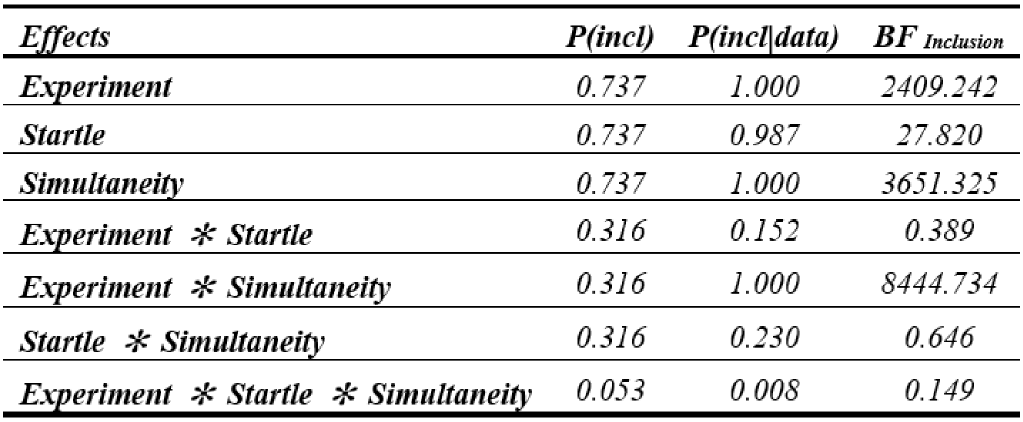
A first analysis of variance was performed with Simultaneity and WS Intensity as within-participants factors and Experiment (1, 2 and 3 as levels) as between-participants factor, in trials classified as "no startle". The main effect of WS intensity resulted significant, $F(2,50)= 25.62$, $p< .0001$, $\eta_p^2=.51$; across the three experimental paradigms, faster responses were observed as sound intensity increased. The main effects of Experiment, $F(2,25)= 1.43$, $p=.2583$, and Simultaneity, $F(1,25)= 1.67$ $p=.2078$, were both not significant. Furthermore, the Simultaneity x WS Intensity interaction reached significance, $F(2, 50)= 4.13$, $p=.0220$,

η_p^2=.14, although planned comparisons indicated that the intensity effect was significant for both the simultaneous condition, *F*(1,25)=30.11, *p*<.0001, and the delayed conditions, *F*(1,25)=25.96, *p*<.0001. The Simultaneity x Experiment interaction was also significant, *F*(2,25)= 5.84, *p*=.0083, η_p^2=.32, as well as the interaction between the three factors, *F*(4, 50)=8.35, *p*<.0001, η_p^2=.40. The significant interaction between the three factors statistically supports the idea that response preparation modulates the effect of WS intensity (i.e., faster RT for higher intensity) as a function of task set. Clearly, both the direction and magnitude of the Simultaneity x WS Intensity interaction seems to depend on task demands, as shown in the specific analyses of each experiment described above.

The second overall ANOVA was restricted to 113 dB trials to assess whether the startle reflex released by higher WS intensity affected the participant's readiness to respond, as a function of the task set. Like in the previous analysis, the Experiment was considered as a between-participants factor and Startle and Simultaneity as within-participants factors. We observed a significant main effect of Simultaneity, *F*(1,24)= 5.69, *p*= .0253, η_p^2=.19, but not of Experiment, *F*(1,24)=1.39, *p*=.2674. As in the previous analysis, the Simultaneity x Experiment interaction resulted statistically significant, *F*(2,24)= 11.76 *p*= .0003, η_p^2=.49. More importantly, in contrast to the effect of WS intensity measured on the no startle trials, the significant main effect of Startle, *F*(1,24)= 14.01, *p*= .0010, η_p^2=.37, was not modulated by any other factor (all *Fs*<.1).

These critical findings were confirmed with Bayesian analyses, which are especially relevant in case of non-significant effects with the null hypothesis testing approach. Importantly, the absence of statistical significance for an effect in the traditional null hypothesis testing approach is not evidence for the absence of such effect. However, Bayesian analyses help to assess whether our data either provide evidence favouring the alternative hypothesis (the larger the Bayes Factor -BF- the stronger the evidence), the null hypothesis (the lower the BF the stronger the evidence), or no evidence (BF between .33 and 3; see for references Jarosz & Wiley, 2014). Given the relatively high number for factors to be included in the Bayesian ANOVA to test the evidence against the three-way interaction, we report the Bayesian model averaging (see Wagenmakers et al., 2018). As shown in Table 5, the posterior probability of the models containing the Startle factor (i.e., P(incl|data)) is much higher than the a priori probabilities (i.e., P(inc)), thus leading to a high BF (27.820). Thus, taking the average across all candidate models, the data strongly support inclusion of the Startle model. In contrast, inclusion of the three way interaction model led to a reduction of the probability of this model after the inclusion (0.008), compared to the a priori probability (0.053), with a very low BF (.149), thus providing strong evidence against the three way interaction.

TABLE 5. The Bayesian model averaging. The table includes the average models across all candidates containing that factor. Each BF sizes the increase in the odds of the models including each factor over the alternative models excluding it (see Wagenmakers et al., 2018).



Effects	*P(incl)*	*P(incl|data)*	*BF $_{Inclusion}$*
Experiment	0.737	1.000	2409.242
Startle	0.737	0.987	27.820
Simultaneity	0.737	1.000	3651.325
*Experiment * Startle*	0.316	0.152	0.389
*Experiment * Simultaneity*	0.316	1.000	8444.734
*Startle * Simultaneity*	0.316	0.230	0.646
*Experiment * Startle * Simultaneity*	0.053	0.008	0.149

GENERAL DISCUSSION

In a series of three experiments we investigated the interaction between intensity effect of WSs, response preparation mechanisms and task setting, by controlling the presence of startle reflex. We presented an acoustic WS in three different intensities (53, 83 and 113 dB) and directly manipulated response preparation by using either no interval between WS and target or a 1400 ms interval between them. In Experiment 1 (simple detection task) the faster RT for the more intense WSs was observed in both the simultaneous and the no simultaneous conditions. However, in this experiment the target always appeared, and the probability of incorrect responses was extremely low, thus leading to fast RT no matter whether WS and target were simultaneous or not. To test whether the lack of interaction between Simultaneity and WS Intensity was due to a low control setting, we ran Experiment 2, in which 25% of catch trials were added, and Experiment 3, in which 25% of the trials had a NoGo target to which participants had to withhold responding. In Experiment 2, the high intensity of WS led to shorter RT, but only in the simultaneous condition. As explained above, in this paradigm the use of catch trials possibly prevented the reorienting of attention and inhibited the normal preparatory process usually observed when the WS precedes the target (Correa et al., 2004; Triviño et al., 2010). Therefore, in Experiment 3 we used NoGo targets instead of catch trials, with the objective of eliminating the state of "dispreparation" induced by trials where the visual target was not presented. As expected, in Experiment 3 participants used the temporal information about the target presentation provided by WS and tried to avoid mistakes (e.g. false alarms and anticipations) by maintaining their response preparation active at the moment of target appearance. Consequently, we observed faster RT in the delayed condition, accompanied by a significant intensity effect. Finally, we ran an overall analysis to test the influence of task demand in the interaction between intensity and response preparation, concluding that the type of task modulates the interaction between simultaneity and intensity.

The first important finding from our experiments was the confirmation of the intensity and response preparation effects as two distinct aspects of alertness, together with the indication of a strong influence of task demand in their behavioural expression. In our first experiment (a simple detection task without catch trials) the target and the WS appeared simultaneously in 50% of the trials and it is likely that participants consequently started to get ready for the response at the beginning of each trial. As the target was presented in 100% of the trials, "dispreparation" would have been useless or counter-productive for participants. In fact, when the WS appeared alone (in the other 50% of the trials), they just had to maintain the preparation state until the target appeared, which always did. In fact, it has been shown that the level of motor hand readiness varies as a function of participant’s expectancy (Burle et al. 2010). The maintenance of the high response preparation state seems to have been efficient in terms of hand readiness. A similar pattern is observed with no catch trials when a valid expectancy for the target to appear at a short interval is induced; responses are faster at the short interval and similarly fast at the longer interval (see, for example, Correa et al., 2006). This might thus explain why responses were faster overall in this experiment, as can be observed in Figure 1.

In contrast, catch trials generated target uncertainty and likely increased response control when the target did not appear together with the WS. Thus, in the delayed condition responses were slower; interestingly, the intensity effect was only observed for the simultaneous conditions. This seems to indicate that response control, as elicited by catch trials, induced a state of "dispreparation" for the delayed condition. As explained above, other studies have shown a modulation of temporal orienting attributable to catch trials (Correa et al. 2004; Triviño, et al., 2010). Furthermore, the "dispreparation" induced by catch trials made the intensity effect disappear. However, perhaps this is not the best way to test whether the intensity effect interacts or not with other response preparation effects in a paradigm where the preparation in time is discouraged. For this reason, in Experiment 3 we replaced the catch trials by NoGo targets and we finally confirmed the intensity effect and response preparation as two aspects of alertness, which nevertheless acted one more time in an interactive way. In this case, participants needed to control responding to the target-WS compound when they appear together in the simultaneous condition, in order not to commit false alarms on NoGo trials. This control over response preparation seems to have made disappear the intensity effect, now in the simultaneous condition.

In contrast to the intensity effect, which was clearly modulated by temporal orienting and the control induced by task set in an interactive way, another important result observed across the three experiments was the independence of the startle reflex response from any temporal information provided by the WS and the task manipulation. In all three experiments, when a startle reflex was recorded, RTs increased compared to when no startle was recorded, an effect that is opposite to the usual finding of RT speeding by the startle reflex (Carlsen et al., 2004; Carlsen et al., 2007). In any case, and importantly, the observed startle-related RT lengthening was not modulated by Experiment or the Simultaneity factor. The startle reflex produced an increase in RT that was robust across the three paradigms and independent from response preparation and task set manipulations, which fits with previous reports of Startle effects independently of temporal uncertainty (Cressman, Carlsen, Chua, & Franks, 2006).

Carlsen and collaborators studied the influence of startle in motor readiness and concluded that a startling stimulus represents the trigger for a faster release of previously prepared movements (Carlsen et al., 2011). Furthermore, a more recent study from his laboratory supported the physiological independence of startle reflex from the mechanism of response preparation (Drummond, Leguerrier, & Carlsen, 2016). Nonetheless, also in this study the direction of the startle RT effect was in line to the classic intensity effect (i.e., fastening RT) and opposite to our results. Some years before, Valls-Solé and colleagues proposed already the dichotomy between the startle response and the effects of a startling stimulus on reaction time (Valls-Solé, Kofler, Kumru, Castellote, & Sanegre, 2005). By analyzing the different response to prepulses, they suggested the existence of two separate phenomena for startle response and RT effects with high acoustic intensities. In particular, the fastening in RT might be the consequence of the progressive enhancement of excitability in the reticulospinal tract that takes place during movement preparation (Valls-Solé et al., 2005; Valls-Solé et al., 1999). In the same period, also Lipp and collaborators set the idea of independence between the RT facilitation and the startle reflex itself, claiming that they are dissociable (Lipp & Hardwick, 2003; Lipp, Kaplan, & Purkis, 2006). In general, as we found RT to be significantly slower in the startle than in the no startle condition, whereas more intense WSs led to faster RT, our outcomes sustain the dichotomy approach.

However, our results and those from previous studies reporting RT shortening in concomitance with startle reflex recording are in evident and sharp contrast. To analyse the possible reason behind this discrepancy it is crucial to understand how the startle reflex influences motor readiness, and the methodological differences between our manipulation and those from other studies. At least three methodological differences are worth considering. The first one is the locus of RT recording. In Carlsen´s studies (Carlsen et al., 2004; 2007; 2011) the response was recorded at premotor level. The premotor time is the interval between stimulus onset and the onset of EMG motor activity (Burle et al. 2010). Differently, in our series of experiments, the participant´s response was directly recorded from the key pressing, that is, the motor response. The motor response is considered as the sum of the premotor time and the motor time, i.e., the time interval between the onset of the first EMG burst and the start of the mechanical execution of the movement (Burle et al. 2010; Van der Molen, Bashore, Halliday, & Callaway, 1991). As consequence, RT in our experiments represent the sum of premotor and motor processes, which could be affected differently by the startle reflex. Thus, although unlikely, an effect startle on motor time larger and in the opposite direction to that on premotor time could explain ours and the previous results.

The second methodological difference is the identification of the startle effect through the OOc muscle. This method is diffusely widespread and accepted in the psychofisiological literature (Balaban et al., 1986; Blumenthal et al, 2005; Lang et al, 1990) and was thus chosen for the startle measures in the present study. However, in some cases the reference for the classification of startle reflex response are other muscles, as the esternocleidmastoid muscle activation (for a detailed explanation see Carlsen et al., 2011). This difference is extremely relevant, also considering the use of different criteria of electrophysiological measures (i. e., microvolt, signal filtering) for the classification of a muscular response as startle reflex.

Third, and perhaps more importantly, in Carlsen´s experiments the movement to perform was usually the arm extension or the angular displacement outwards the starting position of the right wrist (e. g. Carlsen et al. 2004; 2007). This means that the movement required for the response was the extension of limbs toward the external space. As a consequence, the movement in these studies is considerable as an external, outward, open movement. But in our studies participants held in the right palm a handle with a topper response button and responded by pressing it with the thumb´s flexion. This is considered as a proximal, inward, movement. The type of movement required in an experimental task is a crucial aspect of the study because across evolution the natural selection developed complex behavioural sets, in order to dispose the organism to avoidance, escape and defence. It is possible that there are substantial differences between the startling stimuli exposition in case of flexion movements and extension movements. In fact, the startle reflex to a sudden noise is viewed as an aversive or defensive response and would be augmented in case of both ongoing aversive emotions and attentional allocation of foreground tasks (Lang, Bradley, & Cuthbert, 1990). We suggest that an aversive/defensive behaviour, as the startle reflex, is positively associated to movement patterns of avoidance (as the usual response used in previous experiments), and negatively associated with approaching patterns of movements (as the one used in our experiments). Future research should confirm the plausibility of this explanation of the contradictory results.

Before concluding, some methodological and theoretical limits of our experiments could be highlighted. First, our study included in the analysis a high number of observations per participant but a small number of them. This is an important issue, as a small sample size leads to low statistical power, which decreased the chance of discovering effects that are genuinely true, at the same time that increases the likelihood of falsely disclosing some non true effects. It is important to note, however, that the sample sizes used in our experiments are not unusual in this literature (see, for example, samples sizes of 8 participants in Carlsen et al, 2004, 10 in Carlsen et al, 2007, and 8 participants per group in Correa et al., 2006a). Furthermore, the combined null hypothesis testing analysis of the data from the three experiments somehow solved the problem of sample size, leading to clear and robust intensity and startle effects, and a clear modulation of the former by simultaneity and tasks set (i.e., Experiment). On the other hand, Bayesian analysis was used to tackle the problem of the non-significant three-way interaction in the analysis of the startle reflex data, which provided strong evidence that the effect of startle on RT is independent from the modulation of simultaneity and task set.

Second, in our experimental design we manipulated two intervals between WS and target (0 and 1400 ms). However, in the analysis of attentional preparatory processes, it might be highly informative to have an intermediate short interval, that creates a context of temporal unpredictability. Within a combined paradigm with several WS-target intervals, a recent study examined the effect of alerting intensity on visual processing speed and threshold of conscious perception (Petersen, Petersen, Bundesen, Vangkilde, & Habekost, 2017). In this study, the pupil size was measured as a physiological marker of alertness and the increase in pupil size was associated to faster processing speed. Interestingly, the study reported a significant difference in pupil size between conditions without warning and those with a low intensity warning (40 dB), and between those with low and intensity warning (85 dB). Importantly, these differences were reported both for the early WS-target time window (300–800 ms after warning onset) and the late time window (800–2000 ms). Therefore, the processing speed seems to be affected by the intensity manipulation, both for short and long intervals after the WS. Thus, the next question would be whether pure alertness induced by intensity interacts with the process of response preparation in conditions of high temporal unpredictability, as a function of task set (as in our experiments), and whether this interactive modulation would also affect pupil dilation, not only RT. This debate is especially relevant also in relation to the startle reflex, as it has been shown that startling stimuli, in conditions of short temporal intervals, reduce the amount of muscle activation, delaying the preparation and execution of upcoming response (Maslovat, Drummond, Carter, & Carlsen, 2015).

To sum up, from the pattern of results obtained across our series of three experiments, we concluded that the task setting is critical to study the interaction between preparatory and perceptual aspects of alertness. In fact, task set clearly affected the behavioural expression of both response preparation and WS intensity. The phasic alertness, often defined as a purely automatic mechanism, has been demonstrated to be influenced by response preparation induced by temporal expectancies and temporally irrelevant characteristics of the warning signal as its intensity, which are both modulated in a complex way by task set. In contrast, response preparation and task set did not affect the startle response, for which RT increased in the opposite direction to the intensity effect and independently from the WS-target simultaneity and task set manipulations. In general, our findings supported the interaction between acoustic and response preparation mechanisms related to the presentation of a warning signal, as a function of task set, as well as the independence of the startle reflex response from any task-related manipulation.

CHAPTER 4.

EXPERIMENTAL SERIES II

The content of the Experimental Series II is under publication as:

Cappucci, P, Correa, Á., Fischer, R. Schubert, T., Lupiáñez, J. (2021). Differential effects of intensity and response preparation components of acoustic warning signals. *Psicológica Journal*. [in press]. IF:0.668 (Q3)

EFFECTS OF ACOUSTIC WARNING SIGNAL INTENSITY IN THE CONTROL OF VISUOSPATIAL INTERFERENCE

ABSTRACT

Previous studies have reported increased interference when a task-irrelevant acoustic warning signal preceded the target presentation in cognitive tasks. However, the alerting-congruence interaction was mostly observed for tasks measuring Flanker and Simon interferences but not for Stroop conflict. These findings led to the assumption that warning signals widen the attentional focus and facilitate the processing of irrelevant spatial characteristics. However, it is not clear whether these effects are because of the temporal information provided by the warning signal or because of their alerting effects.

Based on these findings, and on the open question about the nature of the warning signal intervention on visuospatial interferences, we decided to test the impact of the warning signal on the processing of irrelevant spatial features, by using a procedure suitable for measuring both Simon and spatial Stroop interferences. We also manipulated the intensity of the warning signal to study the effect of the task-irrelevant characteristics of warning signals in visuospatial interferences. For the Simon conflict, results demonstrated an increased interference provoked by the presence (Experiment 1) and intensity (Experiment 2) of warning signals. In contrast, neither the presence nor the intensity of warning signals affected the spatial Stroop interference.

Overall, these findings suggest that the impact of warning signals primarily depends on the processing of irrelevant spatial attributes and on the type of conflict (e.g., spatial stimulus-response interference in Simon vs. stimulus-stimulus interference in spatial Stroop). In general, acoustic warning signals facilitate the automatic response activation, but their modulatory effect depends on the task setting involved.

KEYWORDS: warning signal; alerting; acoustic intensity; visuospatial interference; conflict resolution; Simon interference; Stroop interference.

Alertness is a cognitive mechanism that allows an organism to rapidly mobilize resources when they are most needed and prepares the system for fast reactions to imminent events. When a warning signal (WS), anticipating the presentation of a target stimulus, activates the general state of readiness to respond, we refer to phasic alerting, which usually leads to shorter reaction times (RTs; Bertelson, 1967; Egan, Greenberg, & Schulman, 1961; Posner & Boies, 1971; Posner & Wilkinson, 1969). Furthermore, a WS's task-irrelevant characteristic, which is not its most essential feature, such as acoustic intensity, has been shown to affect performance. In particular, higher intensities are usually associated with faster RTs in simple reaction times tasks (Angel, 1973; Cappucci, Correa, Guerra & Lupiáñez, 2018; Coull, Frith, Büchel & Nobre, 2000; Jaskowsky, Rybarczyk & Jaroszyk, 1994; Miller, Franz & Ulrich, 1999; Näätänen, 1970).

Although phasic alerting and conflict resolution are considered to be dissociable mechanisms (Posner & Boies, 1971; Posner & Petersen, 1990), there is still a lack of consensus regarding the conditions and the specific processes involved in the interaction between them (Coull, Jones, Egan, Frith & Maze, 2004; Hackley & Valle-Inclàn, 2003; Weinbach & Henik, 2012). In their attempt to clarify the interaction between these two mechanisms, Callejas, Lupiáñez and Tudela (2004) found a detrimental effect of WSs on performance in a flanker task paradigm (Eriksen & Eriksen, 1974), where targets are presented centrally and surrounded by target-like distracters, associated to either the same (congruent condition) or the opposite (incongruent condition) response. The authors reported a larger interference effect after the presentation of a tone and explained their findings in terms of the alerting mechanisms inhibiting the conflict resolution mechanisms and facilitating the response activation (Callejas, Lupiáñez & Tudela, 2004).

However, a few years later, Fischer and collaborators carried out a series of experiments suggesting that WSs speed up the translation of the visual information code into the associated motor code, thus leading to faster responses and larger interference effects when the target stimulus is presented (Fischer, Plessow & Kiesel, 2010). This argumentation is based on findings with the Simon interference paradigm (Simon & Rudell, 1967; Simon & Small, 1969), which is largely used to study stimulus-response (S-R) interference (for a review, see Proctor, 2011). In particular, the Simon interference helps to assess the impact of motor task-irrelevant features on conflicting responses, as a lateralized response must be given on the basis of a feature (e.g., colour or shape) to a lateralized target, being location task-irrelevant. After observing an increased Simon interference in concomitance with the presentation of a WS, Fischer suggested that a WS does not impact the general state of readiness but rather the strength of automatic response activation, speeded up by the WS itself (Fischer, Plessow & Kiesel, 2010).

