

**Attentional influences on learning
under unpredicted situations**

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Attentional influences on learning under unpredicted situations.

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TABLE OF CONTENTS

Preface	i
Chapter I: Introduction	1
Defining the predictive framework: anticipations and readjustments.	3
Predictions inside the lab	4
Cueing paradigms	4
Schema paradigms	5
Chapter II: Motivation and main goal of the research	13
Chapter III: Cue-based predictions	21
<i>Experimental Series I</i>	23
Title	25
Abstract	25
Introduction	26
Series A	31
Experiment 1	31
Experiment 2	34
Experiment 3	36
Series B	37
Experiment 4	38
Experiment 5	39
Series C	41
Experiment 6	41
Experiment 7	43
General discussion	47
Chapter IV: Schema-based predictions	55
<i>Experimental Series II</i>	57
Title	59
Abstract	59
Introduction	60
Experiment 1	63
Experiment 2	68
Experiment 3	72
General discussion	76
<i>Experimental Series III</i>	83
Title	85
Abstract	85
Introduction	86
Experiment 1	89
Experiment 2	98
Experiment 3	101
General discussion	106
<i>Experimental Series IV</i>	117
Title	119
Abstract	119
Introduction	120
Materials and methods	122
Results	126
Discussion	130

Chapter V: Discussion	139
On the search for a pure prediction error	141
Predictions in the real world	143
Object detection	144
Object identification	146
Object recognition	147
Summary of findings and integrative proposal	149
Abstract	155
Resumen	163
References	169

Preface

*I believe I can see the future,
Cause I repeat the same routine.
I think I used to have a purpose,
But then again, it might have been a dream.*
Trent Reznor (Everyday is exactly the same).

Our world is a complex environment. An overwhelming amount of information is continuously presented to our senses. Our cognitive system efficiently and flexibly deals with that huge amount of information so that we can be aware of the most relevant pieces, rapidly respond to them when needed and store a fraction of that information that will later be available for retrieval. This titanic endeavor can be accomplished partially thanks to the inherent redundancy of our environment. Complex as it might seem, repetitions, cycles and regularities are a constant in the world around us. From seasonal changes to repetitive speech patterns in oral language, redundancy is omnipresent in our daily life. If we were to commute to work today, it is most certain that we would run into numerous stimuli that we have seen before and many of them would be even in the exact same point in time and space as the last time we saw them. The elevator's doors would open right after the bell would ring, our friendly neighbor would be walking her dog at the nearby park, green light would always follow red light on that busy intersection... and many more examples.

It would, therefore, make sense to use that redundancy to improve information processing by, as the author from the initial quote states, "seeing the future", or in other words, by anticipating and preparing in advance for the most likely stimulus to be encountered; the subsequent feeling of lack of purpose, although it might as well refer to the pursuing of a PhD, will not be addressed (explicitly) in the present work.

In line with the reasoning followed above, it has been proposed that one of the main functions of the brain could be making predictions and preparing our cognitive system accordingly (Chopin & Mamassian, 2012; Clark, 2013; Summerfield et al., 2006). Predictions about the world would shape and speed up the way we process information and respond to it.

However, and luckily for us, discontinuities among these regularities are also part of our world. Repairing works being done in our usual route to the lab, a new man at the reception or even simple changes in the disposition of the furniture in our office would *capture* our attention. These kinds of situations have major importance for our functioning since they reflect a failure of the system's predictions but, at the same time, they signal a *sweet* opportunity for learning about new information. On the one hand, unpredicted events carry a lot of potentially informative value since they contain, by definition, unknown information that the system cannot anticipate; acquiring that information could help us to eventually predict formerly-unpredicted events if they repeat over time. On the other hand, when information is well predicted the benefit from learning is sparse; at the end, it would not make much sense to learn about what we already know enough (Henson & Gagnepain, 2010).

Therefore, under this framework, mismatches between the system's predictions and actual inputs are thought to trigger encoding mechanisms that would help gathering new information, which in turn would minimize the *prediction error*. This term, prediction error, has been used in the literature to refer to a signal that follows unfulfilled predictions and it has been shown to have both neural (d'Acremont, Lu, Li, Van der Linden, & Bechara, 2009; McClure, Berns, & Montague, 2003; O'Doherty et al., 1997) and electrophysiological correlates (Parmentier, Elsley, Andrés, & Barceló, 2011; Todorovic, van Ede, Maris, & de Lange, 2011; Wacongne et al., 2011; Yabe, Tervaniemi, Reinikainen, & Näätänen, 1997).