This explanation was mainly based on the frame of the dual-route account (Kornblum, Hasbroucq & Osman, 1990). According to this account, the imperative stimulus during the Simon condition activates two parallel processes of response preparation: the direct processing route (priming responses corresponding to irrelevant stimulus location) and the indirect processing route (priming responses based on task-relevant features). The WS-related activation of the direct route produces a faster RT, while the activation of the indirect route increases interference. According to Fischer´s account, WSs speed up responses by activating the direct route, thus increasing interference, as they facilitate the activation of automatic responses, which are based on the direct translation of visual information into the corresponding motor codes (Fischer et al., 2010).

Weinbach and Henik (2012) also tested the modulation of phasic alerting over conflict resolution within several types of interference. One of those was the classical Stroop interference paradigm. The Stroop interference (Stroop, 1935) is frequently used as a tool to study stimulus-stimulus (S-S) interference. In the classic Stroop paradigm, the response is associated with a specific feature of the target (e.g., the ink colour of words), while another stimulus feature is irrelevant to the task (e.g., the meaning of words indicating colours). As in all conflict tasks, for incongruent conditions, the task-relevant feature diverges from the irrelevant one, and longer RTs are usually reported. Weinbach and Henik (2012) found strong Stroop interference, which was nevertheless not modulated by the WS. Conversely, in a flanker task paradigm, they found a clear modulation by a WS, with a larger interference effect in concomitance with the WS presentation, although this result was only observed under specific spatial arrangement of the visual stimuli (Schneider, 2018). Therefore, they concluded that WSs affect the conflict resolution mechanisms, thereby leading to larger interference, but only when there is spatial information to process. The authors claimed that alerting mechanisms induce a global processing bias, a larger attentional focus, and a higher accessibility to any spatial information in the visual field. As a consequence, when a distracter and a target are separated, alerting increases the congruence effect (Weinbach & Henik, 2012). The debate is still ongoing regarding which one is the best interpretation to explain the impact of WSs on the interference effect, the facilitated translation of a stimulus into a response, or the wider attentional scope following a WS.

Böckler and colleagues decided to bring a deeper level of knowledge about the attentional processes involved by recording event-related potentials (Böckler, Alpay & Stürmer, 2011). In a Simon interference paradigm, they found an increased activity of cortical areas involved in the response preparation after the presentation of a WS. In particular, they reported that a WS enhances the incorrect lateralized readiness potential (LRP) activation in incompatible trials. The early, incorrect LRP activation in interference trials supports the idea of facilitated response activation by the WS. These findings stand in clear contrast to interpretations of enlarged interference effects as a result of hampered cognitive control by a WS. In terms of the dual-route framework, their results rather suggest that a WS amplifies the response hand activation, triggered by the spatially corresponding stimulus location (Böckler, et al., 2011).

Another piece of the alerting-conflict resolution puzzle was added by Soutschek, Müller and Schubert (2013), who examined the effects of WSs on conflict processing and post-conflict adjustments in both the Stroop and the Simon paradigms. The results revealed that WSs affected the post-conflict adjustments of sequential congruency effects only in the Stroop interference, but not in the Simon interference, with the Simon effect depending on the congruency of the previous trial independently of the presence or absence of a WS, whereas this post-conflict adjustment was cancelled for the Stroop effect when a WS was presented. They concluded that differential conflict resolution mechanisms are involved in these paradigms, and the differentiation between different types of interference and their specific resolution strategies is essential to understand the differential effect of phasic alerting on post-conflict adjustments in Stroop and Simon interferences (Soutschek et al., 2013).

Considering all studies together, it seems that the modulatory effect of WSs on conflict resolution mechanisms depends on the types of interference involved. To test Weinbach and Henik´s account, Schneider (2019) conducted a series of eight Stroop-like paradigms, concluding that the alerting-conflict interaction typically found with the arrow flanker interference does not generalize to Stroop interference. However, he attributed this difference to the type of target stimulus used and the task setting. More specifically, the alerting mechanisms should influence conflict resolution primarily when the task goals are associated with spatial information processing. In fact, for tasks that have relevant visuospatial features (e.g., classifying the spatial direction of an arrow), the increased alertness affects multiple stages of information processing (e.g., stimulus encoding and response selection), especially when the target stimuli have well-established spatial connotations and the interaction between alerting and control mechanisms should be expected (Schneider, 2019). Weinbach´s work (2012) also motivated a series of Flanker-like paradigms used to measure the variation of attentional focus size (Seibold, 2018). However, in contrast to the predictions based on Weinbach and Henik, no differences between trials with vs. without a WS were reported. These results rather support Fischer´s account that locates the emergence of the congruency-by-alerting interaction at the level of response selection (Seibold, 2018).

However, in the above-mentioned studies (Seibold, 2018; Soutschek et al., 2013; Schneider, 2018; Weinbach & Henik, 2012), the separation of the relevant and irrelevant features of WS information was not taken into account. This is important because the mere separation of the target and distracter objects indicated by Weinbach and Henik (2012) cannot be the core element, as other studies found the interaction when target and visuospatial information are integrated (Böckler et al., 2011; Fischer et al., 2010; Funes & Lupiàñez, 2003; Seibold, 2018; Schneider, 2018). For this reason, in the current study, we directly manipulated alerting and conflict resolution in a task designed to have integrated target and task-irrelevant visuospatial information in the same visual object, which, according to Weinbach´s account (2012), should lead to no modulation of WSs over the conflict resolution mechanisms. Importantly, this paradigm was suitable to measure both S-S and S-R interferences and test how they are modulated by the presentation of a task-irrelevant acoustic WS. The task, involving the Simon interference and the spatial version of Stroop interference (Lu & Proctor, 1995), required participants to respond with left or right hands to target (arrows) pointing up or down and presented at the top, bottom, left, or right positions (Lupiáñez & Funes, 2005). Fischer´s account (Fischer, et al., 2010) indicated that a WS should speed up congruent responses and be followed by larger interferences, even in the case of integration between target and task-irrelevant visuospatial features. For this reason, we expected faster RTs in trials where a WS was presented, and we expected the Simon interference effect to be increased by the presence of the WS. We did not expect to report a modulation of the spatial Stroop interference, as the effect of the WS was expected at the level of response selection.

In addition, we studied the impact of a fully irrelevant characteristic of WS (i.e., acoustic intensity) in both types of interference. Note that not only is acoustic intensity task-irrelevant, but it also provides no temporal information beyond that provided by the mere presentation of the WS. This aspect is relevant because temporal preparation has been shown to modulate Simon and spatial Stroop interferences differently (Correa, Cappucci, Nobre & Lupiáñez, 2010). Thus, the manipulation of acoustic intensity allows for an increase in alertness, without temporal preparation. To test whether the influence of WS acoustic intensity is interference-specific, we presented the same stimulus as the WS but with two levels of intensity, and we expected faster responses in conditions in which the intensity of the WS was higher.

EXPERIMENT 1

In Experiment 1, we used a version of the Simon and spatial Stroop paradigm suitable to measure both S-S and S-R interferences within the same trial (for a similar paradigm see Luo, Lupiáñez, Funes & Fu, 2011). To test phasic alerting and intensity-related modulation, targets were preceded or not by an acoustic warning signal, and we presented the same stimulus as WS but with two levels of intensity.

Participants

Thirty-two students (mean age: 21 years; age range: 18-25 years; 3 males) from the

Universidad de Granada took part to the study. Participants had normal or corrected-to-normal audition and vision. The experiment followed the ethical guidelines from the Department of Experimental Psychology (Universidad de Granada), in accordance with the ethical standards of the Declaration of Helsinki (1964).

A priori power analyses were not performed. Therefore, we conducted a post-hoc sensitivity analysis using G*power (Faul, Erdfelder, Lang & Buchner, 2007). Results revealed that with our sample size ($N=32$), the minimum detectable effect size for $\alpha=.05$, and $1-\beta=0.80$, is $f=0.16$.

Apparatus and stimuli

A PC running E-prime 2.0 (Schneider, Eschman & Zuccolotto, 2002) and a 17 Inches BenQ FP731 monitor located at approximately 60 cm from the participant were used for stimulus presentation and data collection. The warning signal consisted of an auditory burst of white noise presented for 40 ms and amplified by a Logitec X-540 sound system through a pair of Philips headphones. A 1.43° x 1.15° white arrow, pointing either upwards or downwards, was displayed as target stimulus for 100 ms in one of four possible positions at 4.39° from the 0.67° x 0.67° central fixation (see Figure 1).

Task and experimental design

Participant’s task consisted of responding as fast and accurately as possible to the upwards/downwards direction of the arrow target, by pressing either the “v” key with the left hand or the “m” key with the right hand. The association between the key and the arrow direction was counterbalanced across participants: in 50% of participants “m” key was associated to “upward” arrow’s direction and the “v” key to “downward” arrow’s direction; for the remaining half of participants such association was reverted. The position of target was an important element of our manipulation. During the experiment, the arrow was equally presented in either of four positions of the screen: top left, top right, bottom left and bottom right. Each of the target locations leaded to S-S or S-R sources of interference and was equally distributed through each block with a pseudorandom order. In particular, when an arrow pointing up appeared above the fixation point or an arrow pointing down appeared below the fixation, the trial was categorized as spatial Stroop congruent; when an arrow pointing up appeared below the fixation or an arrow pointing down appeared above the fixation, the trial was categorized as spatial Stroop incongruent. On the other hand, trials where target position coincided with the associated hand to respond were categorized as Simon congruent; when the target appeared in opposite side to the corresponding hand, trials were categorized as Simon incongruent. Overall, and depending on the arrow´s direction, four types of conditions were obtained: spatial Stroop congruent/Simon congruent trials (25% of cases); spatial Stroop incongruent/Simon incongruent trials (25%); spatial Stroop incongruent/Simon congruent trials (25%); spatial Stroop congruent/Simon incongruent trials (25%) (Figure 1).

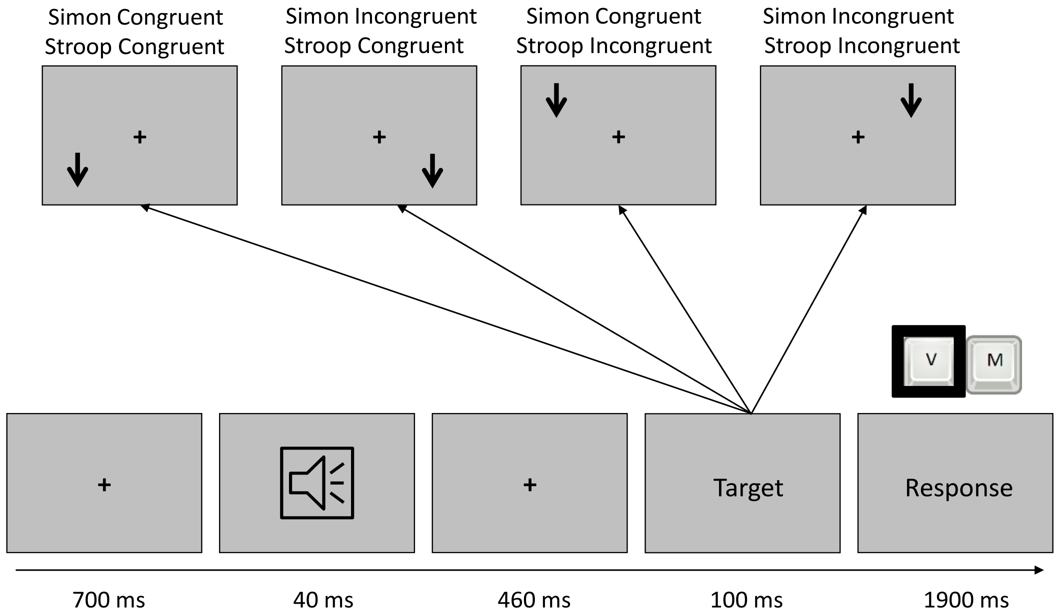


FIGURE 1. The timeline and all possible target positions in Experiment 1 (from left to right). The acoustic warning signals were accompanied by a fixation point and presented for 40 ms, only in 2/3 of trials. The remaining 1/3 of trials had no warning signal prior to target presentation. After a 460 ms interval, the target was presented for 100 ms and responses were allowed up to 1900 ms later; participants were asked to indicate as fast as possible the direction of the target (the up/down pointing arrow). The black contour framing the key´s letters indicates the correct response of the trial (in this case, the target is a down-pointing arrow and the "v" key is the correct answer). Each trial could be spatial Stroop and Simon Congruent (C) or Incongruent (I).

The experiment yielded one training block (32 trials) and nine experimental blocks of 48 trials each, for a total of 432 experimental trials. Each trial started with a black display and a white fixation point presented for 700 ms. Then, a burst of white noise was presented for 40 ms in 2/3 of the trials. When presented, this acoustic WS reached a medium intensity of 63 dB in half of trials and a high intensity of 83 dB in the other half, followed by a 460 ms long fixation point. In the remaining 1/3 of the trials, no warning signal was disclosed at all and just the fixation point was presented for 500 ms. At this point, we presented the target display with one of four possible targets. Intervals between WS and target presentation (stimulus onset asynchrony, SOA) at around 400 ms were often associated in literature with a peak of alerting efficiency (Fernandez-Duque & Posner, 1997; Fan et al., 2002; Callejas et al., 2004; Callejas, Lupiàñez, Funes & Tudela, 2005; Fuentes & Campoy, 2008). The target (an arrow pointing up or down) was presented only for 100 ms, however responses were recorded for the following 1900 ms (Figure 1). During the experiment, feedbacks for anticipation/incorrect responses were provided.

Results

Data analysis

Our analyses were based on the distribution of mean RT and error rates. Reaction times measured participant´s speediness to respond after the target onset. All anticipatory responses (e.i. participants responding after the WS onset but before the target onset) were excluded from analysis (0.36%). Concerning the error analysis, we considered a trial incorrect when participants pressed the incorrect key, or did not respond to the target appearance. This resulted on 4.08% of trials excluded. In line with the literature about behavioural post-error adaptations for reaction times and accuracy (Notebaert, Houtman, Van Opstal, Gevers, Fias & Verguts, 2009), trials preceded by anticipatory responses and incorrect trial were also excluded. In the RT analysis, all incorrect trials and trials with responses slower or faster than 2.5 standard deviations from the sample RT mean (*M*=529 ms, *SD*=117 ms) were also excluded from analyses (2.66%). To test the assumption of sphericity in both distributions, we ran the Mauchley's test. In case of violation of the assumption of sphericity (for one or more factors), *p* values were adjusted following the Greenhouse-Geisser correction of sphericity.

Mean reaction times and errors rate were analysed by a mixed-design ANOVA with

Warning signal (No WS, 63 dB, 83 dB), spatial Stroop interference (congruent, incongruent) and Simon interference (congruent, incongruent) as within-participants factors. For each experimental condition, in the Table 1 we reported the mean RT, the standard deviations and the errors percentages. Given that significant main effects for both visuospatial interferences were observed, we calculated two indices of interference effect, by subtracting congruent from incongruent mean RT for each one separately and submitted those indices to two separate univariate ANOVA.

TABLE 1. Experiment 1. The table indicates values of all possible levels of spatial Stroop interference, Simon interference and Warning signal. Value of mean reaction times and standard deviations are in milliseconds. Parentheses contain mean errors percentages for each condition.

	Spatial Stroop Congruent		*Spatial Stroop Incongruent*	
	Simon Congruent	*Simon Incongruent*	*Simon Congruent*	*Simon Incongruent*
No WS	541±78 (2.2%)	562±83 (6.1%)	551±73 (3.8%)	572±70 (5.8%)
63 dB	498±65 (1.5%)	531±66 (5.3%)	512±61 (3.3%)	540±64 (6.6%)
83 dB	491±63 (0.8%)	520±71 (4.8%)	510±60 (2.4%)	527±63 (7.9%)

RT analysis

For the reaction times distribution, Mauchly’s test indicated a sphericity violation for the Warning signal factor ($\chi 2(2)=12.8$, $p=.002$). From the ANOVA, a main effect of Warning signal was found, $F(2,62)=92.19$, $p<.001$, $\eta_p^2=.75$. Planned comparisons confirmed that trials without WS ($M=555$ ms, $SD=121$ ms) were slower compared to trials with WS of 63 dB ($M=520$ ms, $SD=114$ ms), $F(1,31)=77.32$, $p<.001$, and 83 dB ($M=512$ ms, $SD=112$ ms), $F(1,31)=12.86$, $p=.001$. Moreover, RT were significantly faster for 83 dB compared to 63 dB conditions, $F(1,31)=12.86$, $p=.001$. In line with our expectations, we also observed main effects of spatial Stroop, $F(1, 31)=16.02$, $p<.001$, $\eta_p^2=.34$, and Simon, $F(1,31)=57.7$, $p<.001$,

η_p^2=.65, responses being faster for congruent (s. Stroop: *M*=523 ms, *SD*=121 ms; Simon: *M*=517 ms, *SD*=118 ms) than incongruent conditions (s. Stroop: *M*=535 ms, *SD*=113 ms; Simon: *M*=542 ms, *SD*=115 ms). In line with our initial premises, we reported a significant interaction between Simon interference and Warning signal factors, *F*(2, 62)=4.2 *p*=.020, η_p^2=.12. As shown in Figure 2, the Simon interference was modulated by the irrelevant dimensions of WS (i.e., the intensity and the presentation of the WS itself).

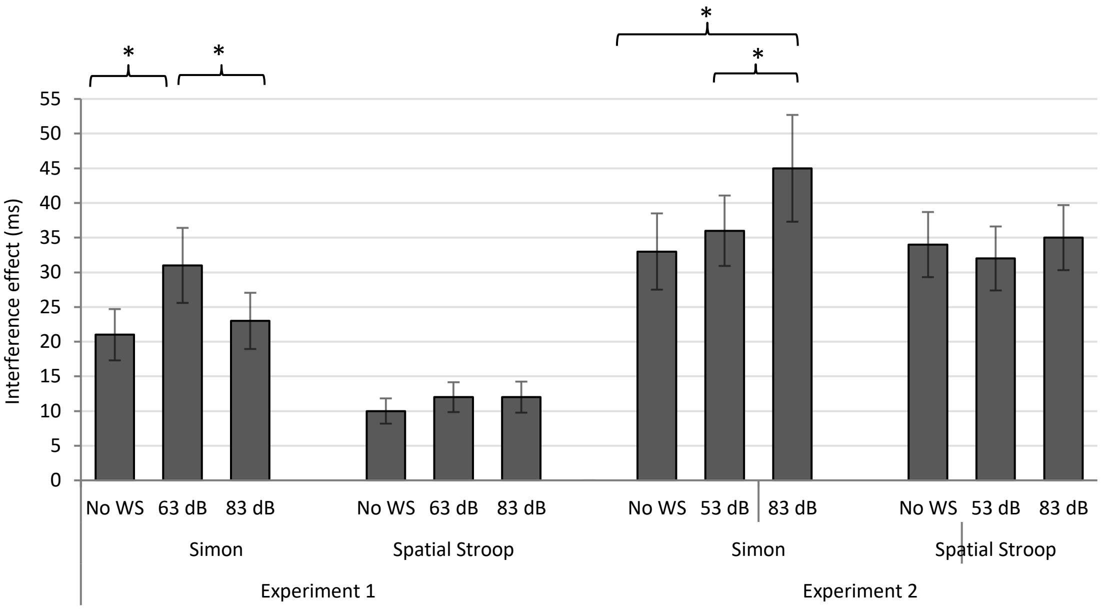


FIGURE 2. The Simon and Spatial Stroop interference effect (incongruent minus congruent mean RT) as a function of Warning signal (No WS, 53/63 dB, 83 dB) for Experiment 1 (left panel) and 2 (right panel). The gray lines above each bars indicate the standard error of the mean for each condition. *Asterisks* ("*") indicate *p* <.05.

On the other hand, Warning signal and spatial Stroop factors did not interact, *F*(2,62)=.18, *p*=.832. The Simon and spatial Stroop interferences are independent, *F*(1,31)=1.92, *p*=.175, and the three-way interaction Warning signal X spatial Stroop X Simon was also not significant, *F*(2,62)=1.69, *p*=.195.

The ANOVA on the Simon indices of interference effect showed a significant main effect for WS, *F*(2,62)=4.11, *p*=.021, η_p^2=.12. The planned comparisons showed a larger interference effect for 63 dB WS (interference effect: 31 ms) compared to No WS conditions (interference effect: 21 ms), *F*(1,31)=7.52, *p*=.010. However, the Simon effect decreased again for 83 dB WS (interference effect: 23 ms), *F*(1,31)=5.33, *p*=.028 (see Figure 2). No differences were found between No WS and 83 dB conditions, *F*(1,31)=.28, *p*=.602. As suggested from the ANOVA on RT, the main effect of spatial Stroop was not significant, *F*(2,62)=.17, *p*=.841, being negligible the difference between the effects observed in the No WS conditions (spatial Stroop effect: 10 ms), the 63 dB WS conditions (spatial Stroop effect:12 ms) and the 83 dB WS conditions (spatial Stroop effect: 13 ms).

Error analysis

Mauchley's test indicated that the errors rates distribution violated the assumption of sphericity for the Simon interference factor ($\chi 2$(2)=25.84, *p*<.001). Running the ANOVA we found a main effect of spatial Stroop, *F*(1,31)=11.25, *p*=.002, η_p^2=.27, with more errors in incongruent (4.81%) than congruent conditions (3.36%). The same was observed for the Simon interference, *F*(1,31)=25.88, *p*<.001, η_p^2=.45: participants committed more errors in incongruent (5.9%) compared to congruent conditions (2.28%). The effect of Warning signal was not significant, *F*(2,62)=.45, *p*=.637, but it was qualified by a marginally significant Warning signal X Simon interaction, *F*(2,62)=2.99, *p*=.058, η_p^2=.09, which showed an impact of WS on the Simon interference, without a clear difference in the Simon task reported for 63 dB and 83dB trials compared to those with No WS, *F*(1,31)=3, *p*=.093. Also, the two intensity levels did not significantly differ, F(1,31)=2.97, p=.095. On the other hand, the manipulation of WS neither affect the spatial Stroop interference observed in error rates, *F*(2,62)=2.77, *p*=.077. The three-way interaction Warning signal X spatial Stroop X Simon was also no significant, $F(2,62)=2.19$, $p=.120$, $\eta_p^2=.07$.

Discussion

In order to test the relationship between phasic alerting and cognitive control, and in consideration of Fischer´s (Fischer et al., 2010) and Weinbach´s (Weinbach & Henik, 2012) frameworks, we used a Simon-spatial Stroop paradigm suitable to measure both S-S and S-R visuospatial interference in which the target and distracter dimensions were integrated in the same visual object. Results showed a significant effect of the WS, with faster RTs when it was presented. Significant spatial Stroop and Simon interference was also observed in both RT and error rates. Importantly, also in line with our expectations, results showed larger Simon incongruence in trials with a WS, so that the presence of WS affected S-R conflict (i.e., Simon interference) but not S-S conflict (i.e., spatial Stroop interference). On the other hand, the increased intensity of WS caused a reverse effect for Simon interference with a diminution of the interference effect for 83 dB compared to 63 dB WS. However, this advantage was reflected in RT but not in the accuracy rates. In general, WS with higher intensities seem to impact less the Simon interference than lower WS intensity. The fact that the WS modulated Simon but not spatial Stroop interference allowed the rejection of the hypothesis that the modulation of visuospatial interferences through WS implicates the involvement of a general, unspecific alerting activation, affecting all kinds of spatial conflict. Furthermore, the assumption that the separation between spatial distracters and target is required for the modulation of WS over spatial conflict (Weinbach & Henik, 2012) was therefore rejected, as in our paradigm the distracting dimension (i.e., target location) was an integrated feature of the target.

EXPERIMENT 2

Experiment 1 showed that acoustic warning signals and their internal characteristics (i.e. the acoustic intensity) modulate Simon but not spatial Stroop interference. However, the experimental design used does not allow to explain whether the modulation of WS over the Simon but not the spatial Stroop effect takes place in terms of co-occurrence of two competitive interferences. Moreover, in Experiment 1, the congruence effect for Simon was larger compared to the spatial Stroop. Therefore, it can be argued that a strengthened S-R conflict might minimize or conceal the impact of WS over the spatial Stroop interference. In order to clarify these two aspects, we conducted the Experiment 2, with a different procedure where the Simon and spatial Stroop interference were manipulated in distinct trials (Lupiáñez & Funes, 2005) and further grouped in Simon-trial and spatial-Stroop-trials blocks.

Participants

Forty-eight students (mean age: 26.1 years; age range: 18-40 years; 13 males) from the Humboldt University of Berlin participated to the experiment. Participants had normal or corrected-to-normal audition and vision. The experiment was conducted in accordance with the ethical standards of the Declaration of Helsinki (1964).

A priori power analysis was not performed, for this reason we conducted a post-hoc sensitivity analyses using G*power (Faul, et al., 2007). Results revealed that with this sample size ($N=48$) the minimum detectable effect size for $\alpha=.05$, and $1-\beta=0.80$, is $f=0.12$.

Apparatus and stimuli

The stimulus presentation, the software of data collection (E-prime 2.0) and the experimental setting were the same as Experiment 1. The sounds were presented by Sennheiser HD 201 headphones and the visual stimuli by an HDMI senseye 3 led screen.

Task and experimental design

The task and experimental design were almost identical to Experiment 1. The main difference was the arrangement in distinct trials of the two visuospatial interferences. In the spatial Stroop trials, the target (an arrow) was presented along the central vertical axis of the screen, either 3.15° above or 3.15° below the fixation point. During the incongruent trials, the arrow pointing up appeared below the fixation and the arrow pointing down appeared above the fixation. For the Simon interference manipulation, the arrow was presented along the central horizontal axis, either to the left or to the right of the fixation point. When target position and hand associated with the correct response coincided, the trial was categorized as Simon congruent; when the target position was opposite to the response hand, it was categorized as Simon incongruent (see Figure 3).

The experiment yielded two practice blocks (12 practice trials each), five Simon blocks (240 trials) and five spatial Stroop blocks (240 trials). Blocks of the same types of interference were grouped together in the first or second part of the experiment. The timeline and duration of displays were the same as for Experiment 1. Warning signals were presented in 2/3 of trials, 460 ms before the target, with a medium (53 dB) or high intensity (83 dB) (See Note 1). In the remaining 1/3 of trials, the target was not anticipated by any warning signal.

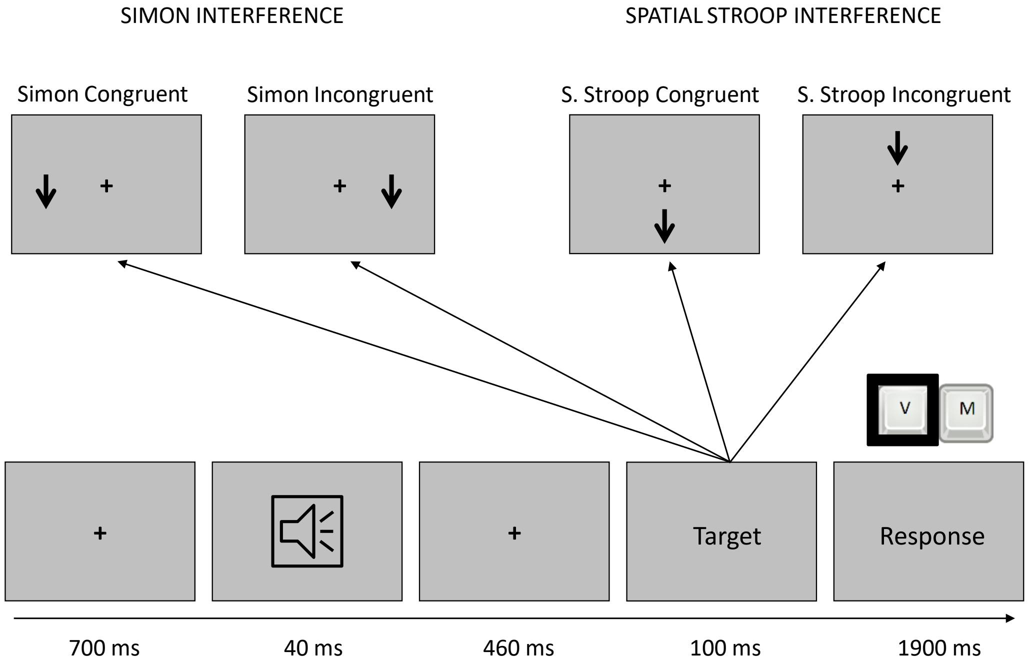


FIGURE 3. The timeline and all possible target positions in Experiment 2 (from left to right). Each trial presented only one type of interference and it could be Congruent (C) or Incongruent (I). Trials were distributed in spatial Stroop blocks (*S.Stroop Congruent* and *S.Stroop Incongruent* trials) and Simon blocks (*Simon Congruent* and *Simon Incongruent* trials). Warning signals were presented for 40 ms, only for 2/3 of trials. The remaining 1/3 of trials had no warning signal prior to target presentation. The target was presented for 100 ms and responses were allowed for a maximum of 1900 ms. Participants were asked to indicate the direction of target (the up/down pointing arrow). The black contour, framing the key´s letters, indicates the correct response of the trial (in this case, the "v" key associated to down pointing arrows).

Results

Data analysis

As for Experiment 1, we computed the errors rates for each participant and we excluded from analysis anticipatory responses (0.1%) and trials preceded by an incorrect response (4.23%). One participant reported more than 2 SD above the mean errors rate and was eliminated from the analysis. For the RT analysis, we excluded from analysis trials with anticipatory or incorrect responses, preceded by an incorrect response and with responses slower or faster than 2.5 standard deviations from RT mean (2.34%). Mean RT, standard deviations and errors standard deviation for Experiment 2 were detailed in Table 2. To test the assumption of sphericity in our distribution, we ran the Mauchley's test and correct *p* values following the Greenhouse-Geisser correction of sphericity. The ANOVA was performed for mean reaction times and errors rate with Type of Conflict (Simon, spatial Stroop), Warning signal (No WS, 63 dB, 83 dB) and Congruency (Congruent, Incongruent) as within-participants factors (see Table 2).

TABLE 2. Experiment 2. Conditions indicate all possible levels of Type of Conflict, Warning signal and Congruency factors. Values of the mean reaction times and standard deviations are in milliseconds. Parentheses contain mean errors percentage for each condition.

	Simon Congruent	*Simon Incongruent*	*Spatial Stroop Congruent*	*Spatial Stroop Incongruent*
No WS	513±67 (2.1%)	546±66 (5.9%)	515±69 (2.1%)	549±62 (4.1%)
53 dB	481±67 (1.8%)	517±64 (7.7%)	488±79 (2.3%)	520±81 (4.8%)
83 dB	472±71 (1.7%)	517±72 (6.1%)	481±72 (2%)	516±74 (5.7%)

In order to more specifically test our hypotheses, and in line with the analysis reported in Experiment 1, we computed interference effect indexes separately for spatial Stroop and Simon, by subtracting congruent from incongruent mean RT, and submitted the data to separate univariate ANOVAs.

Note $_1$. Experiment 1 and 2 differ in the lower intensity level of WS (53 dB versus 63 dB). This was due to the different level of background noise through headphones between Experiment 1 (≈ 40/45 dB) and Experiment 2 (≈ 30/35 dB).

In order to more specifically test our hypotheses, and in line with the analysis reported in Experiment 1, we computed interference effect indexes separately for spatial Stroop and Simon, by subtracting congruent from incongruent mean RT, and submitted the data to separate univariate ANOVAs.

RT analysis

Mauchly's test indicated that the assumption of sphericity was violated for the Warning signal factor ($\chi2(2)=33.1$, $p<.001$) and the interaction Type of Conflict X Warning signal ($\chi2(2)=6.9$, $p=.032$). A main effect of WS was found, $F(2,92)=120.41$ $p<.001$, $\eta_p^2=.72$: slower RT in the No WS conditions ($M=532$ ms, $SD=116$ ms) than in the 53 dB WS conditions ($M=502$ ms, $SD=110$ ms) were reported, $F(1,46)=105.02$, $p<.001$. Moreover RT were faster for 83 dB conditions ($M=496$ ms, $SD=111$ ms) than for 53 dB conditions, $F(1,46)=14.94$ $p<.001$. The main effect of Congruency, $F(1, 46)=198.18$, $p<.001$, $\eta_p^2=.81$, indicated faster RT for congruent ($M=492$ ms, $SD=114$ ms) than incongruent conditions ($M=528$ ms, $SD=109$ ms), but it did not interact with type of conflict, $F(1, 46)=.85$, $p=.360$, $\eta_p^2=.02$.

Importantly, the interaction Warning signal X Congruency reached significance, $F(2,92)=3.67$, $p=.031$, $\eta_p^2=.07$, with no difference between No WS and 53 dB WS trials, $F(1,46)=.01$, $p=.921$, but a difference in congruency effect between 53dB and 83 dB WS trials, $F(1,46)=6.43$, $p=.015$. Although the three-way interaction Type of Conflict X Warning signal X Congruency did not reach statistical significance, $F(2,92)=2.16$, $p=.121$, planned comparisons showed that Simon interference trials caused the WS modulation over interference. Indeed, as shown in Figure 2, the presence of the 53 dB WS did not affect the Simon effect, compared to the no WS condition, $F(1,46)=.49$, $p=.489$; however the Simon effect was significantly increased with WS of 83 dB compared to 53 dB, $F(1,46)=5.70$, *p*=.021.On the other hand, as shown in Figure 2, the spatial Stroop interference was not modulated by either the presence, *F*(1,46)=.43, *p*=.516, or the intensity of WS, *F*(1,46)=.93, *p*=.339.

The ANOVA on Simon interference indices showed a significant main effect of Warning signal, *F*(2,92)=4.79, *p*=.010, $\eta_p{}^2$=.09.The presentation of a WS did not impact the performance as the No WS (interference effect: 32 ms) and 53 dB WS (35 ms) conditions did not statistically differ, *F*(1,46)=.49, *p*=.489, but significantly increased in the 83 dB conditions (45 ms), *F*(1,46)=5.70, *p*=.021. On the other hand, the ANOVA for the Stroop interference confirmed an absolute absence of WS modulation, *F*(2,92)=.44, *p*=.644, $\eta_p{}^2$=.01.

Error analysis

We reported a main effect of Congruency, *F*(1,46)=64.10, *p*<.001, $\eta_{\mathrm{p}}{}^2$=.58, with higher errors score for incongruent (5.73%) than congruent trials (2%). The main effect of Type of conflict was also significant, *F*(1,46)= 5.05, *p*=.029, $\eta_{\mathrm{p}}{}^2$=.1, with generally more errors for Simon (4.22%) than spatial Stroop (3.52%) conditions. However, the factor Warning signal was not significant, *F*(2,92)=1.72, *p*=.184. The Type of conflict X Congruency interaction, *F*(1,46)=11.13, *p*=.002, $\eta_{\mathrm{p}}{}^2$=.19, showed a larger errors rate for for Simon incongruent (6.58%) compared to Stroop incongruent (4.89%) conditions. However, the three-way interaction did not reach statistical significance, *F*(1,46)=2.35, *p*=.101.

Discussion

As expected, in Experiment 2 we observed the classic interference effect of Simon and spatial Stroop (i.e., more errors and slower RT in incongruent conditions), the effect of alerting (faster RT after a warning signal), and the intensity effect (faster RT for the higher intensity condition). Again, the manipulation of the acoustic WS did not modulate the spatial

Stroop interference. Therefore, the lack of interaction between WS and spatial Stroop, reported in both Experiment 1 and 2, was not attributable to the co-presence of the Simon interference in Experiment 1. An important difference with Experiment 1 was that the 53 dB WS did not significantly affect the Simon effect. Nevertheless, WS impacted those trials with the higher WS intensity. We therefore confirmed that the type of visuospatial interference (i.e., S-S versus S-R) is a fundamental aspect to consider in order to understand the interaction between cognitive control and alerting mechanisms, although the specific impact of WS on Simon interference (either due to WS intensity or mere presence) might depend on whether the two interferences are presented separately in different blocks or mixed within the same trial.

To further test the differential modulation of WSs over both Simon and spatial Stroop interferences, we conducted a Bayesian repeated measure ANOVA (for spatial Stroop conditions only) across data from Experiments 1 and 2. The Bayesian analysis is relevant in cases showing a non-significant effect with the null hypothesis testing approach. In particular, Bayesian analyses help to assess whether our data provide evidence favouring the alternative hypothesis (the larger the Bayes factor [BF_{10}], the stronger the evidence; for references, see Jarosz & Wiley, 2014), the null hypothesis (the lower the BF_{10}, the stronger the evidence), or no evidence (BF_{10} between .33 and 3). Therefore, a Bayesian ANOVA was carried out on the spatial Stroop interference, with the WS as a within-participants variable, providing a $BF_{10}=0.060$. This constitutes strong evidence in favour of the null hypothesis (i.e., the absence of modulation of a WS over spatial Stroop being 1/.060=16.67 times more likely than its modulation). Together with the previous analysis, the Bayesian ANOVA confirmed our conclusion: the presence of an acoustic WS influences the Simon and spatial Stroop interference resolutions differently.

GENERAL CONCLUSIONS

The interaction between alerting and control mechanisms has heretofore been explained in terms of the involvement of cognitive mechanisms strictly related to spatial attention (Schneider, 2019; Weinbach & Henik, 2012) or not (Callejas et al., 2004; Fischer et al., 2010; Fischer, Plessow & Kiesel, 2012). In two experiments, we studied how the nature of interference impacts the interaction between phasic alerting and executive control mechanisms, taking into account the role of the irrelevant characteristics of a WS, such as its intensity. For this purpose, in Experiment, 1 we used a paradigm suitable for measuring both S-S (i.e., spatial Stroop) and S-R (i.e., Simon) interference in the same trial. We found that, on the one hand, the presence of a WS increased Simon interference, although the effect tended to disappear with a higher intensity. On the other hand, the spatial Stroop interference was not affected by any of the WS manipulations (i.e., presence and intensity). In Experiment 2, we presented both interferences again, but in separate trials, and the outcomes mostly replicated the results from Experiment 1. The influence of a WS in the Simon interference was confirmed, although, in this case, phasic alertness increased Simon interference for the high intensity condition. Altogether, we observed that alerting and intensity-related modulation influenced the Simon interference. In line with other literature about conflict control (Egner, 2008; Funes, Lupiáñez & Humphreys, 2009; Hommel, 1998), these findings confirm the different impacts of phasic alerting mechanisms on the two types of conflict. We therefore confirm that the type of visuospatial interference plays an important role in the reported interaction between conflict resolution and alerting mechanisms.

The most relevant finding in our study perhaps concerns the WS-related modulation separately for Simon and spatial Stroop interferences. In the past, the combination of Simon and Stroop paradigms has already been tested and has demonstrated additive effects

(Kornblum et al., 1990; Simon & Berbaum, 1990; Hommel, 1998). Simon and spatial Stroop interferences were also used to investigate the differential effect of temporal cues providing information about the moment of target appearance (Correa, et al., 2010). In the present study, we confirm once more that the conflict resolution mechanisms, activated by the visuospatial interferences, are selective and specific for one type of conflict (Egner, 2008; Funes, Lupiáñez, & Humphreys, 2010; Kornblum et al., 1990; Torres-Quesada, Funes & Lupiáñez, 2013); however, they could be modulated by task-irrelevant features, such as the acoustic intensity of the WS.

To further test the differential modulation of WSs over both Simon and spatial Stroop interferences, we conducted a Bayesian repeated measure ANOVA (for spatial Stroop conditions only) across data from Experiments 1 and 2, which showed strong evidence in favour of the null hypothesis (i.e., the absence of modulation of a WS over spatial Stroop). Together with the frequentists analyses, the Bayesian ANOVA confirmed our conclusion: the presence of an acoustic WS influences the Simon interference but not the spatial Stroop interference.

Another recent work has highlighted the importance of the task setting for observing the alerting-related modulation – the modulation primarily found when the main task included some spatial information processing (Schneider, 2019). The author explained that for those types of tasks, the activated alerting mechanism passes through multiple stages of information processing, especially when the target stimuli has precise spatial connotations, and therefore an interaction between the two mechanisms takes place (Schneider, 2019). However, not all spatial conflicts involving targets with spatial connotations seem to be modulated by WSs. In our two experiments, the observed conflict was always of a spatial nature (participants had to respond to the direction of the target while ignoring its location);

however, only one conflict type (i.e., Simon) was impacted by the WS, whereas the other (i.e., Stroop) was not. These results are consistent with the literature demonstrating that some functions of executive control (i.e., sequential conflicts) seem to depend on whether the same conflict type repeats in consecutive trials (Egner, 2008; Funes et al., 2010; Notebaert & Verguts, 2008). Moreover, the alerting modulation over sequential conflicts is also affected by the nature of the spatial conflict. In particular, Soutschek et al. (2013) found dissociable effects of WSs on the sequential congruency effect reported in Simon and Stroop interferences, when presented in separate experimental conditions. The effect of WSs on the sequential congruency effect, only observed in one type of incongruence, further supported the specificity of the control mechanisms involved in the resolution of spatial interference.

Another aim of our study was to test whether the alerting-interference interaction was because of better perceptual encoding by the amplified attentional focus or rather because of the direct involvement of alerting mechanisms in the S-R association. In Weinbach and Henik´s study (2012), alerting did not facilitate the activation of the automatic irrelevant response, despite a robust congruency effect. Therefore, their attentional spotlight account assumes that a WS increases the attentional focus and causes general accessibility of spatial information (making possible the interaction) in cases where relevant and (spatial) irrelevant characteristics are separated. However, following this framework in Experiment 1, we should not observe an increase in either Simon or Stroop interferences, as the target direction and spatial irrelevant characteristics (target location) were integrated into the same object in all trial conditions. Nevertheless, we reported a clear modulation of the WS over the Simon effect in both Experiments 1 and 2. Therefore, the attentional spotlight account seems to be insufficient to explain the evidence reported in the current work. Indeed, our findings rather support the idea that attending a WS does not demand a general state of readiness but rather a stronger level of visuo-motor response activation (Fischer et al., 2010; 2012).

However, the role that spatial information processing might play in the interaction is not entirely excluded. As stated in Weinbach and Henik (2012, page 1538), alerting can influence the congruency effect only when there is spatial information to process. This was inspired by previous findings from our lab indicating that alertness induces a global processing bias (Weinbach & Henik, 2011). Global processing bias may drive any spatial information in the visual field (be it relevant for the task or not) to higher accessibility. It is true that in both manipulations the processing of some sort of spatial information was required. As a consequence, the current results do not completely eliminate the role that spatial information processing might play in the interaction. Nevertheless, both Experiments 1 and 2 confirmed the importance of a strong S-R association in the alerting-conflict resolution interaction. Indeed, we found that whether spatial interference is modulated by WSs clearly depends on the nature of the interference that is measured, rather than the mere co-occurrence of relevant and/or irrelevant spatial information.

Despite the number of studies on this topic, many aspects of the interaction between alerting and interference resolution are still unclear. A recent work has focused on the influence of task setting on the WS impact and has demonstrated a decreased efficiency of interference resolution, in terms of RT and accuracy of responses, caused by the manipulation of phasic alerting (Asanowicz & Marzecová, 2017). In particular, the researchers used the attention network test (Fan et al., 2002), which combines Posner's cueing task (Posner, 1980) and the flanker task (Eriksen & Eriksen, 1974), and they manipulated the strength of a visual and acoustic WS (i.e., no WS vs. single, centred WS vs. a double WS presented in the locations corresponding to target positions). Their results indicated a WS-related modulation of the interference by showing increased interference from conditions of no WS, to the centred WS, and to the double WS (Asanowicz & Marzecová, 2017).

An important, but still unsolved question concerns the perceptual vs. motoric nature of this interaction. It is still unclear whether these dissociable attentional mechanisms interact with those dedicated to the perceptual inhibition of irrelevant visual information or with response selection processing. There is some evidence in the literature about modulations of alerting in the earlier stages of visual perceptual processing (Matthias, Bublak, Müller, Schneider, Krummenacher & Finke, 2010; Fischer, Plessow & Ruge, 2013; Thiel, Zilles & Fink, 2004). In other words, Simon and Stroop interference may be affected in different stages of elaboration from the WS manipulation. Nevertheless, the two paradigms presented in the current work might not be sufficient to perfectly dissociate each of the perceptual and motor preparation steps involved.

The current study suggests that the impact of alerting and intensity effect might differ depending on the types of interference involved. On the one hand, the expected RT shortening with a highly intense WS was reported in both manipulations. On the other hand, however, we found that the direction of the influence of WS intensity on the Simon interference varies. In particular, Simon interference decreased in conditions of high WS intensity in Experiment 1 (compared to low intensity), while it increased under high WS intensity in Experiment 2. Previous studies have shown that sounds increase the perceptual rate over the visual cortex (Romei, Gross & Thut, 2012; Romei, Murray, Cappe & Thut, 2009), even when they are not relevant to the task (McDonald, Störmer, Martinez, Feng & Hillyard, 2013). Therefore, one possibility to interpret our findings is that the intensity features intervene at two levels of performance: the motor readiness (i.e., a faster RT) and the perceptual elaboration, which might improve the analysis and selection of a target. The involvement of the intensity in one or both levels might depend on visuospatial control demands. In particular, in a previous work, we demonstrated how highly intense WSs increase the motor preparation to respond in simple detection tasks (Cappucci et al., 2018; see

Experiment 1). However, when the presence of catch trials required a stronger response control, the increased intensity impacted both the motor readiness and the target detection, also depending on the temporal information about the target provided by the WS (Cappucci et al., 2018; see Experiments 2 and 3). In the current study, we confirm that lower perceptual demands (Experiment 2; when the target only produces one conflict type in a given trial) raises the intensity-related motor readiness (i.e., faster RTs), while a high perceptual demand (Experiment 1) activates both motor readiness and perceptual elaboration (i.e., faster RTs and more efficient response selection). However, we acknowledge that the method employed in the current study might not be perfectly suited to fully test this hypothesis. Further studies would help to answer these still open questions.

To recapitulate, our findings show an interaction between alerting and conflict resolution mechanisms, supporting the existing literature on this topic (i.e., Callejas et al., 2004; Fischer et al., 2010; 2012; Weinbach & Henik, 2012). Importantly, different results for the Simon (S-R) and spatial Stroop (S-S) interferences were observed: the WS had a detrimental effect on Simon interference, increasing the interference, but not on spatial Stroop interference. Moreover, the WS intensity manipulation seems to play an important role in visuospatial conflict resolution, although how exactly it affects the S-R interference remains unclear. In general, these results confirm that an increase in the size of the attentional spotlight following a WS is insufficient to exhaustively explain the interaction between alerting and visuospatial interference. As previously suggested in the literature (Fischer et al., 2010; 2012; Seibold, 2018), the alerting mechanism is more likely interacting with the conflict resolution mechanism during the activation of the direct transmission of visual information into corresponding motor code processing.

CHAPTER 5.

EXPERIMENTAL SERIES III

The content of the Experimental Series III is in preparation as:

Cappucci, P., Correa, Á., Fischer, R., and Lupiáñez, J.. Acoustic warning signals increase speed but impair efficiency of visual search. [Manuscript in preparation].

ACOUSTIC WARNING SIGNALS INCREASE SPEED BUT IMPAIR EFFICIENCY OF VISUAL SEARCH

ABSTRACT

It has been suggested that warning signals benefit both target perceptual encoding and motor response execution. Intense sounds might also accelerate target detection and response execution. In this study, we tested whether the presence and intensity of acoustic warning signals affects performance in visual search tasks. In Experiment 1, we manipulated the presence/absence and two acoustic intensities of a task-irrelevant warning signal, while asking participants to detect a target among distracters on the basis of either colour differences (*Feature search*, Experiment 1A) or colour and shape (Conjunction search, Experiment 1B). Moreover, we studied the impact of warning signals in a context of increased complexity of target selection in Experiment 2, where participants performed a visual Conjunction search with discrimination of target orientation, and in Experiment 3 (Conjunction search – target orientation and increased set size), where the number of distracters per set size was increased.

The results confirmed that he increases in the intensity of the warning signal led to an overall faster reaction time (i.e., shorter intercept), but also to a decrease of the search efficiency (i.e., increased slope), In general, our study established that warning signals accelerate responses in visual search tasks, with beneficial effect on motor execution of motor responses, while they might weaken the target selection with a detrimental effect on processes involved in perceptual elaboration and target selection, depending on their intensity and the set size.

KEYWORDS: phasic alerting; warning signal; acoustic intensity; visual search; conjunction search; feature search.

When an imperative stimulus is preceded in time by an abrupt stimulus, the response to the imperative is usually accelerated, in spite of the abrupt stimulus providing no information about which visual information needs to be processed and requires a response (Posner, 2008; Robertson, Mattingley, Rorden, & Driver, 1998). The capacity to get ready for responding after the appearance of these abrupt stimuli is called phasic alerting (Posner, 2008). Thus, phasic alerting represents the ability to increase response readiness after the presentation of a warning signal (WS) which indicates the imminent appearance of a target stimulus. Nevertheless, it is not clear which process of target perception, categorization and/or response is affected by alertness (Coull, 2004; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Hackley, Langner, Rolke, Erb, Grodd, & Ulrich, 2009).

In the past, the impact of warning signals on reaction times has been linked to an improved perceptual efficiency. For instance, Vroomen and De Gelder (2000) showed that the detectability of a visual stimulus is enhanced by the presentation of unexpected, simultaneous acoustic WSs. The authors attributed the effect to an enhanced perceptual organization. In the following years, it became clear that WSs activate brain areas associated to attentional orienting and executive control processes (Coull, 2004; Fan, McCandliss, et al., 2005; Hackley, et al., 2009; Raz & Buhle, 2006). The enhanced alerting state not only impacts the perceptual processing and the visual perception of the target (Matthias, Bublak, Müller, Schneider, Krummenacher & Finke, 2010; Kusnir, Chica, Mitsumasu & Bartolomeo, 2011), but also influences the resolution of visuospatial interference.

Some studies have provided neural evidence relating the impact of the phasic alerting with an increased activity in regions involved in perception and processes of stimulus encoding as the extrastriate cortex (Thiel, Zilles, and Fink, 2004). Other findings suggested that the temporal orienting induced by WSs facilitates early perceptual encoding stages

(Correa, Sanabria, Spence, Tudela & Lupiáñez, 2006b) and the visuo-motor response activation (Fischer, Plessow & Kiesel, 2012). Finally, other studies rather pointed to facilitation of late motor execution (Hackley & Valle-Inclán, 2003; Weinbach & Henik, 2012). However, the mechanisms mostly impacted by the presentation of a WS that underlies the facilitation of target responses remains unclear. In the present study we aimed at investigating the processes that are affected by alertness. By using a visual search paradigm with the search display being preceded by a WS, we investigated the effects of alertness as a function of the complexity of the search environment to be faced.

To cope with the vast amount of incoming sensory information, the visual system must selectively process relevant information while avoiding irrelevant one. In tasks as visual search, where a target stimulus may be accompanied by distracting visual stimuli, and especially when they are similar to the target, the target detection is difficult, and depends greatly on the set size, i.e., the number of task-irrelevant distracting stimuli (Treisman, 1993; Wolfe, 1998). How the attentional mechanism reacts to the increasing number of stimuli presented in the visual scene has been successfully framed by the Treisman´s feature integration theory (Treisman & Gelade, 1980; Treisman 1998). In the footsteps of Neisser (1967), Treisman proposed a two-stages architecture for visual search. The first stage is defined as *Feature search* and indicates a fast processing of visual information, with all features being processed in parallel. *Feature search* occurs when the target saliently differs from distracters in a single feature (i.e., a red T among green Ts) and therefore responses to individual features is independent on set size. In the other stage, defined as *Conjunction search*, stimuli are analysed following a self-terminating (serial) search. Because the target differs in a combination of two features from the surrounding distracters (i.e., a red T among red Ls and green Ts), target identification among similar distracters requires attention resources, and therefore visual attention needs to be directed to one item after the other.

Consequently, by increasing the number of visual elements (or set size), the time required to find the target grows linearly.

The common performance parameters recorded during the visual search are the overall reaction times (RT), defined as an interval between the onset of a stimuli set and the subject's response, and the overall accuracy rate of target selection. However, a more meaningful index of performance for most visual search tasks is the measurement of RT as a function of set size, i.e., the search function. This search function can be reduced to two parameters, the slope and the intercept. The slope of the search function represents the cost in RT of adding each visual element item to the search display (for a reference, see Wolfe, 2016). That is, the larger the search slope the less efficient the search. In *Feature search* paradigms, the search slope is relatively flat showing a weak (or no) increase in RT, due to a lack of impact of distracters on the search process. In contrast, during *Conjunction search* tasks the target shares at least one feature with each distracter, leading to less efficient search and higher search slope for each added distracter (Wolfe, 1998). The second component of the search function is the intercept, which represents the RT needed to respond to a display with a minimum set size. Therefore, it informs about processes needed to respond to the target independently of the time spent in searching for the target. By differentiating between effects of WSs on slope and intercept of the search function, we aimed at investigating the effects of alertness on different processes involved in finding and responding to the target.

From previous literature, we know that acoustic WSs increase the interference between task-relevant and task-irrelevant spatial dimensions (Callejas, Lupiáñez, & Tudela, 2004; Fischer, Plessow & Kiesel, 2010). Dalton and Spence (2007) investigated the impact of audio-visual stimuli in sequential visual search in which participants attended a stream of stimuli sequentially presented at the centre of the screen, looking for a visual target, in the presence versus absence of an irrelevant acoustic sound that served as WS. The authors demonstrated that irrelevant auditory stimuli captured attention during visual search tasks, leading either to interference when they coincided with a visual distracter or to facilitation when they coincided with targets (Dalton & Spence, 2007). Nevertheless, all objects appeared at the same spatial location, and the question of how acoustic WS affect the competition between multiple objects concurrently present in a spatial layout remained unanswered. Moreover, it has been demonstrated that a spatially nonspecific WS boosts the saliency of a simultaneously presented visual signal. This attentional boost by simultaneous acoustic and visual stimuli resulted rather automatic, as this effect occurred when such events involve a distractor on most of the trials (Van der Burg, Olivers, Bronkhorst, & Theeuwes, 2008). In another study (Botta, Lupiáñez, & Chica, 2014), the presentation of a WS together with a central orienting cue helped endogenous orienting to modulate conscious perception of near-threshold stimuli, a modulation that was absent without the WS. Similarly, the presence of a WS has been shown to boost both exogenous (Callejas et al., 2004) and endogenous attentional orienting by visual cues (Asanowicz & Panek, 2020). Therefore, auditory WSs seem to interact with processing of visual information boosting whatever the visual stimulus is, be it a cue or a target.

Indeed, it has been suggested that the presentation of WSs affects both early stages of visual processing (Seibold & Rolke, 2014) and later ones (Hackley & Valle-Inclán, 2003). It is important to note that the WS, as a signal providing temporal information, can affects at several stages the spatial competition between multiple visual objects or alternative responses. In fact, other studies have demonstrated that the temporal predictability of the target occurrence after a WS is beneficial in responding to a visual task (Seibold & Rolke, 2014). For instance, with the help of functional magnetic resonance imaging (fMRI), it has been investigated how temporal predictability of the stimulus onset affects neural processing in visual cortical areas (Fischer, Plessow, & Ruge, 2013). The presence or absence of an auditory WS served as temporal predictor for stimulus onset. The analysis of neuroimaging data revealed reduced activity in primary visual areas with temporal predictability, which perfectly correlated with the behavioural performance benefit derived by the presence of the acoustic WS. The authors suggested that reduced neural processing in primary visual areas would reflect less neural "effort" to process visual information. Consequently, acoustic WS increase the efficiency of transmitting perceptual stimulus information into respective motor codes (Fischer et al., 2013; see also Alink, Schwiedrzik, Kohler, Singer, & Muckli, 2010).

In our study we tested at a behavioural level the effect of WS on reaction time, by differentiating in a specific way between effects of WSs on the intercept and the slope of the visual search function. The analysis of the slope and intercept parameters accompanied the RT analysis with a more specific measure of performance in visual search. As stated above, in the case of *Feature search* the slope is usually close to 0. In the case of *Conjunction search*, the impact of distracters on RT is larger and the index reflects the sequential analysis needed with much higher slope values. On the other hand, the differences between *Feature* and *Conjunction search* in the intercept values would indicate differences in target categorization and response.

In a series of three visual search experiments, we manipulated visual features of targets and distracters. By employing both *Feature* and *Conjunction search* in our experimental series, we tested whether the presentation of a WS facilitates target selection when this process is guided through a variable number of visual items presented in the scene (set size). In particular, the manipulation of small, medium, and large set size conditions helped to assess how efficiently people search for a relevant target among irrelevant distracters in the presence versus absence of an acoustic WS. For both search tasks, we expected to observe faster RTs in the condition with the acoustic WS preceding the target.

Furthermore, we were interested in dissociating in the general readiness caused by the appearance of the WS between two different processes. On the one hand, the temporal orienting component induced by the predictability by the WS of target's appearance. On the other hand, a pure alerting effect, independent of temporal predictability, induced by some task-irrelevant features of WS like the intensity of the sound (Cappucci, Correa, Guerra & Lupiáñez, 2018; Cappucci, Correa, Fischer, Schubert & Lupiáñez, in press; Miller, Franz & Ulrich, 1999; Ulrich, Rinkenauer & Miller, 1998). It has recently been suggested that affective salient sounds facilitate the search efficiency in a subsequent visual search (Asutay & Västfjäll, 2017). This facilitation might apply to other internal characteristics of a WS, such as its acoustic intensity. It is known that high intense sounds are associated to faster reaction times compared to less intense ones (Angel, 1973; Kohfield, 1971; Jaskowsky, Rybarczyk, & Jaroszyk, 1994; Miller, et al., 1999; Ulrich, et al., 1998), an effect that seems to depend on other factors like task set (Cappucci et al., 2018). Therefore, the specific mechanisms underlying the impact of acoustic intensity on target selection remains rather unclear. Thus, we manipulated the intensity of an acoustic WS, as task-irrelevant feature, to verify whether the intensity of the WS leads to a general increase of activation and unspecific response readiness. Boosting this more automatic component of phasic alerting (e.g., Asutay & Västfjäll, 2017) should result then in smaller RTs, according to the pure acoustic intensity effect (Kohfield, 1971; Angel, 1973), which would be reflected in a shorter intercept of the search function. We were also interested on investigating whether the search of the target among competing distracters would be also benefited by the intensity of the sound, which would be reflected in a reduced slope of the search function.

EXPERIMENT 1

The Experiment 1 tested the impact of the presence vs. absence of a WS, as well as its intensity, on visual search, by manipulating three different intensity levels (i.e., WS absence versus medium or high intensity WS) and three set size conditions. In Experiment 1A, we used a *Feature search* task, in which the visual target differed from all distracters in the target defining feature, either colour or shape (e.g., a red T among green Ls and Ts). In contrast, in Experiment 1B we used a *Conjunction search*, in which the target shared one feature (either colour or shape) with all distracters (e.g., a red T among green Ts and red Ls), thus requiring a serial processing of distracters for target selection.

The described overall faster RT after the WS, and even faster after the more intense sound, was clearly expected for the *Feature search* task in Experiment 1A, in which no effect of set size and a flat slope of the search function was expected. In contrast, for the *Conjunction search* task (Experiment 1B), we expected a steep slope of the search function. In addition, we also considered the possible impact of the WS on the search slope. In fact, it is conceivable that a WS flattens the slope of the search function and thus, may facilitate visual search. Alternatively, a WS may steepen the search function and thus, negatively impact the visual search. The first possibility is in line with previous work (Weinbach & Henik, 2012), suggesting that WSs generally broaden the attentional spot. A wider attentional spot would likely improve search, leading to larger beneficial effect of the WS in case of high intense sounds. Alternatively, the effect of a WS might be mainly due to the acceleration of an automatic response to the target (Fischer, Plessow, & Kiesel, 2010; 2012). In this scenario, WS effects should be most effective with few distracters and should dissipate with increasing set size. This would lead to a steeper slope of the search function (i.e., steeper slopes for the more intense WS).

Method

Participants

Eighty students from the university of Granada took part in the Experiment 1 (see Note [1]). Forty students (mean age 21.6 ± 3.3 years; 11 males; 3 left-handed) performed the *Feature search* task (Experiment 1A) and the remaining forty (mean age 21.5 ± 3.92 years; 9 males; 3 left-handed) performed the *Conjunction search* task (Experiment 1B). Two participants performing the Conjunction search task were discarded due to their high errors rates (>20% of trials). All participants had self-reported normal hearing and vision. This and the following experiments followed the ethical guidelines of the University of Granada, as part of a larger research project (PSI2011-22416), in accordance with the ethical standards of the Declaration of Helsinki (1964).

A priori power analyses were not performed. Therefore, a sensitivity analysis was conducted for both Experiment 1A and 1B, using the software package G*Power (Faul, Erdfelder, Lang & Buchner, 2007). For Experiment 1A, with a sample size of N=40, the minimum effect size that could be detected for $\alpha = .05$, and $1-\beta = .80$, for 3 x 3 repeated measurements (WS x Set size), is $f = .146$ (minimum detectable effect). In Experiment 1B, the sample size being N=38. A similar sensitivity analysis revealed that the minimum detectable effect of $f = .150$.

---

[1] In a first session of Experiment 1, we balanced the number of distracters presented in each quadrant of the target display. These two sessions included a total of 40 participants (20 for Experiment 1A and 20 for Experiment 1B). For the remaining participants, the number of distracters per quadrant was random rather than balanced. At the end of the first data recollection, we conducted an explorative analysis to test possible differences between the two groups of participants in each experiment. However, no significant differences between the two sessions were found. For this reason, we performed the analyses described in the present manuscript with the two merged groups, only considering whether they performed the *Feature search* or the *Conjunction search* task.

Apparatus and stimuli

Stimulus presentation, timing and behavioural data collection were accomplished by using a PC running E-Prime 2.0 (Schneider, Eschman & Zuccolotto, 2002) and a BenQ XL 24IIT monitor, arranged at around 60 cm from the participant. Responses were recorded by means of a Logitec K120 keyboard and the v and m keys served as response keys. The sound was delivered using two loudspeakers (Logitech LS11) placed at the right and left side of the screen with an intensity of either 53 or 83 decibels (dB), respectively. The warning signal consisted of an auditory burst of white noise (instantaneous rise time) presented for 40 ms. The target display had a uniform black background. Target and distracters, of about 1 cm of height, were presented at 6.5 cm from the white fixation point and consisted of "T" and "L" letters, which were presented simultaneously in a set size of 4, 8, or 12. The possible positions of target and distracters were 16 in total and randomly arranged across the four quadrants (see Note [1]). However, the exact position for target and distracters slightly varied (± 0.5 cm), to avoid the perfect circular arrangement of letters (see Figure 1).

For the *Feature search* task (Experiment 1A), the target letter consisted in one letter defined exclusively by colour, e.g., a red T amongst green Ts and green Ls or a green L amongst red Ts and red Ls. However, in the *Conjunction search* task (Experiment 1B) the target letter was defined by colour and shape, so that the distracters always shared with the target one feature (colour or shape). As an example, in conditions where target was a red “T”, we used red “L” and green “T” letters as distracters. Otherwise, if the target was a green “L” we used green “T” and red “L” letters as distracters (see Figure 1). The same target was constant for a given participant (either the red “T”, or the green “L”) but stimulus target was counterbalanced across participants.

Task, procedure and design

Participant’s task was to respond to the presence versus absence of the target as fast as possible by pressing the “v” or the “m” key. For half of the participants the m-key reflected the presence and the v-key the absence of the target. For the other half, this assignment was reversed. The target was represented in 50% of all trials.

During the experimental session, we recorded the accuracy of participant´s response and their reaction times from the target onset. The experiments started with a short practice session (20 trials) followed by eight blocks amounting to a total of 576 experimental trials (see Note [1]). Trials started with a fixation display with a random duration between 500 and 1500 ms. After that, the 40 ms white noise used as WS was presented. In 1/3 of trials the white noise was presented with 53 decibels (dB), in another 1/3 of trials with an intensity of 83 dB, and in the remaining 1/3 of trials a 40 ms silent display was presented. Another fixation display remained for 460 ms. Finally, the target display was presented until a response was given, or for a maximum of 3000 msec in case there was no response.

Data analysis: accuracy and reaction times

Practice trials, trials with incorrect key selection, without response or with an anticipated response were excluded from the analysis. In the reaction time analysis also RTs outside the range of ±2.5 standard deviations from mean RT per subject and set size, were also filtered out. For the *Feature search* task, were discarded 2.78% incorrect trials and 2.69% trials with RTs outside the range of ±2.5 standard deviations from mean RT. For the *Conjunction search* task, 7.48% incorrect trials and 2.31% trials with RTs outside the range of ±2.5 standard deviation from mean RT were excluded from analyses.

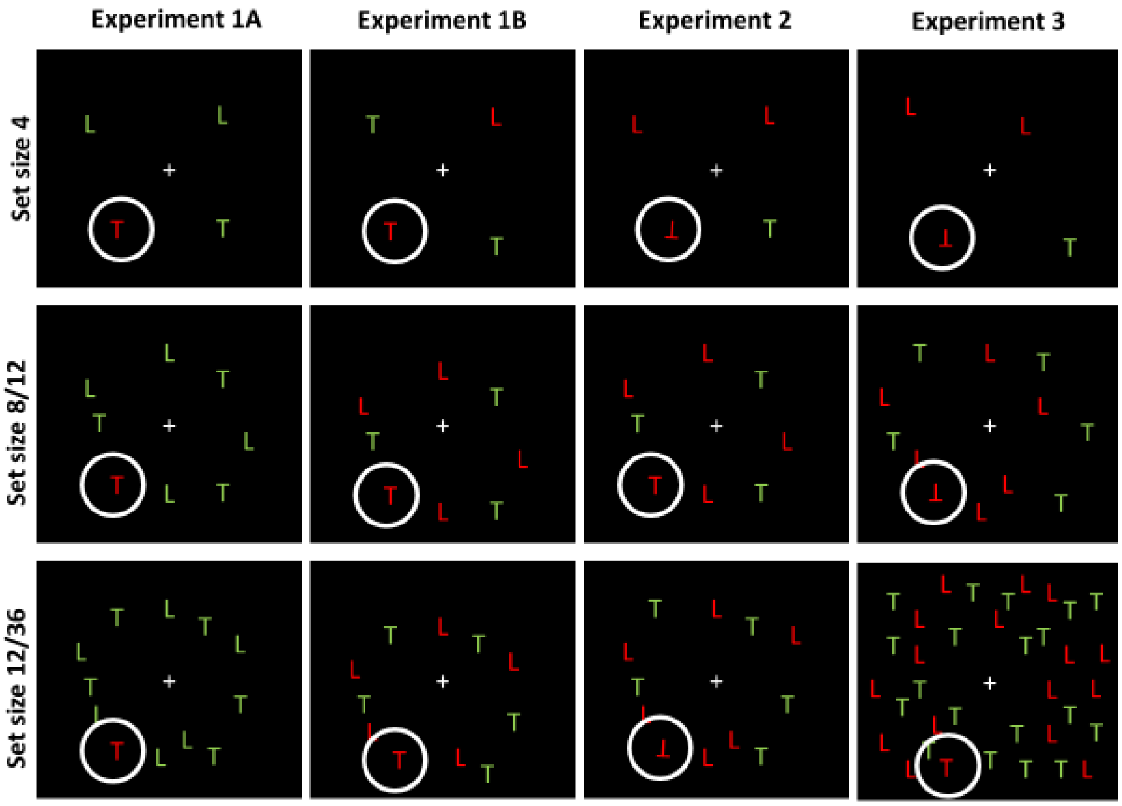


FIGURE 1. Examples of target displays for Experiments 1A and 1B, 2 and 3. Here, the target (red "T" letter) is circled in white. In experiments 1A and 1B, the target was preceded in 1/3 of the trials by a WS of 53 and by a WS of 83 dB in another 1/3 of the trials. In the remaining 1/3 of trials no warning was presented. In Experiments 2 and 3, a WS was presented in all trails, with each intensity in 50% of the trials. In Experiments 1A and 1B, targets were represented only in 50% of trials. In Experiment 2 and 3, targets were represented in 100% of trials and the participant's task was to discriminate the target orientation.

To test the assumption of sphericity in both distributions, we ran the Mauchley's test. In the case of violation of the assumption of sphericity (for one or more factors), the *p* values were adjusted following the Greenhouse-Geisser correction of sphericity.

For both *Feature search* task (Experiment 1A) and *Conjunction search* tasks (Experiment 1B), accuracy rates and mean RT were analysed in a 3 x 3 repeated measurement ANOVA with Warning signal (No WS, 53 dB, 83 dB) and Set size (4, 8, 12 items) as within-participant factors. Mean RT and accuracy were computed separately for target-absent and target-present conditions. Only target-present conditions were considered for analyses, as we were interested in target processing as a function of the WS.

Data analysis: Intercept and slope coefficients

As explained above, the search slope is the index to analyse the performance for most visual search tasks, representing the cost of each visual distracter. Therefore, the larger the search slope the less efficient the search. In the current study the search slope (b) was calculated with the Excel software by the equation $\mathrm{b} = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}$, being x and y the variables set size and RT.

The intercept, on the other hand, informs processes related to response selection and motor execution, independently of the time spent searching the target. The intercept (a) was also computed with the Excel software by the equation $a = \bar{y} - b\bar{x}$. Intercept and search slope were calculated independently for each participant, based on the three display sizes.

Afterwards, for both Experiment 1A and 1B the intercept and search slope coefficients obtained were analysed by means of a univariate ANOVA with the three levels of Warning signal: No WS, 53 dB WS and 83 dB WS (see Table 1).

Results

Mean and standard deviation of RT, errors percentages, and the slope values are reported in Table 1 for each experimental condition.

Analysis: reaction times

In Experiment 1A (*Feature search* task), the reaction time distribution violated the assumption of sphericity for both Warning signal, $\chi 2(2)=8.21$, $p=.016$, and Set size factors, $\chi 2(2)=14.10$, $p<.001$. Therefore, the Greenhouse-Geisser corrections were applied (Warning signal, ε=.84; Set size, ε=.76). We found a significant main effect of Warning signal, $F(2,78)=54.04$, $p<.001$, $\eta_p^2=.58$. Planned comparisons showed that RTs for trials with a WS of 53 dB were shorter than conditions without WS, $F(1,39)= 40.12$, $p<.001$. Also the increase of WS intensity from 53 to 83 dB was accompanied by faster RT, $F(1,39)=29.54$, $p<.001$. The main effect of Set size was also significant, $F(2,78)=6.61$, $p=.002$, $\eta_p^2=.14$, although there was no clear linear increment across set size, $F(1,39)=3.11$, $p=.086$, as shown by post-doc comparisons. Finally, the interaction WS x Set size was not significant, $F(4,156)=.61$, $p=.655$.

Also in Experiment 1B (*Conjunction search* task), the reaction time distribution violated the assumption of sphericity for Set size factors ($\chi 2(2)=20.24$, $p<.001$) and the Greenhouse-Geisser corrections were applied when needed (ε=.70). The main effect of Warning signal, $F(2,74)=16.21$, $p<.001$, $\eta_p^2=.30$, and Set size, $F(2,74)=145.25$, $p<.001$, $\eta_p^2=.80$, were significant. In accordance with our expectations, RT linearly increased from set size 4 (*M*=707 ms) to 8 (*M*= 813 ms) and 12 (*M*= 899 ms), $F(1,37)=176.25$, $p<.001$. Also, RTs decreased when the WS was presented, $F(1,37)=10.90$, $p=.002$, and decreased even more in concomitance with the more intense WS, $F(1,37)=5.99$, $p=.019$. The interaction between these two factors did not reach significance, $F(4,148)=1.62$, $p=.173$, $\eta_p^2=.04$.

Analysis: accuracy

For Experiment 1A, no significant effects were found for error rates (all p´s>.233).

Differently from Experiment 1A (*Feature search* task), the distribution of error rates of Experiment 1B (*Conjunction search* task) violated the assumption of sphericity, as the Mauchley´s test indicated. Greenhouse-Geisser corrections were then applied for Set size, $\chi 2(2)=16.98$, $p<.001$, ε=.73. From the accuracy analysis we found significant main effect of Set size, $F(2,74)=23.49$, $p<.001$, $\eta_p^2=.39$, with a linear increase of errors rate with the increase of the number of distracters, $F(1,37)=27.36$, $p<.001$. The main effect of Warning signal was not significant, $F(2,24)=.60$, $p=.553$, $\eta_p^2=.02$. The factors Set size and Warning signal marginally interacted, $F(4,148)=2.37$, $p=.055$, $\eta_p^2=.06$, although the error rate linearly increased with set size for each WS condition (all *ps* <.05).

TABLE 1. Experiment 1A and 1B. Mean reaction times (RT), standard deviations (SD), Intercept and Slope values (in ms) for target present conditions. Parentheses contain mean errors percentage per condition (it includes anticipations and missed trials).

	53 dB WS			*83 dB WS*			*53 dB WS*		
Items	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*
Experiment 1A **RT ± SD** **% Errors**	540±93 (2.5)	533±90 (3.6)	547±121 (2.8)	523±97 (2.4)	512±95 (2.5)	531±124 (3.4))	502±98 (2.4)	502±111 (2.4)	516±106 (2.1)
Intercept (ms) Slope(ms/item)		533 0.83			515 0.93			492 1.82	
Items	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*
Experiment 1B **RT ± SD** **% Errors**	727±100 (5.5)	822±140 (7.7))	926±169 (11.6)	709±105 (6.3)	818±141 (7.3)	890±162 (10.5)	683±87 (4.5)	800±140 (5.7)	882±173 (12.3)
Intercept (ms) Slope(ms/item)		626 24.82			625 22.59			590 24.78	

Analysis: Intercept and slope coefficients

The intercept analysis of Experiment 1A showed a significant main effect of Warning signal, $F(2,78)= 16.18$, $p<.001$, $\eta_p^2=.29$: responses were faster compared to conditions without a WS ($M=533$ ms) for both 53 dB WS ($M=515$ ms), $F(1,39)=8.25$, $p=.007$, and 83 dB WS conditions ($M=492$ ms), $F(1,39)=10.71$, $p=.002$ (see Figure 2). Also in Experiment 1B, the intercept analysis reported a significant main effect of Warning signal, $F(2,74)=4.17$, $p=.019$, $\eta_p^2=.10$. Responses for conditions with a 53 dB WS (625 ms) were not significantly faster compared to No WS conditions (626 ms), $F(1,37)=.009$, $p=.92$, but were slower compared to 83 dB WS conditions (590 ms), $F(1,37)=4.76$, $p=.035$.

In the slope analysis the main effect of Warning signal was not significant neither in Experiment 1A (*Feature search* task), $F(2,78)=.97$, $p=.385$, $\eta_p^2=.02$, nor in Experiment 1B

(*Conjunction search* task), $F(2,74)=1.01$, $p=.368$, $\eta_p^2=.03$. Nevertheless, as can be observed on Figure 3, a trend was observed for a deeper rather than shallow slope for the more intense 83 dB WS. In fact, for Experiment 1A this increase in the slope at the 83 dB condition led to a mean slope significantly above 0 for this intensity level, $t(39)=3.16$, $p=.003$.

Discussion

The main goal of Experiment 1 was to investigate whether the availability of an acoustic warning signal facilitates target selection, among a variable set of distracting items in a visual search task. In line with expectations, responses were speeded up in trials when a WS was presented compared to those without WS. Also, responses were faster in conditions with the higher WS intensity. The intercept, as an index of RT without the addition of the target search time, further confirmed the RT analysis result. As the *Feature search* should involve parallel processing of all stimuli (Treisman & Gelade, 1980; Treisman, 1993), we expected unvaried RT across the set size in Experiment 1A. The linear components confirmed this hypothesis.

In Experiment 1B, as typically observed in *Conjunction search* tasks, we reported linearly slower responses with the increase of the set size. As expected, the increase of WS intensity also accelerated RTs, and the intercept coefficients clearly reflected that acceleration. Compared to Experiment 1A, the intercept values for Experiment 1B were higher, a rather typical outcome for a comparison between *Conjunction* versus *Feature search*, reflecting the increased impact of distracters in performance and the additional time needed to categorize the target and select the appropriate response in the *Conjunction search* task.

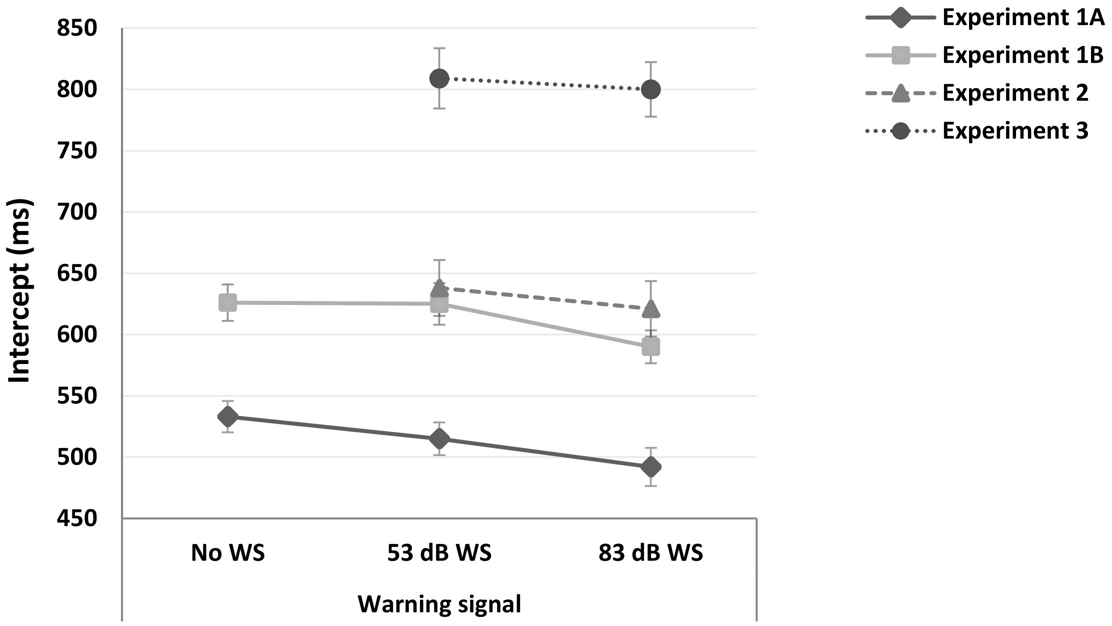


FIGURE 2. Graphic representation of the ***intercept*** of the search function (in milliseconds), for each WS condition (No WS, 53 dB WS and 83 dB WS). The black diamond landmarks represent data from Experiment 1A (*Feature search*). The light grey square landmarks represent data from Experiment 1B (*Conjunction search*, target detection, present in 50% of trials). The dark grey triangle landmarks represent data from Experiment 2 (*Conjunction search*, target discrimination, presenting 100% of trials). The black circle landmarks represent data from Experiment 3 (*Conjunction search*, target discrimination, set sizes 4/12/36 items). For Experiment 1, only target present conditions are presented. For Experiments 2 and 3, data are collapsed across the two target conditions. The gray lines above and below each landmark indicate the standard error of the mean computed with Cousineau’s (2005) method.

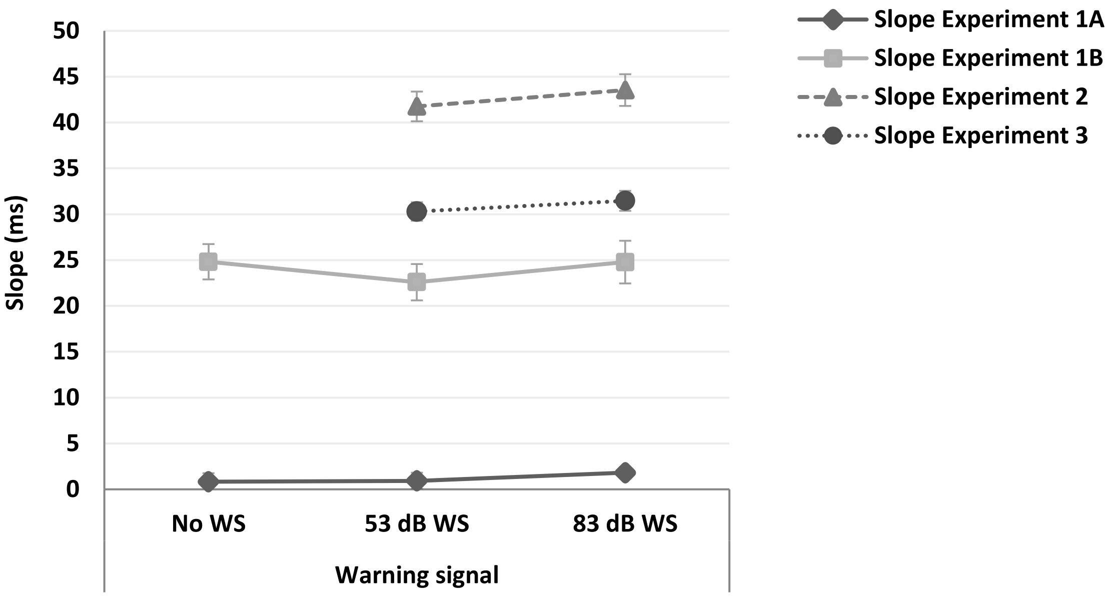


FIGURE 3. Graphic representation of the ***slope*** of the search function for all WS conditions (No WS, 53 dB WS and 83 dB WS). The black diamond landmarks represent data from Experiment 1A (*Feature search*). The light grey square landmarks represent data from Experiment 1B (*Conjunction search*, target present in 50% of trials). The dark grey triangle landmarks represent data from Experiment 2 (*Conjunction search*, target inverted in 50% of trials). The black circle landmarks represent data from Experiment 3 (*Conjunction search*, target inverted in 50% of trials, set sizes 4/12/36 items). The values in the graphic show both target conditions combined, calculated for each subject separately. For Experiment 1, only target present conditions are presented. For Experiments 2 and 3, data are collapsed across the two target conditions. The gray lines above and below each landmark indicate the standard error of the mean computed with Cousineau's (2005) method.

Even more importantly, although increasing WS intensity generally speeded up visual search, search efficiency was clearly not facilitated by the WS intensity, as the slope coefficient rather tended to increase for higher WS intensities, even leading to a significant slope in the *Feature search* task with 83 dB WS, where a flat slope is expected. Therefore, in general, Experiments 1A and 1B supported the hypothesis that the intercept (i.e., processes other that those involved in searching for the target) is accelerated by the presence of the WS, and more importantly, by its intensity. However, regarding the slope it seems clear that it is neither benefited by the presence, nor by the intensity of the WS. If anything at all, a tendency to detrimental influence of the WS intensity was observed.

EXPERIMENT 2

The Experiment 2 was conducted to test further for a possible impact of the WS intensity on the search efficiency when target discrimination and response selection demands are increased. Participants were asked to discriminate the orientation of the target rather than simply detect its presence. Therefore, in this new experiment the target (e.g., a red T with either canonical or inverted orientation among canonical green Ts and red Ls) was presented in 100% of the trials. It was presented in one of the two orientations in each half of the trials and participants responded to its orientation by pressing one of two keys. Furthermore, given that we were mainly interested on the phasic alertness rather than the temporal orienting of WSs, in this new experiment the WS was presented in all trials, with each intensity condition in half of them.

We expected slower RTs (i.e., larger intercept) as compared to Experiment 1B, due to the increased complexity of the task. We also expected faster RT for WS at higher intensity in our discrimination task, accordingly with previous evidence (Righi & Ribeiro-do-Valle, 2013; Cappucci, et al., 2018; in press). In contrast, given the results of Experiment 1, we expected the WS intensity not to be beneficial for the slope of the visual search, as predicted by the first scenario following Weinbach and Henik (2012); rather, the slope would be larger for the more intense WS, as predicted by the alternative scenario, following Fischer et al. (2010; 2012).

Participants

Thirty-five students from University of Granada participated to the experiment (mean age 23.9 ± 4.7 years; 6 males; 7 left-handed). Participants had normal or corrected-to-normal vision and normal audition.

The post-hoc sensitivity analysis, ran with G*power, revealed that with a sample size of N=35, the minimum detectable effect size for $\alpha=.05$, and $1-\beta=0.80$, for 12 repeated measurements (WS x Set size x Target), is $f= .143$.

Apparatus and stimuli

Technical supplies, acoustic stimulus used as warning signal and display durations were unvaried from Experiment 1. In the current experiment a *Conjunction search* was also employed, so that targets and distracters shared colour or shape features. As an example, a red “T” target was accompanied by red “L” and green “T” distracters or a green “L” target accompanied by green “T” and red “L” distracters. However, in contrast to the previous experiment, the target was presented in 100% of the trials, either in the upright canonical orientation (50% of trials) or rotated of 180° degrees. The similarity between a distracter “L” with an inverted target “T” and between a distracter “T” with an inverted target “L” increased the difficulty of the discrimination. On each trial, all distracters were presented on the canonical orientation (see Figure 1).

Task, procedure and design

Participants had to discriminate the target orientation and press one of the same two keys to report the target orientation, as in Experiment 1. Mean RT and accuracy (5.03% of errors) were analysed by means of a WS (53 dB, 83 dB) x Set size (4, 8, 12 items) x Target (Upright, Inverted) repeated measured ANOVA, with the three variables manipulated within participants. Note that the No WS condition was eliminated from the design of this experiment. The effect of Set size on RT was reduced to intercept and slopes coefficients, which were analysed by means of repeated measures WS (53 dB, 83 dB) x Target (Upright target, Inverted target) ANOVAs.

Data analysis: accuracy and reaction times

Criteria for trials exclusion for accuracy and reaction times remained unvaried from Experiment 1. Incorrect trials and trials with RT 2.5 standard deviations below/above the mean RT (1.88%), based on subject and set size distribution, were excluded from further analyses. As for Experiment 1, we ran the Mauchly's test and adjusted the degrees of freedom and *p* values with the Greenhouse-Geisser correction of sphericity.

Results

Mean and standard deviation of RT, errors percentages, and the slope values are reported in Table 2 for each experimental condition.

Analysis: reaction times

The assumption of sphericity was violated for the Set size factor ($\chi 2(2)=37.73$, $p<.001$) and the Greenhouse-Geisser corrections were applied when needed (Set size $\varepsilon=.59$). We found a main effect of Target, $F(1,34)=78.62$, $p<.001$, $\eta_p^2=.70$, being responses to Upright targets on average 97 ms faster compared to those to the Inverted ones. As expected, the main effect of Set size was also significant, $F(2,68)=682.47$, $p<.001$, $\eta_p^2=.95$, with RT increasing linearly from the smallest to the largest set size, $F(1,34)=749.42$, $p<.001$. Furthermore, Target X Set size interacted significantly, $F(1,34)=9.24$, $p<.001$, $\eta_p^2=.21$. The Inverted target conditions seemed to be more impaired by the number of distracters that the Upright target conditions, with a larger increase in RT between set size 4 and size 12 for the Inverted (367 ms) than the Upright target (316 ms). More importantly, the main effect of WS was not significant, $F(1,34)=.44$, $p=.514$, but marginally interacted with Set size, $F(2,68)=3.13$, $p=.054$, $\eta_p^2=.08$.

Analysis: accuracy

Error rates did not reveal any significant effects, all *Fs*<1.

Analysis: intercept and slope coefficients

A lower intercept was observed for the Upright target ($M=606$ ms) compared to the Inverted target condition ($M=652$ ms), $F(1,34)=20.30$, $p<.001$, $\eta_p^2=.37$. Although the main effect of WS was only marginally significant, $F(1,34)=3.59$, $p=.067$, $\eta_p^2=.10$, we reported lower intercepts coefficients with the increased WS intensity (638 and 621 ms, respectively for the condition 53 and 83 dB). The interaction between the two factors was not significant, $F(1,34)=.01$, $p=.911$.

The ANOVA on the search slopes showed a significant main effect of Target, $F=(1,34)=13.24$, $p=.001$, $\eta_p^2=.28$, with higher slope coefficients in case of Inverted target ($M=45,83$ ms) compared to Upright targets ($M=39,47$ ms). As in Experiment 1, although the main effect of WS did not reach statistical significance, $F(1,34)=2.07$, $p=.159$, $\eta_p^2=.06$, at least numerically the slope tended to be larger for the higher WS intensity conditions (see Table 2). Also, the two factors did not interact, $F(1,34)=.12$, $p=.735$.

TABLE 2. Experiments 2 and 3. Mean reaction times (RT), standard deviations (SD), Intercept and Slope values (in ms). Parentheses contain mean errors percentage per condition (it includes anticipations and missed trials).

	Inverted Target						*Upright Target*					
	53 dB WS			*83 dB WS*			*53 dB WS*			*83 dB WS*		
Items	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*
Experiment 2 **RT ± SD** **% Errors**	834±144 (5.8)	1034±177 (4.1)	1195±191 (3.9)	833±144 (5.5)	1013±177 (3.9)	1205±207 (5.3)	764±162 (5)	932±200 (4.7)	1071±234 (5.9)	757±164 (4.8)	927±204 (5.8)	1082±232 (5.8)
Intercept (ms) Slope(ms/item		660 45.12			644 46.54			615 38.39			598 40.54	
Items	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*	*4*	*8*	*12*
Experiment 3 **RT ± SD** **% Errors**	909±120 (3.2)	1319±209 (3.5)	1971±254 (8.1)	903±112 (3.3)	1335±227 (3.1)	1995±293 (7.8)	829±142 (3.4)	1189±225 (3.9)	1788±314 (7.2)	823±128 (2.9)	1187±217 (3.1)	1827±352 (7.5)
Intercept (ms) Slope(ms/item		849 31.79			846 32.61			770 28.81			754 30.30	

Discussion

In Experiment 2, we tested whether the intensity effect from the previous experiment impacts performance in a *Conjunction search* more clearly under increased complexity for target discrimination and response selection. Task manipulation and search difficulty indeed increased in Experiment 2, as revealed by slower intercept (629 ms) and steeper slopes (42.65 ms) compared to its analogue, Experiment 1B (intercept: 608 ms intercept; slope: 23.69 ms). Furthermore, search performance also varied with the type of target, with longer RT and steeper visual slope in case of harder target discrimination.

Nevertheless, results showed a pattern remarkably similar to the one observed in Experiment 1B regarding the modulation caused by the WS intensity over the visual search. As evidenced in the RT analysis, the increase of WS intensity was able to fasten reaction to the target. However, this effect seems to be again due to processes other than target search, as shown by lower intercept values for the more intense WS. Indeed, a tendency for steeper rather than shallower search slopes was again observed for the more intense WS.

EXPERIMENT 3

In this experiment we aimed at replicating the previous experiment but with a further increase in perceptual difficulty. In this case, we increased search difficulty by increasing the amount of information participants had to process when searching for the target. Therefore, in this experiment we manipulated set size also at three levels, but with higher values: 4, 12, and 36 stimuli. One more time, we expected the higher intensity of the WS to reduce the intercept values, thus showing that irrelevant but alerting properties of WSs can produce an alerting effect (speeding up responses) independent from attentional orienting. Regarding the effects of WS intensity on the efficiency of the search, the trend reported in the previous experiments suggest that WS intensity does not improve the efficiency of the search; rather, it might impair visual search of the target, leading to a steeper slope. Nevertheless, a potential impairment is not clear due to the lack of statistical evidence. As this trend was consistently reported in the previous Experiments 1B and 2, the accumulation of evidence might lead to the conclusion that the pure alerting effects of WS induce an acceleration of target responses but impair specific search processes.

Participants

Participants were 36 students from the University of Dresden (mean age 20.86 ± 2.54 years; 8 males; 6 left-handed), all self-reporting normal hearing and vision. Two participants were discarded for high errors scores. The post-hoc sensitivity analysis, ran with G*power, revealed that with a sample size of N=34, the minimum detectable effect size for α=.05, and $1-\beta$=0.80, for 12 repeated measurements (WS x Set size x Target) is f= .145.

Apparatus and stimuli

The letters used as targets and distracters and their arrangement in the screen were the same as Experiment 2 (see Figure 1). The main differences with Experiment 2 were a larger set sizes were used (4, 12 and 36 stimuli), and the technical equipment. A PC running E-Prime 2.0 (Schneider et al., 2002), a 19″ TFT monitor and a QWERTZ keyboard, located in a quiet experimental room at the University of Dresden, were used for stimulus presentation and data recording.

Task, procedure and design

In Experiment 3, the target and distracters were randomly arranged in 36 possible positions. In each trial, the target display contained three possible sets of 4, 12 or 36 letters, of which one was the target. The target display duration was extended for a maximum of 5000 msec, due to the increased amount of distracter stimuli. The other display durations, the procedure and the warning signal noise manipulated were identical to Experiment 2.

Data analysis: accuracy and reaction times

Two participants with high errors scores (>20%) were discarded from analyses. Incorrect trials (5.49%) and trials with RT above/below the mean RT ±2.5 standard deviations (2.08%), based on participants and set size distribution, were excluded from RT, intercept and slope parameters analyses. To test the assumption of sphericity, we ran the Mauchly’s test and adjusted the degrees of freedom and *p* values with the Greenhouse-Geisser correction of sphericity. With the remaining RTs we computed means for each combination of Target (Upright target, Inverted target), Warning signal (53 dB WS, 83 dB WS) and Set size (4, 12, 36 items) as factors for the ANOVA. As for the other experiments of this series, the intercept and the search slope parameters were analysed.

Results

Mean and standard deviation of RT, errors percentages, and the slope values are reported in Table 2 for each experimental condition.

Analysis: Reaction times

The distribution violated the assumption of sphericity for the factor Set size ($\chi 2(2)=19.01$, $p<.001$, $\varepsilon=.69$) and corrections were applied. The ANOVA again yielded a main effect of Target, with faster responses for the Upright target conditions, $F(1, 33)=24.74$, $p<.001$, $\eta_p{}^2=.43$. The main effect of Set size was also significant, $F(2, 66)=788.21$, $p<.001$, $\eta_p{}^2=.96$, with RT increasing linearly form the smallest to the largest set size, $F(1,33)=958.15$, $p<.001$. Furthermore, the Target x Set size interaction was also significant, $F(2, 66)=3.97$, $p<.001$, $\eta_p{}^2=.11$. As in Experiment 2, the Inverted target were more impaired by the number of distracters than the Upright target, with the slowdown of RT between set size 4 and 36 being more prominent for Inverted (1077 ms) than Upright target conditions (982 ms).

More importantly, as in Experiment 2, the main effect of WS was not significant, $F(1, 33)=2.22$, $p=.145$, $\eta_p{}^2=.06$, and again the interaction WS x Set size was only marginally significant, $F(2,66)=2.58$, $p=.0837$, $\eta_p{}^2=.07$.

Analysis: accuracy

Mauchly's test indicated that the assumption of sphericity was violated (Set size $\chi 2(2)=14.40$, $p<.001$), therefore degrees of freedom were corrected ($\varepsilon=.74$). The main effect of Set size, $F(2, 66) = 26.39$, $p<.001$, $\eta_p{}^{2=}.44$, was significant, showing that error rates linearly increased with the number of visual items in the set size, $F(1,33)=29.01$, $p<.001$.

Analysis: intercept and slope coefficients

The analysis of visual intercepts confirmed what previously was observed in the analysis of mean RT: a significant main effect of Target was again observed, $F(1,33)=40.24$, $p<.001$, $\eta_p^2=.55$, with a larger values for Inverted target (i.e. slower RT). The main effect of WS intensity, however, did not reach statistical significance, $F(1,33)=1.25$, $p=.272$, $\eta_p^2=.04$, although the same tendency as in previous experiments was observed.

The analysis of the search slope indicated a significant increase for Inverted target conditions, $F(1,33)=4.47$, $p=.042$, $\eta_p^2=.12$. The increase of WS intensity also tended to impact negatively in the slope, $F(1,33)=4.10$, $p=.051$, $\eta_p^2=.12$, with slope values increasing with WS intensity (from 30.30 ms/item for 53 dB to 31.46 ms/item for 83 dB) .

Discussion

Data from Experiment 3 confirmed that the increased number of distracters in the visual scene produced longer RT. Nevertheless, the high intensity WS triggered faster RTs, as captured by a lower intercept of the search function. On the other hand, however, search efficiency was impaired rather than facilitated, as suggested in our previous experiments. Indeed, a steeper slope was observed for the more intense WS.

However, whereas a similar pattern of results was observed in the three experiments in which a *Conjunction search* tasks was used, with the more intense WS leading to lower intercept but larger slopes, the effects were not significant in all cases. Therefore, we decided to perform a combined analysis of the data from those 3 experiments, to have a clearer picture of the overall pattern of data with increased statistical power.

Combined analysis of *Conjunction search* tasks

We ran a mixed ANOVA with Experiment (1B, 2 and 3) as a between participants variable and WS Intensity (53 and 83 dB) as a within participants factor, for both intercept and slope as dependent variables. In order to focus the analysis on the pure alertness effect of the WS, excluding its temporal orienting component, the condition of no WS in Experiment 1B was excluded from this analysis. In the *analysis of the intercept* parameters, a significant main effect of Experiment, $F(2,104)=29.61$, $p<.001$, $\eta_p^2=.36$, was found. More importantly, the two levels of Intensity led to significantly different intercepts, $F(1,104)=8.65$, $p=.004$, $\eta_p^2=.07$, with a 20 ms lower intercept values for 83 than for 53 dB trials, as shown in Figure 4.

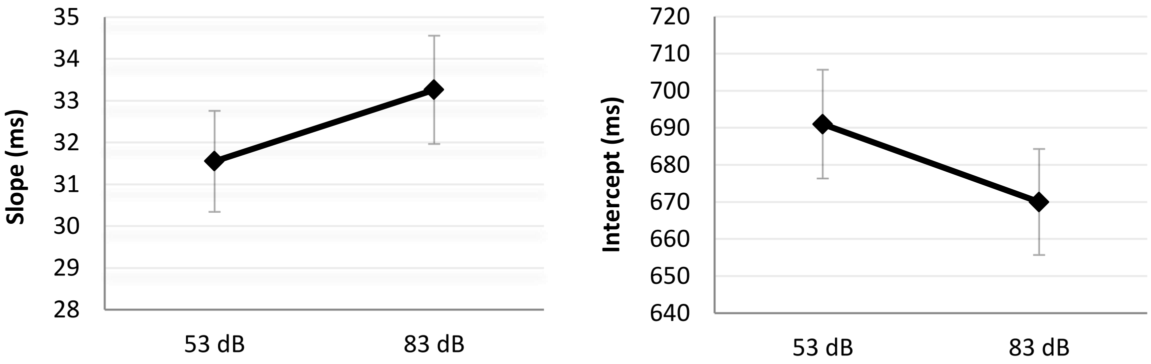


FIGURE 4. Graphic representation of the ***search slope*** (left side) and the ***intercept*** (right side) for 53 and 83 dB WS conditions. Data from Experiment 1B (only WS present and target present condition), Experiment 2 and Experiment 3. The gray lines above and below each landmark indicate the standard error of the mean computed with Cousineau's (2005) method.

In the *analysis of the slope search*, the Experiment factor was also significant, $F(2,104)=37.76$, $p<.001$, $\eta_p^2=.42$, with steeper slopes for Experiment 2 (M=42,6 ms) compared to Experiment 1B (M=23,7 ms) and Experiment 3 (M=30,9 ms). However, the most important finding in this analysis was the significant main effect of WS Intensity,

$F(1,104)=4.03$, $p=.048$, $\eta_p^2=.04$, with a 2 ms steeper slope for 83 than 53 dB conditions (see Figure 4). Note that the small but reliable increase in the slope (1.71) would lead, on average, from a 6.84 ms increase in RT for the set size 4 to an increase of 61.56 ms for the set size 36.

From this analysis, it can be concluded that the increase in WS intensity leads to an overall faster response, but at the same time mildly impairs the efficiency of the search.

GENERAL CONCLUSIONS

In a series of three experiments, we manipulated visual features of target and distracters with the aim of studying how pure alertness modulates different processes involved in visual search. In Experiments 1A and 1B, we asked participants to detect the presence of a target, which in 2/3 of trials was preceded by a WS of either 53 or 83 dB. Both Experiments 1A and 1B showed faster RTs when the WS preceded the target especially for the higher intensity WS. Given our main interest on pure alerting rather than the temporal orienting properties of WSs, in the following experiments only the 53 and 83 dB intensity WS conditions were used. As expected, results from Experiments 1A and 1B were replicated in Experiment 2 (where we increased the level of complexity of target discrimination and response selection, by requiring participants to discriminate between two orientations of the target) and Experiment 3 (where we increased target discrimination difficulty from Experiment 2 with a higher number of distracters per set size).

However, the most relevant findings came from the analysis of the slope and intercept of the visual search function, which allowed us to distinguish between the pure alerting effects of WSs on response related processes (i.e., in the intercept) and those on the search processes (i.e., in the slope). From previous studies we know that the intensity of a WS affects the ability to select a single target in the context of visual discrimination tasks and during specific types of visuospatial interference (Cappucci et al., in press; Correa, et al., 2010; Fischer, et al., 2010; Seibold & Rolke, 2014). When distracting information is presented together with the target, nevertheless, alertness can have different effects, depending on whether the distracting information is integrated within the target object or presented in the periphery (Weinbach & Henik, 2012), or depending on whether or not it involves spatial information (Schneider, 2019; 2020). Furthermore, to our knowledge no study has investigated the effects of pure alertness in a search task, when both the target and the distracters are presented in the periphery.

Consequently, in the current study it was hypothesized that the WS intensity might be also beneficial for the visual search efficiency, but the exact nature of this beneficial effect was not clear. We had two possible interpretations of how the intensity of a WS might impact performance. One possibility was that the more intense WSs, by increasing pure alertness, would boost the attentional visual spotlight (Weinbach & Henik, 2012). Another possibility was that alertness triggered by the intensity of the WS would accelerate the activation of the visuomotor response, in line with Fischer´s (2012) findings for visuomotor interference tasks. An overall pattern of results emerged across the three experiments, which was mostly clarified in the combined analysis including all three *Conjunction search* tasks (Experiments 1B, 2 and 3). This analysis confirmed that the manipulation of WS intensity manifests as two opposite effects on visual search: indeed, the speediness of responses to the target, as shown by lower intercept values for the more intense WS, was accompanied by a negative impact on its search, with steeper slopes of the search function for the higher intensity WS, as shown in Figure 4.

As the general pattern was not clear in the analysis run for each single experiment, only a combined data analysis was able to highlight the impact of the intensity manipulation during *Conjunctions search* tasks. Thus, we could affirm that the reported increase in the slope was not due to a specific task demand (Experiment 1B versus Experiment 2 and 3) or a limited number of distracters (Experiment 2 versus Experiment 3). However, as explained above, the alertness effect on visual search efficiency appears to be quite small, and therefore given its small effect size (η_p^2=.04) a higher statistical power and the use of especially complex visual search seems to be necessary to observe the effect. Future research should consider this important distinction between the presence/absence of WS and their irrelevant alerting properties, to replicate the observed pattern of data and further test the nature of the impairments and benefits of pure alertness in the context of smaller and larger set sizes, especially when employing overly complex, or perceptually demanding visual search tasks.

In any case, our study highlighted the importance of manipulating not only the presence/absence of the WS, but also its task-irrelevant features, such as its acoustic intensity when the goal is to investigate the pure alertness effect, as independent from temporal orienting. By doing so and by analysing the effects of WSs on the slope and the intercept components, we were able to investigate the effects of alertness on different processes involved in target selection and response. Whereas the RT analysis mainly showed a generic facilitation of responses, which was also prominent on the analysis of the intercept, the effect on the search slope highlighted that the more intense WS made it more difficult to find the target among the distracters added to the visual scene. In the current study, both intercept and slope of the visual search demonstrated to be important parameters to study the effect of pure phasic alertness on visual search, and future research on this topic should take these parameters into consideration.

The observed pattern of data is opposite to the one we anticipated on the basis of Weinbach and Henik’s (2012) proposal that WSs would broaden the attentional spotlight. We predicted that the search would be facilitated by the broadening of attention due to alertness.

In contrast, the proposal by Fischer et al. (2010; 2012) that WSs accelerates automatic responses to the target could easily explain the observed pattern of results by assuming that only when the target appears alone can alertness facilitate target response. When the target appears among many distracters, the time needed to find it might make the alertness effect to dissipate, therefore not facilitating responses anymore. Thus, the observed pattern of data indicated that the acceleration of responses exclusively occurred at the smallest set size, but it dissipated for the largest size, as shown by a shorter intercept and steeper slopes for the more intense WS. However, results of two additional post-hoc analyses seem only partially in line with this interpretation. That is, the general direction of the effect of WS intensity was opposite depending on the set size. As predicted and in line with Fischer et al. (2010, 2012), a clearly significant effect of WSs accelerating responses was particularly observed with the smallest set size.[2] In contrast, for the larger set sizes and difficult search task of Experiment 2 and 3, however, an even negative effect of WS on search was found (i.e., high intensity WS increased RTs)[3]. In speculative terms, it could be assumed that for large set sizes an initial WS-facilitated response activation needs to be stopped until target detection allows for response execution. Therefore, in conditions of large set sizes, the WS effect not only dissipates, but may even directly reduce the efficiency with which the target is found. Future research should confirm this last pattern of data and clearly indicate that pure alertness induced by the irrelevant increased intensity of the WS not only accelerate responses when

---

[2] An ANOVA with the factors Experiment (1B, 2 and 3) x WS Intensity (53 and 83 dB) performed on the set size 4 conditions revealed faster responses for 83 than 53 dB trials, $F(1,104)=8.48$, $p=.004$, $\eta_p^2=.07$. The Experiment x WS Intensity interaction was marginally significant, $F(2, 104)=2.78$, $p=067$, $\eta_p^2=.05$, suggesting a larger alertness effect in the simpler detection task of Experiment 1B (26 ms) than in the more difficult discrimination task of Experiments 2 (4 ms) and 3 (7 ms).

[3] The Experiment (2 and 3) x WS Intensity (53 and 83 dB) ANOVA performed on the larger set size conditions only showed a main effect of WS, $F(1,104)=5.04$, $p=.027$, with RT being now significantly slower for the more intense WS (11 ms slower in Experiment 2, and 33 ms slower in Experiment 3).

automatic responding to the target is possible, as predicted by Fischer et al. (2010; 2012), but also impairs other processes, when the target needs to be searched.

The attentional broadening hypothesis would also have to be accommodated in order to explain the observed pattern of results. One possibility might be to assume that when only distracters are presented in the periphery the attentional broadening by alertness would impair responses by increasing interference (Weinbach & Henik, 2012). However, it has been recently shown that, only when the distracters and the task set have a spatial component, does alertness indeed increase interference (Schneider, 2019; 2020). Furthermore, we have shown that the higher intensity of WSs only modulates perceptual-motor interference (i.e., Simon), but not purely perceptual interference (i.e., Spatial Stroop) (Cappucci et al., in press). Therefore, a combination of the two proposals might be needed to explain our pattern of data. Pure alertness might accelerate automatic reaction to the target, thus facilitating selection and overall automatic responses when the target is presented alone, and even increasing perceptual-motor interference; but attentional broadening by pure alertness might in fact also boost automatic reaction and perhaps accidental selection of peripheral stimuli. When most of them are distracters, as in visual search, the facilitation of automatic reaction to the distracters, and the consequent need to filter them, would end producing the observed difficulty to find the target.

In conclusion, our findings contribute to further specify the impact of acoustic warning signals and their accessory characteristics on visual search. Our study turned out to be helpful to understand the impact of task irrelevant features (i.e., intensity) of WSs in *Conjunction search* tasks, with a clear acceleration of automatic responding to the target, but at the same time an impairment in processes involved in searching for it. Existing theories need to be adapted to account for this pattern of results.

CHAPTER 6.

GENERAL DISCUSSION

An important function of human attention is the ability to prepare and maintain a state of alert to process high-priority signals coming from the outside world (Petersen & Posner, 2012). At the behavioural level, this preparation is observable by faster reaction times (RT) in conditions with the stimulus target following an abrupt warning signal (WS) compared to conditions without WS. Temporal, spatial, motor and perceptual features may be manipulated in order to study the mode of operation of the alerting mechanisms. Past evidences have supported that phasic alertness and control mechanisms interact because of the ability of WSs to sustain target selection and response preparation in time (Posner, 2008; Petersen & Posner, 2012; Weinbach & Henik, 2012b). Moreover, existing theoretical frameworks predict that alertness mostly benefits the response release, at cost of an enhanced impact of task-irrelevant information (Weinbach & Henik, 2012a; Schneider, 2020). When acoustic WSs are used to manipulate alertness, it is crucial to pay attention to some characteristics of the sound used to study pure alertness mechanisms. In particular, it has been shown that, by increasing the WS intensity, RT is shortened. However, the implications of this phenomenon, called intensity effect, when the sound is used as WS, are still under debate.

The main goal of the current dissertation was the understanding of which mechanisms are triggered by acoustic warning signals, and their accessory characteristics, to modulate perceptual processing and/or response preparation. The two main objectives were: 1) to investigate whether response preparation and the intensity effect are controlled by independent mechanisms of phasic alertness; 2) to differentiate between positive and detrimental effects of task-irrelevant, accessory characteristics of WS.

To accomplish these goals, we carried out three series of experiments as part of our research. In the Experimental Series I (**Chapter 3**), we tested the possibility of a mutual influence between response preparation and pure alertness mechanisms. We directly manipulated these two factors by varying the simultaneity between WS and target as well as the WS intensity, in tasks requiring different levels of control (visual detection with and without catch trials versus visual discrimination Go-NoGo task). In order to study the startle reflex as a separate phenomenon from the intensity effect, we analysed the orbicularis oculi muscle contraction. In the Experimental Series II (**Chapter 4**), we focused in understanding the relevance of WS intensity manipulation during the target selection in conditions of spatial interference (Simon, or Stimulus-Response interference, and spatial Stroop, or Stimulus-Stimulus interference). Finally, during the Experimental Series III (**Chapter 5**) we tried to clarify whether the expression of the intensity effect interacts with the target selection on the domain of Feature-based and Conjunction-based visual search.

Across these experimental series, some general conclusions have been made. Our findings confirmed that highly intense WSs increase motor readiness and target detection. In addition, the involvement of response preparation and pure alertness mechanisms might impact differently the performance depending on the types of task set (in this case, visuospatial interferences) involved. Nonetheless, under specific task demand, the presence of a WS, especially at the highest intensity, not only boosts the selection between task-relevant and task-irrelevant visual information but might also impact in a negative way the direct transmission of visual information into the corresponding motor code.

These results lead us to conclude that the pure alerting effect produces an automatic facilitation of the direct response of target stimuli. In conditions of easy selection of target, or when the correct response is directly associated to a fast motor execution, this automatic facilitation results in an acceleration of response motor execution. However, in conditions when the target needs to be selected among distracters, or some task-irrelevant characteristics of the target automatically activate incorrect responses, the automatic response speediness triggered by the WS may increase the chance of committing mistakes. In those cases, the increased intensity of the WS may have a negative effect and need to be inhibited, in order to allow the selection of the correct response. In these situations, the initially facilitated response must be inhibited, which finally leads to a loss of the initial alerting advantage, or even to a detrimental effect (i.e., higher impact of distracters in large set size conditions). Altogether, our findings highlighted the importance of manipulating not only the presence/absence of the WS, but also its task-irrelevant features, such as its acoustic intensity, when the goal is to investigate the pure alerting effect, independently from temporal orienting.

In the following sections, we will present a critical discussion of our main results, an overview of the findings and further directions of investigation.

1. What is the role of task demand in the dissociation between response preparation and pure alertness mechanisms?

The behavioural expression and interaction of pure alertness and response preparation mechanisms is modulated in a complex way by the task demand. The criticality of the task demand is evident in the case of simple detection tasks, were participants might not use the temporal information provided by the WS and not prepare the response in advance. Neither the insertion of catch trials encourages participants to prepare the response in advance. Only the presence of NoGo targets (Experiment 3, **Chapter 3**) urged participants to use the temporal information provided by the WS. Thus, when the task demand allows to take advantage of the temporal information provided by the WS, the response preparation mechanisms are involved in interaction with other alerting functions, as the pure alerting effect. Therefore, the task demand has a key role in dissociating the expression of pure alertness and response preparation mechanisms and in their interaction. In contrast, other more automatic effects of pure alertness, as the startle reflex, are independent on task set and response preparation.

On the other hand, cognitive control mechanisms, despite of being selective and specific for one type of conflict (Egner, 2008; Funes, Lupiáñez & Humphreys, 2009; Hommel, 1998), seems to be also modulated by task-irrelevant features, such as the acoustic intensity of the WS. In accordance with the dual-route account (Kornblum, Hasbroucq, & Osman, 1990), during the resolution of a Simon interference, the presence of WS speeded up the automatic response activation in a direct route processing (which primes responses corresponding to the irrelevant stimulus location), at the cost of the indirect processing route (which primes responses based on task-relevant features), thus specifically increasing the Simon interference as a result (Fischer, plessow & Kiesel, 2010).

Importantly, the spatial Stroop interference seems to not be affected by any of the WS manipulations (i.e., presence and intensity). Nevertheless, despite of not being directly influenced by the WS, the presence of the spatial Stroop interference has an impact on overall performance. Indeed, whether the WS intensity increases or decreases the congruence effect depends on the separation versus co-occurrence with other interferences. In particular, when the two interferences are manipulated in different trials and blocks (Experiment 2, **Chapter 4**), the impact of WS intensity resulted beneficial for the resolution of the Simon interference. Indeed, the response preparation and the pure phasic mechanisms seem to influence specific visuospatial interferences, in a positive or negative way, depending on the co-occurrence with another visuospatial interferences.

2. What theoretical framework better explains the impact of WS intensity on control mechanisms?

It was proposed that WSs increase the attentional spotlight and cause a general accessibility of spatial information, but only in the case of separation between target and distracting spatial information (Weinbach & Henik, 2012a). However, Fischer and collaborators suggested that WSs speed up the automatic motor response by strengthening the association of visual stimulus with the response execution (Fischer et al., 2010; Fischer, Plessow, & Kiesel, 2012). In cases of interferences involving both visual and motoric components (i.e., in a S-R conflict as the Simon interference), the interfering effect of phasic alerting might be caused by a stronger level of visuo-motor response activation. Our findings pointed in the direction of the latter theoretical framework, as the interaction between alertness and visuospatial interference processing was only reported in the Simon interference, but not for spatial Stroop interference, despite target and spatial irrelevant characteristics were integrated in the same stimulus for both types of interference. Rather than the co-occurrence of relevant versus irrelevant spatial information in separate stimuli, the impact of the intensity of a WS seems to be mainly dependent on the type of interference performed and by the strength of the visuo-motor response activation (Fischer et al., 2010; 2012).

In general, it is difficult to predict whether the interaction between alerting and cognitive mechanisms would be found or not. As also mentioned by Weibach and Henik (2012a), the common ground for all the studies reporting interaction between WS and interference seems to be the involvement of spatial attention. Note that orienting of spatial attention is indeed increased by alertness (Callejas et al., 2004). Therefore, in line with Schneider (2019; 2020), spatial attention and spatial information processing seems to be important aspects of the interaction. Also, in consideration of the results reported in the present dissertation, we suggest that WSs do not impact the general attentional focus (either in terms of attentional spotlight or general readiness), but rather the strength of automatic response activation, especially when the visual stimuli activate response competition in the visuospatial domain. Thus, the increase of WS intensity might boost the automatic response release, leaving insufficient time for the attentional mechanisms to deal with eventual target uncertainty or distracters, in case of S-R conflicts and large set sizes.

3. The intensity of WS boosts the speed on target detection but deteriorate other aspects of the performance.

An important distinction has been made between the impact of the WS intensity and the activation of automatic reflex-like responses, as the eye startle effect. When an eye startle reflex was recorded, the responses resulted to be on average slower than when no eye startle reflex was reported. In all three experiments, the average slower RT after eye startle reflex were reported regardless of task demand manipulation and response preparation (**Chapter 3**). Previous evidence supported the existence of two separate phenomena for startle response and RT effects with high acoustic intensities (Drummond, Leguerrier, & Carlsen, 2016; Lipp & Hardwick, 2003; Lipp, Kaplan, & Purkis, 2006; Valls-Solé, Kofler, Kumru, Castellote, & Sanegre, 2005), and our data supported the existence of two separate mechanisms.

Despite some evidence in literature indicates that earlier stages of visual perceptual processing are the most impacted by the manipulation of WSs (Matthias, Bublak, Müller, Schneider, Krummenacher & Finke, 2010; Fischer, Plessow & Ruge, 2013; Thiel, Zilles & Fink, 2004), it is still under debate whether the alerting effect produced by WSs, impacts mostly the perceptual elaboration of irrelevant versus relevant visual information, or rather the response selection processing. Based on the results obtained with visuospatial interferences, we hypothesized that high intense WS lead to a faster response but may impact differently other dimensions of target selection. We had two possible interpretations on how the intensity of a WS might impact performance. One possibility was that intense WSs, by increasing pure alertness, boost the attentional visual spotlight (Weinbach & Henik, 2012a). Another possibility was that alertness, triggered by the intensity of the WS, accelerates the activation of the motor programming, in line with Fischer´s (2012) findings for visuomotor interference tasks.

Our results showed that more intense WSs impaired the search of the target among the distracters. Remarkably, this result was not clearly visible in the RT analysis and the intercept parameter, that mainly showed a generic response facilitation after a WS. Only by analysing the slope of the search function as direct index of the search processes, we were able to highlight the negative impact of the WS intensity on the target selection processing when the target appears surrounded by many distracters and target selection was also made more difficult.

Two separated effects seem to be involved in the manipulation of WS intensity. On the one side, the target detection is facilitated in conditions of highest intensity. Nevertheless, this speediness of responses is also accompanied by a negative impact on other search processes. On the other side, our data challenge the function of intensity as mere “response facilitator” (Carlsen, 2011), and we argue that the need to attend and inhibit task-irrelevant information (i.e., irrelevant spatial information and competitive visual distracters), in order to allow an adequate selection of the target, might in fact dissolve, or even revert, the response facilitation driven by acoustic WSs.

4. Further directions and conclusions.

Our findings generate novel questions circa the impact of acoustic WS on target detection and motor response programming. In two cases, the experimental paradigms presented in the current dissertation were not completely suited to test these hypotheses.

A first important, but still unsolved question comes from the explorative post-doc analysis conducted across the Conjunction search tasks in the Experimental Series III

(**Chapter 5**), where we found that WSs facilitate the search process, especially in conditions with small set size. However, this facilitation seems to dissipate for the largest set size. One possibility to explain these results is that, in conditions when the target appears among many distracters, the response activation needs to be inhibited until the target detection allows the response execution. When the target is presented alone, the pure alertness mechanisms accelerate not only the target selection, but also automatic responses, increasing the perceptual-motor interference. However, in presence of distracters, participants need to inhibit any response to those distracters, and this facilitation tourn out to be an impairment for performance. This explanation would be also compatible with the attentional broadening hypothesis (Weinbach & Henik, 2012a), under the assumption that when distracters are presented in the periphery, the attentional broadening by alertness may impair responses by increasing interference not at a purely perceptual level interference but at a visuomotor level (**Chapters 4** and **5**). Nevertheless, our data are not conclusive. The differential impact of WS intensity in the set size dimension may be further explored in future research.

Another open question concerns the distinction between pure alerting and the expression of the eye startle reflex response. When an eye startle reflex was recorded, the responses resulted to be on average slower to when no eye startle reflex was reported. In all three experiments, the average slower RT were reported regardless of the interval between WS and target, or by the presence of catch trials (Experiment 2) and NoGo trials (Experiment 3). The average slower responses were reported regardless of the interval between WS and target, and other task manipulations. As the slower RT after a startle reflex, found in all experiments of Experimental Series I, contrasted with the usual RT speeding reported in previous literature (Carlsen et al., 2004; Carlsen et al., 2007), we analyse the methodological differences behind this discrepancy. The discrepancy raised our interest about the possible methodological causes. Some methodological differences were considered responsible of this difference, as the locus of RT recording (in the Experimental Series I we recorded the startling response at the motor level, while Carlsen and collaborators recorded it at premotor level (Carlsen, Carlsen, Chua, Inglis, Sanderson, & Franks, 2004; Carlsen, Chua, Inglis, Sanderson, & Franks, 2007; Carlsen, Maslovat, Lam, Chua, & Franks, 2011) and the identification of the startle effect through the orbicularis oculi muscle, rather than other muscles activation, as the esternocleidmastoid muscle (Carlsen et al., 2011). More importantly, in Carlsen´s experiments the movement required for the response was considerable as a distal movement (the extension of limbs toward the external space), instead in our studies participants responded with a proximal movement (i.e., to press a key with the right thumb). As the evolution developed a complex behavioural system of avoidance, escape and defence of aversive events (Lang, Bradley, & Cuthbert, 1990), we suggested that the extremely high sounds might be positively associated to distal movements and patterns of avoidance (i.e., faster responses) and negatively associated with proximal movements, as the one used in our studies (i.e., slower responses). It is therefore possible that the WS intensity, which although task-irrelevant intervene in the motor code processing, might impact the target detection in accordance with its emotional valence on the one hand, and the level of adaptivity of motor response on the other hand. It has recently been suggested that affective salient sounds facilitate the search efficiency in a subsequent visual search (Asutay & Västfjäll, 2017). The use of a visual search paradigms in future investigations might allow to verify this hypothesis. Although experimental paradigms were not able to give an answer, our data point out the importance of monitoring motoric aspects of the task, such as the aversive/defensive movement required by the response.

Based on the results presented during this chapter, some general conclusions can be made. High intense WSs increase the motor preparation to respond in simple detection tasks. In addition, the increased intensity impacts both the motor readiness and the target detection, also depending on the state of response preparation. The involvement of response preparation and pure alertness mechanisms might impact differently the performance depending on the types of task demand and the co-occurrence of more than one type of visuospatial interference. Finally, high intense acoustic WSs seem to lead to a general faster execution of visuomotor tasks. This faster execution is however accompanied by an enhanced impact of task-irrelevant visual information, such as task-irrelevant target location or distracters, which might negatively affect the performance. In general, the observed pattern of data supports the framework proposed by Fischer et collaborators (2010; 2012). Whereas the RT and intercept analysis mainly showed a generic facilitation of responses, the effect on the search slope highlighted that the more intense WS made it more difficult to find the target among the distracters added to the visual scene. Indeed, to study the effect of phasic alertness on visual search, both intercept and slope of the visual search are two fundamental parameters. Future research on this topic should take these parameters into great consideration when visual search tasks are manipulated.

CHAPTER 7. REFERENCES

Aasen, Håberg, A. K., Olsen, A., Brubakk, A., Evensen, K. A. I., Sølsnesg, A. E., Skranes, J., and Brunner, J. F. (2016). The relevance of the irrelevant: Attention and task-set adaptation in prematurely born adults. *Clinical Neurophysiology*, 127 (10), 3225-3233.

Alink, A., Schwiedrzik, C.M., Kohler, A., Singer, W., and Muckli, L. (2010). Stimulus predictability reduces responses in primary visual cortex. *Journal of Neuroscience,* 30(8): 2960-6.

Angel, A. (1973). Input-output relations in simple reaction time experiments. Quarterly *Journal of Experimental Psychology*, 25, 193-200.

Arnott, S.R., and Alain, C. (2011). The auditory dorsal pathway: orienting vision. *Neuroscience and Biobehavioural Reviews*, 35(10), 2162-73.

Asanowicz, D. & Marzecová, A. (2017). Differential effects of phasic and tonic alerting on the efficiency of executive attention. *Acta Psychologica*, 176, 58-70.

Asutay, E., Västfjäll, D. (2017). Exposure to arousal-inducing sounds facilitates visual search. *Scientific Reports*, 7, 10363.

Balaban, M., Losito, B., Simons, R. F., and Graham, F.K. (1986). Off-line latency and amplitude scoring of the human reflex eye blink with Fortran IV. *Psychophysiology*, 23, p. 612.

Bertelson, P. (1967). The time course of preparation. *Quarterly Journal of Experimental Psychology*, 19 (3).

Blumenthal, T. D., Cuthbert, B. N., Filion, D. L., Hackley, S., Lipp, O. V., and van Boxtel, A. (2005). Committee report: Guidelines for human startle eyeblink electromyographic studies. *Psychophysiology*, 42(1), 1-15.

Böckler, A., Alpay, G., & Stürmer, B. (2011). Accessory stimuli affect the emergence of conflict, not conflict control. A Simon-Task ERP study. *Experimental Psychology*, 58(2), 102-109.

Boksem, M. A. S., Meijman, T. F., and Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research* 25, 107 – 116.

Botta, F., Lupiáñez, J., and Chica, A. B. (2014). When endogenous spatial attention improves conscious perception: Effects of alerting and bottom-up activation. *Consciousness and Cognition*, 23, 63-73.

Bradley, M. M., & Sabatinelli, D. (2002). Startle reflex modulation: perception, attention, and Emotion. In Hugdahl, K.. *Experimental methods in neuropsychology*. Kluwer Academic Publishers.

Broadbent, D.E. (1977). Levels, hierarchies, and the locus of control. *Quarterly Journal of Experimental Psychology*, 29, 181-201.

Broadbent, D.E. (1958). *Perception and Communication.* London: Pergamon Press.

Burle, B., Tardonnet, C. and Hasbroucq, T. (2010). Excitatory and inhibitory motor mechanisms of temporal preparation. In Nobre, A. C. & Coull, J. T. *Attention and Time*. Oxford University Press Inc., New York.

Callejas, A. Lupiáñez, J. & Tudela, P. (2004). The three attentional networks: on their independence and interactions. *Brain and Cognition*, 54, 225-227.

Callejas, A., Lupiàñez, J., Funes, M.J., and Tudela, P. (2005). Modulations among the alerting, orienting and executive control networks. *Experimental Brain Research*, 167(1), 27-37.

Carlsen, A. N., Chua, R., Dakin, C. J., Sanderson, D. J., Inglis, J. T., and Franks, I. M. (2008). Startle reveals an absence of advance motor programming in a Go/No-go task. *Neuroscience letters*, 434(1), 61-5.

Carlsen, A. N., Chua, R., Inglis, J. T., Sanderson, D. J., and Franks, I. M. (2004). Prepared movement are elicited early by startle. *Journal of Motor Behavior*, 36(3), 253-264.

Carlsen, A. N., Dakin, C. J., Chua, R., and Franks, I. M. (2007). Startle produces early response latencies that are distinct from stimulus intensity effects. *Experimental Brain Research*, 176(2), 199-205.

Carlsen, A. N., Maslovat, D., Lam, M. Y., Chua, R., and Franks, I. M. (2011). Considerations for the use of a startling acoustic stimulus in studies of motor preparation in humans. *Neurocience and Biobehavioral Reviews*, 35 (3), 366-376.

Cohen, R. M., Semple, W. E., Gross, M., Holcomb, H. H., et al. (1988). Functional localization of sustained attention: Comparison to sensory stimulation in the absence of instruction. *Neuropsychiatry, Neuropsychology, & Behavioral Neurology, 1*(1), 3–20.

Corbetta, M., Patel, G., Shulman, G.L. (2008). The reorienting system of the human brain: from environment to theory of mind. *Neuron*, 58(3), 306-24.

Corbetta, M., Shulman, G. L., Miezin, F. M., and Petersen, S. E. (1995). Superior parietal cortex activation during spatial attention shifts and visual feature conjunction. *Science,* 270(5237), 802-805.

Correa, A., Cappucci, P., Nobre, A. C., and Lupiáñez, J. (2010). The two sides of temporal orienting: facilitating perceptual selection, disrupting response selection. *Experimental* *psychology*, 57(2), 142-8.

Correa, A., Lupiáñez, J., Madrid, E., and Tudela, P. (2006a). Temporal attention enhances early visual processing: A review and new evidence from event-related potentials. *Brain Research*, 1076(1), 116-128.

Correa, A., Lupiáñez, J., Milliken, B., and Tudela, P. (2004). Endogenous temporal orienting of attention in detection and discrimination tasks. *Perception and Psycho*physics, 66(2), 264-278.

Correa, A., Sanabria, D., Spence, C., Tudela, P., and Lupiáñez, J. (2006b). Selective temporal attention enhances the temporal resolution of visual perception: Evidence from a temporal order judgment task. *Brain Research*, 1070(1), 202-205.

Coull, J.T., (2004). fMRI studies of temporal attention: allocating attention within, or towards, time. *Cognitive Brain Research*, 21 (2), 216–226.

Coull, J.T., Frith, C.D., Büchel, C., and Nobre, A.C. (2000). Orienting attention in time: behavioural and neuroanatomical distinction between exogenous and endogenous shifts. *Neuropsychologia*, 38(6), 808-819.

Coull, J.T., Jones, M. E.P., Egan, T.D., Frith, C.D. and Maze, M. (2004). Attentional effects of noradrenaline vary with arousal level: selective activation of thalamic pulvinar in humans. *Neuroimage*, 22, 315-322.

Coull, J. T., Nobre, A. C., and Frith, C. D. (2001). The noradrenergic alpha2 agonist clonidine modulates behavioural and neuroanatomical correlates of human attentional orienting and alerting. *Cerebral Cortex*, 11(1), 73–84.

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to

Loftus and Masson's method Tutorial in *Quantitative Methods for Psychology*, 1(1), 42-45.

Cressman, E. K., Carlsen, A. N., Chua, R., and Franks, I. M. (2006). Temporal uncertainty does not affect response latencies of movements produced during startle reactions. *Experimental Brain Research*, 171(2), 278-282.

Dalton, P., Spence, C. (2007). Attentional capture in serial audiovisual search tasks. *Perception & Psychophysics*, 69, 422–438.

Davies, D. R., and Parasuraman, R. (1982). *The psychology of vigilance*. London, UK: Academic Press.

Davis, M. (1984). The Mammalian Startle Response. In Eaton, R. C., *Neural Mechanisms of Startle Behavior*, Springers US.

Davis, E. T., and Palmer, J. (2004). Visual search and attention: An overview. *Spatial Vision*, 17(4-5), 249–255.

Deutsch, J.A. and Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review*s, 87, 272–300.

Driver, J., and Spence, C. (1998). Crossmodal attention. *Current Opinion in Neurobiology*, 8(2), 245–253.

Donders, F. C. (1969). On the speed of mental processes. *Acta Psicologica*, 30, 412-431.

Drummond, N. M., Leguerrier, A., and Carlsen, A. N. (2016). Foreknowledge of an impending startling stimulus does not affect the proportion of startle reflexes or latency of StartReact responses. *Experimental Brain Research*, 235(2), 379-388.

Egan, J.P., Greenberg, G.Z., and Schulman, A.I. (1961). Interval of time uncertainty in auditory detection. *Journal of the Acoustical Society of America*, 33, 771-778.

Egner, T. (2008). Multiple conflict-driven control mechanisms in the human brain. *Trends in Cognitive Science*, 12(10), 374-380.

Egner, T., Delano, M., and Horsch, J. (2007). Separate conflict-specific cognitive control mechanisms in the human brain. *NeuroImage*, 35 (2), 940-948.

Eimer, M., Schröger, E. (1998). ERP effects of intermodal attention and cross-modal links in spatial attention. *Psychophysiology*, 35(3), 313-27.

Eriksen, B.A. and Eriksen, C.W. (1974). Effects of noise letters upon the identification of a target letter in a non search task. *Perception & Psychophysics*, 16, 143–149.

Fan, J., McCandliss, B.D., Fossella, J., Flombaum, J.I., and Posner, M.I., (2005). The activation of attentional networks. *Neuroimage*, 26 (2), 471–479.

Fan, J., McCandliss, B.D., Sommer, T., Raz, M., and Posner, M.I. (2002). Testing the Efficiency and Independence of Attentional Networks. *Journal of Cognitive Neuroscience*, 14, 340-347.

Fan, J., Gu, X., Guise, K.G., Liu, X., Fossella, J., Wang, H., Posner, M. (2009). Testing the behavioural interaction and integration of attentional networks. *Brain and Cognition*, 70(2), 209–220.

Faul, F., Erdfelder, E., Lang, A. et al. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods* 39, 175–191.

Fernandez-Duque, D., and Posner, M.I. (1997). Relating the mechanisms of orienting and alerting. *Neuropsychologia,* 35(4), 477–486.

Fischer, R., Plessow, F. and Kiesel, A. (2010). Auditory warning signals affect mechanisms of response selection: Evidence from a Simon Task. *Experimental Psychology,* 57, 89-97.

Fischer, R., Plessow, F. and Kiesel, A. (2012). The effects of alerting signals in action control: activation of S-R associations or inhibition of executive control processes? *Psychological Research*, 76, 317-328.

Fischer, R., Plessow, F., and Ruge, H. (2013). Priming of visual cortex by temporal attention? The effects of temporal predictability on stimulus(-specific) processing in early visual cortical areas. *Neuroimage,* 66, 261-269.

Fossella, J., Sommer, T., Fan, J., Wu, Y., Swanson, J. M., Pfaff, D.W., and Posner, M.I. (2002). Assessing the molecular genetics of attention networks. *Neuroscience*, 3, 14.

Fuentes, L.J. and Campoy, G. (2008). The time course of alerting effect over orienting in the attention network test. *Experimental Brain Research*, 185(4), 667-72.

Funes, M.J. and Lupiáñez, J. (2003). La teoría atencional de Posner: Una tarea para medir las funciones atencionales de orientación, alerta y control cognitivo y la interacción entre ellas. *Psicothema*, 15, 260-266.

Funes, M.J., Lupiáñez, J., and Humphreys, G. (2010). Analyzing the Generality of Conflict Adaptation Effects. *Journal of Experimental Psychology: Human Perception and Performance,* 36(1), 147-161.

Funes, M.J., Lupiáñez, J., and Humphreys, G. (2009). Sustained vs. Transient cognitive control: Evidence of a behavioral dissociation. *Cognition,* 114(3), 338-347.

Gabay, S., and Henik, A. (2008). The effects of expectancy on inhibition of return. *Cognition*, 106(3), 1478-1486.

Hackley, S. A. (2009). The speeding of voluntary reaction by a warning signal. *Psychofisiology*, 46 (2), 225-233.

Hackley, S. A., and Valle-Inclán, F. (2003). Which stages of processing are speeded by a warning signal? *Biological Psychology*, 64(1-2), 27-45.

Hackley, S. A., Langner, R., Rolke, B., Erb, M., Grodd, W., and Ulrich, R. (2009). Separation of phasic arousal and expectancy effects in a speeded reaction time task via fMRI. *Psychophysiology*, 46 (1), 163–171.

Hawley, M.L., Sherlock, L.P., and Formby, C. (2017). Intra- and Intersubject Variability in Audiometric Measures and Loudness Judgments in Older Listeners with Normal Hearing. *Seminars in Hearing*, 38(1), 3-25.

Hommel, B. (1998). Automatic stimulus-response translation in dual-task performance. *Journal of Experimental Psychology: Human Perception & Performance*, 24(5):1368-84.

Jarosz, A.F., and Wiley, J. (2014). What Are the Odds? A Practical Guide to Computing and Reporting Bayes Factors. *The Journal of Problem Solving*, 7 (1).

Jaskoswki, P., and Wlodarczyk, D. (2006). Task modulation of the effects of brightness on reaction time and response force. *International Journal of Phychophysiology*, 61(2), 98-112.

Jaskowski, P., Rybarczyk, K., and Jaroszyk, F. (1994). The relationship between latency of auditory evoked potentials, simple reaction time, and stimulus intensity. *Psychological*

Research, 56(2), 59-65.

Jasp (2017). Retrieved from http://jasp-stats.org/

Kahneman, D. (1973). *Attention and Effort.* Englewood Cliffs, NJ: Prentice-Hall.

Kimchi, R. (1982). Mental effort and task interference in auditory attention. *Perception & Psychophysics*, 32 (5), 473-480.

Kornblum, S. (1994). The way irrelevant dimensions are processed depends on what they overlap with: The case of Stroop- and Simon-like stimuli. Psychological Research, 56, 130-135.

Kohfeld, D. L. (1971). Simple reaction time as a function of stimulus intensity in decibels of light and sound. *Journal of Experimental Psychology*, 88(2), 251-257.

Kornblum, S., Hasbroucq, T., and Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus-response compatibility - a model and taxonomy. *Psychological Review*, 97, 253-270.

Kristjansson, A. (2015). Reconsidering visual search. i-Perception, 6.

Kusnir, F., Chica, A. B., Mitsumasu, M. A., and Bartolomeo, P. (2011). Phasic auditory alerting improves visual conscious perception. *Conscious Cognition*, 20, 1201–1210.

Lalor, E. C., Kelly, S. P., Pearlmutter, B. A., Reilly, R. B. and Foxe, J. J. (2007). Isolating endogenous visuo-spatial attentional effects using the novel visual-evoked spread spectrum analysis (VESPA) technique. *European Journal of Neuroscience*, 26(12), 3536–3542.

Lang, P. J., Bradley, M. M., and Cuthbert, B. N. (1990). Emotion, Attention, and the Startle

Reflex. *Psychological Review*, 97 (3), 377-395.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451–468.

Lavie, N., and Tsal, Y., (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, 56 (2), 183-197.

Lavie, N., and Dalton, P. (2014). Load Theory of Attention and Cognitive Control. *The Oxford Handbook of Attention*. Edited by Anna C. (Kia) Nobre and Sabine Kastner. Oxford University Press.

Ledgeway, T., and Hutchinson, C. V. (2008). Choice reaction times for identifying the direction of first-order motion and different varieties of second-order motion. *Vision Research*, 48 (2), 208-222.

Lipp, O. V., and S.A. Hardwick S. A. (2003). Attentional blink modulation in a reaction time task: performance feedback, warning stimulus modality, and task difficulty. *Biological Psychology*, 62, pp. 115–132.

Lipp, O.V., Kaplan, D.M. and Purkis H. M. (2006). Reaction time facilitation by acoustic task-irrelevant stimuli is not related to startle. *Neuroscience Letters*, 409, pp. 124–127.

Liu X., Banich, M.T., Jacobson, B.L., and Tanabe, J.L. (2004). Common and distinct neural substrates of attentional control in an integrated Simon and spatial Stroop task as assessed by event-related fMRI. *Neuroimage*. 22(3), 1097-106.

Liu, X., Park, Y., Gu, X., and Fan, J. (2010). Dimensional overlap accounts for independence and integration of stimulus—response compatibility effects. *Attention, Perception &*

Psychophysics, 72(6), 1710-20.

Lu, C., & Proctor, R.W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review,* 2, 174.

Luo, C., Lupiáñez, J., Funes, M., and Fu, X. (2011). The modulation of spatial congruency by object-based attention: Analysing the “locus” of the modulation. *The Quarterly Journal of Experimental Psychology,* 64 (12), 2455-2469.

Lupiáñez, J., and Funes, M. (2005). Peripheral spatial cues modulate spatial congruency effects: Analysing the "locus" of the cueing modulation. *European Journal of Cognitive Psychology,* 17(5), 727-752.

Mackworth, J. F. (1964). Performance decrement in vigilance, threshold, and high-speed perceptual motor tasks. *Canadian Journal of Psychology/Revue canadienne de psychologie, 18*(3), 209–223.

Marinovic, W. and Tresilian, J. R. (2016). Triggering prepared actions by sudden sounds: reassessing the evidence for a single mechanism. *Acta Psychologica,* 217, 13-32.

Maslovat, D., Drummond, N. M., Carter, M. J., and Carlsen, A. N. (2015). Reduced motor preparation during dual-task performance: evidence from startle. *Experimental Brain Research,* 233(9), 2673-83.

Mather, M., and Sutherland, M. R. (2010). Arousal-Biased Competition in Perception and Memory. *Perspective on Psychological Scienc*e, 6(2), 114-133.

Matthias, E., Bublak, P., Müller, H. J., Schneider, W. X., Krummenacher, J., and Finke, K. (2010). The influence of alertness on spatial and nonspatial components of visual attention. *Journal of Experimental Psychology: Human Perception and Performance*, 36, 38–56.

McDonald, J.J., Störmer, V.S., Martinez, A., Feng, W. and Hillyard, S.A. (2013). Salient Sounds Activate Human Visual Cortex Automatically. *Journal of Neuroscience*, 33 (21), 9194-9201.

McDonald, J.J., Teder-Sälejärvi, W.A., Di Russo, F., Hillyard, S.A. (2005). Neural basis of auditory-induced shifts in visual time-order perception. *Nature Neuroscience*, 8(9), 1197-202.

Miller, E.K., and Buschman, T.J. (2014**)**. Neural Mechanisms for the Executive Control of Attention**.** *The Oxford Handbook of Attention***.** Edited by Anna C. (Kia) Nobre and Sabine Kastner. Oxford University Press.

Miller, J., Franz, V., and Ulrich, R. (1999). Effects of auditory stimulus intensity on response force in simple, go/no-go, and choice RT tasks. *Perception & Psychophysic*, 61(1), 107-19.

Näätänen, R. (1970). The diminishing time-uncertainty with the lapse of time after the warning signal in reaction-time experiments with varying fore-periods. *Acta Psychologica*, 34, 399-419.

Neisser, U. (1967). *Cognitive psychology*. New York: Appleton-Century-Crofts.

Nobre, A. C., Sebestyen, G. N., Gitelman, D. R., Frith, C. D., and Mesulam, M. M. (2002). Filtering of distractors during visual search studied by positron emission tomography. *NeuroImage* (16), 968–976.

Norman, D., Shallice, T. (1980). Attention to action: willed and automatic control of behavior.

In Davidson, R.J., Schwartz, G.E., Shapiro, D.: *Consciousness and Self-Regulation*. Plenum Press, New York.

Niemi, P., and Näätänen, R. (1981). Foreperiod and simple reaction time. *Psychological Bulletin*, 89(1), 133–162.

Notebaert, W. and Verguts, T. (2008). Cognitive control acts locally. *Cognition*, 106(2), 1071-80.

Notebaert, W., Houtman, F., Van Opsal, F., Gevers, W., Fias, W. and Verguts, T. (2009). Post-error slowing: an orienting account. *Cognition*, 111(2), 275-279.

Petersen, A., Petersen, A. H., Bundesen, C., Vangkilde, S., and Habekost, T. (2017). The effect of phasic auditory alerting on visual perception. *Cognition*, 165, 73-81.

Petersen, S. E. and Posner, M. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience*, 35, 73-89.

Posner, M. and Petersen, S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, 13, 25-42.

Posner, M. I. (1978). *Chronometric explorations of mind*. Lawrence Erlbaum.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32(1), 3–25.

Posner, M. I. (2008). Measuring alertness. *Annals of the New York Academy of Sciences*, 1129, 193-199.

Posner, M.I. (2016). Orienting of Attention: Then and Now. *Quarterly Journal of Experimental Psychology*. 69(10), 1864-1875.

Posner, M.I., and Boies, S.J. (1971). Components of attention. *Psychological Review*, 78, 391–408.

Posner, M.I., Snyder, C.R., Davidson, B.J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology*, 109(2), 160-74.

Posner, M.I., and Wilkinson, R.T. (1969). On the process of preparation. Paper presented to Psychonomic Society (USA).

Proctor, R.W. (2011). Playing the Simon game: Use of the Simon task for investigating human information processing. *Acta Psychologica*, 136(2), 182-188.

Raz, A., and Buhle, J. (2006). Typologies of attentional networks. *Nature Reviews: Neuroscience*, 7(5), 367–379.

Righi, L.L., and Ribeiro-do-Valle, E. (2013). Which factors are important for crossmodal attentional effect? *Experimental Brain Research*, 225(4), 491-498.

Robertson, I. H., Mattingley, J. B., Rorden, C., and Driver, J. (1998). Phasic alerting of neglect patients overcomes their spatial deficit in visual awareness, *Nature*, 395(6698), p.169-72.

Romei, V., Gross, J., and Thut, G. (2012). Sounds Reset Rhythms of Visual Cortex and Corresponding Human Visual Perception. *Current Biology*, 22 (9), 807-813.

Romei, V., Murray, M.M., Cappe, C. and Thut, G. (2009). Preperceptual and Stimulus-Selective Enhancement of Low-Level Human Visual Cortex Excitability by Sounds. *Current Biology*, 19 (21), 1799-1805.

SanMiguel, I., Morgan, H.M., Klein, C., Linden, D., and Escera, C. (2009). On the functional significance of Novelty-P3: facilitation by unexpected novel sounds. *Biological Psychology*, 83(2), 143-52.

Schneider, D.W. (2018). Alertness and cognitive control: Toward a spatial grouping hypothesis. *Attention, Perception & Psychophysics*, 80(4), 913-928.

Schneider, D. W. (2019). Alertness and cognitive control: Is there a spatial attention constraint? *Attention, Perception & Psychophysics*, 81(1), 119-136.

Schneider, D. W. (2020). Alertness and cognitive control: Interactions in the spatial Stroop task. *Attention, Perception & Psychophysics*, 82(5), 2257-2270.

Schneider, W., Eschman, A., and Zuccolotto, A. (2012). E-Prime User's Guide. Pittsburgh: Psychology Software Tools, Inc..

Seibold, V., and Rolke, B. (2014). Does temporal preparation speed up visual processing? Evidence from the N2pc. *Psychophysiology*, 51, 529–538.

Seibold, V.C. (2018). Do alerting signals increase the size of the attentional focus? *Attention, Perception & Psychophysic*, 80(2), 402-425.

Simon, J. R., and Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology*, 51(3), 300-304.

Simon, J.R., and Berbaum, K. (1990). Effect of conflicting cues on information processing: The "Stroop effect" vs. the "Simon effect." *Acta Psychologica*, 73(2), 159-170.

Simon, J.R., and Small, A.M., Jr. (1969). Processing auditory information: Interference from an irrelevant cue. *Journal of Applied Psychology*, 53, 433-435.

Soutschek, A., Müller, H.J. and Schubert, T. (2013). Conflict-specific effects of accessory stimuli on cognitive control in Stroop task and Simon task. *Experimental psychology*, 60(2), 140-147.

Stahl, J., and Rammsayer, T. H. (2005). Accessory stimulation in the time course of visuomotor information processing: Stimulus intensity effects on reaction time and response force. *Acta Psychologica, 120*(1), 1–18.

Sternberg (1966). High speed scanning in human memory. *Science*, 153, 652-654.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 28, 643-662.

Sturm, W., and Willmes, K. (2001). On the functional neuroanatomy of intrinsic and phasic alertness. *NeuroImage*, 14(1 Pt 2), S76-84.

Thiel, C. M., Zilles, K., and Fink, G. R. (2004). Cerebral correlates of alerting, orienting and reorienting of visuospatial attention: An event-related fMRI study. *Neuroimage*, 21(1), 318-328.

Torres-Quesada, M., Funes, M., and Lupiáñez, J. (2013). Dissociating proportion congruent and conflict adaptation effects in a Simon-Stroop procedure. *Acta Psychologica*, 142(2), 203-210.

Townsend, J. T., and Van Zandt, T. (1990). New theoretical results on testing self-terminating vs. exhaustive processing in rapid search experiments. In H. G. Geissler, M. H. Müller, and W. Prinz (Eds), *Psychophysical Explorations of Mental Structures*. Toronto, Lewiston, NY, Bern, Götingen, Stuttgart: Hogrefe & Huber Publishers.

Townsend, J.T., and Wenger, M.J. (2004). A theory of interactive parallel processing: new capacity measures and predictions for a response time inequality series. *Psychological*

Review, 111(4), 1003-35.

Treisman, A.M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology*, 12, 242–248.

Treisman, A. (1993). The perception of features and objects. In A. Baddeley & L. Weiskrantz (eds.). *Attention: Selection, Awareness and Control*. Clarendon Press.

Treisman, A. (1998) Feature binding, attention and object perception. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences,* 353(1373), 1295–1306.

Treisman, A., and Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, 12, 97–136.

Triviño, M., Correa, A., Arnedo, M., and Lupiàñez, J. (2010). Temporal orienting deficit after prefrontal damage. *Brain*, 133, 1173-1185.

Ulrich, R., Rinkenauer, G., and Miller, J. (1998). Effects of stimulus duration and intensity on simple reaction time and response force. *Journal of Experimental Psychology: Human Perception and Performance*, 24 (3), 915-928.

Valls-Solé, J., Kofler, M., Kumru, H., Castellote, J. M., and Sanegre, M. T. (2005). Startle-induced reaction time shortening is not modified by prepulse inhibition. *Experimental Brain Research*, 165 (2005), 541–548.

Valls-Solé, J., Valldeoriola, F., Molinuevo, J. L., Cossu, G., and Nobbe, F. (1999). Prepulse modulation of the startle reaction and the blink reflex in normal human subjects. *Experimental Brain Research*, 129(1), 49-56.

Van de Schoot, R. Broere, J. J., Perryck, K. H., Zondervan-Zwijnenburg, M., and van Loey, N. E. (2015). Analyzing small data sets using Bayesian estimation: the case of posttraumatic stress symptoms following mechanical ventilation in burn survivors. *European Journal of Psychotraumatology,* 6.

Van der Burg, E., Olivers, C. N. L., Bronkhorst, A. W., and Theeuwes, J. (2008). Pip and pop: Nonspatial auditory signals improve spatial visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 34(5), 1053–1065.

Van der Molen, M. W., Bashore, T., R., Halliday, R. and Callaway, E. (1991). Chronopsychophysiology: mental chronometry augmented by psychophysiological time markers. In Jennings, J. & Coles, M. (Eds.) *Handbook of Cognitive Psychophysiology,* Central and Autonomic Nervous System Approaches, pp. 9-178. Wiley, New York.

Vincent, B. T. (2015). A tutorial on Bayesian models of Perception. *Journal of Mathematical Psychology*, 66, 103-114.

Vroomen, J., and Gelder, B. d. (2000). Sound enhances visual perception: Cross-modal effects of auditory organization on vision. Journal of *Experimental Psychology: Human Perception and Performance*, 26(5), 1583–1590.

Wagenmakers, E. J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, Selker, R., Gronau, Q. F., Dropmann, Bruno Boutin, B., Meerhoff, F. Knight, P., Akash Raj, A., van Kesteren, E., van Doorn, J., Martin ˇSm´ıra, M., Epskamp, S., Etz, A., Matzke, D., de Jong, T., van den Bergh, D., Sarafoglou, A., Steingroever, H., Derks, K., Rouder, J. N., and Morey, R. D. (2018). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic Bulletin Review*, 25(1), 58-76.

Wager, T.D., Jonides, J., and Reading, S. (2004). Neuroimaging studies of shifting attention: a meta-analysis. *Neuroimage*. 22(4), 1679-93.

Wang, Y. F., Cui, Q., Liu, F., Huo, Y. J., Lu, F. M., Chen, H., and Chen, H. F. (2014). A new method for computing attention network scores and relationships between attention networks. *PloS one*, *9*(3), e89733.

Washington, J. R. and Blumenthal, T. D. (2015). Effect of a startle stimulus on response speed and inhibition in a go/no-go task. *Psychophysiology*, 52 (6), 745-753.

Watanabe, T., Koyama, S., Tanabe, S., and Nojiba, I. (2015). Accessory stimulus modulates executive function during stepping task. *Journal of Neurophysiology*, 11, 419-426.

Weinbach, N. and Henik, A. (2012a). The relationship between alerting and executive control. *Journal of Experimental Psychology: Human Perception and Performance*, 38(6), 1530-1540.

Weinbach, N. and Henik, A. (2012b). Temporal orienting and alerting: the same or different? *Frontiers in Psychology*, 3, 236-241.

Weinbach, N., and Henik, A. (2011). Phasic alertness can modulate executive control by enhancing global processing of visual stimuli. *Cognition*, 121, 454–458.

White, M.J. (1981). Response selection and visual search. *Bulletin of the Psychonomic Society*, 18, 201-202.

Włodarczyk D, Jaśkowski P, and Nowik A. (2002). Influence of sleep deprivation and auditory intensity on reaction time and response force. *Perceptual and Motor Skills,* 94(3 Pt 2), 1101-12.

Wolfe, J. M. (1998). What can 1 million trials tell us about visual search? *Psychological*

Science, 9 (1), 33-39.

Wolfe, J. M. (2016). Visual Search Revived: The Slopes Are Not That Slippery: A Reply to Kristjansson (2015). *Iperception*, 7(3).