The framework described above has been used to separately study the impact of predictions at both the short- and the long-term. For instance, predictive behavior has been shown to impact processes such as perception (Friston, 2003; Lee & Mumford, 2003; Summerfield et al., 2006), attention allocation (Hollingworth & Henderson, 2000; Stirk & Underwood, 2007) or object identification (Bar, 2003; Gorlin et al., 2012). Likewise, the influence of predictions can also impact recognition memory and free recall (Friedman, 1979; Goodman, 1980; Hock, Romanski, Galie, & Williams, 1978; Pedale & Santangelo, 2015; Pezdek, Whetstone, Reynolds, Askari, & Et Al, 1989). This thesis aims at building bridges between studies in short- and long-term effects of predictions by jointly exploring the effects of predictions at both points in time.

In this introduction we will define key concepts, paradigms as well as current models that are necessary to fully contextualize the present work and we will summarize previous work exploring the immediate and delayed effects of predictions across the stream of information processing.

CHAPTER I: INTRODUCTION

Defining the predictive framework: anticipations and readjustments

The predictive coding framework assumes that our cognitive system uses previous knowledge about the structure of the world to set itself up in advance to account for upcoming inputs. Take, for instance, one of the examples described above. When stopped at an intersection, our thousands of previous experiences with traffic lights tell us that, if the red light has been on for a while, it is almost certain that the green light will light up shortly. As a consequence, we can be prepared to put the car into first gear, press the clutch and start moving before the driver behind us honks loudly. However, this conscious and volitional prediction is just one intuitive and easy to understand example. The predictive coding framework encompasses any kind of situation in which the system is prepared to respond to a given stimulus before its appearance (Rao & Ballard, 1999). For example, upon entering our office we *get prepared* to encounter a particular set of items arranged in a particular way so that actions like turning on the lights, taking off our jacket or navigate through nearby tables can easily and effortlessly be accomplished without paying much attention. Thus, in the present dissertation, the term *predictions* would be used to refer to anticipations of forthcoming stimuli, either voluntary and conscious or automatically derived from contextual cues.

Another central concept within the predictive framework is the management of irregularities. What happens if, once inside the office, we find that someone has moved the chairs and tables and instead of our desktop there is a wild rhinoceros staring at us? We need to have some sort of *circuit-breaker* that takes us out from that *automatic-pilot mode* and enables a quick and adaptive reaction. This and other less arousing examples, like keys moved away from its usual location or encountering a new cupcakes store where our beloved bakery was, are also good illustrations of situations that require the system to be re-adjusted from a previous state to accommodate an unpredicted stimulus. Therefore, and following from the previous definition of predictions, in the present dissertation we will consider as *prediction errors* any situation that forces the system to readjust from a previous preparatory state in response to a novel stimulus (Rao & Ballard, 1999; Summerfield et al., 2006).

Predictions inside the lab

The establishment and breaking of predictions can be studied inside the lab with a wide variety of approaches; in the present work, we have used two of the mainstream experimental paradigms: cueing and semantic paradigms. On cueing paradigms the system is set up based on an external cue that anticipates some stimulus feature. Conversely, semantic paradigms make use of pre-existing real world associations between stimuli to generate predictions. In the next section, we will more deeply describe cueing and semantic paradigms to better understand the theoretical reasons for using them in the current thesis.

Cueing paradigms.

Assigning different ringtones to different *apps* on our smartphone will allow us to automatically know whether we have received a text message from a friend or an email from work. In other words, the nature of the tone will *cue* which type of message we will find upon unlocking our phone. In this example, a cue (i.e., the ring tone) anticipates a target (i.e., the message) feature (i.e., which *app* has a notification for us). The anticipated target feature can be as diverse as the number of features we are able to identify on the target: from very simple features such as color or shape (Maljkovic & Nakayama, 1994; Milliken, Tipper, & Weaver, 1994; Tulving & Schacter, 1990) to complex semantic information such as target's belonging category (Neely, 1977; Rosch, 1975). Anticipatory cues can even go beyond target features and carry instructions on what type of task is required to perform over the upcoming target (Braver, Reynolds, & Donaldson, 2003).

Among the different types of cueing paradigms, one of them is of great interest for the purpose of the present work. If the reader is familiarized with sports, they would know that it is a common practice among expert players to pretend they are about to direct their action (either a smash in tennis or a penalty kick in soccer) toward a given location with the intention of generating an expectation on the opponent. If the opponent believes the feint, then they would choose another direction to seize the opportunity to attempt at scoring a point.

An equivalent situation can be reproduced inside the lab with spatial cueing paradigms, amongst which, Posner's (1980) is probably the most studied (Correa, 2010;

Coull & Nobre, 1998, for a similar reasoning concerning temporal cueing). In spatial cueing paradigms, a central or peripheral stimulus is used as cue to anticipate, with a certain degree of confidence, the spatial location of an upcoming target stimulus. Arrows are usually used as central cues and flashing asterisks are used as peripheral ones. The precise timing parameters such as cue duration, stimulus (i.e., cue-to-target) onset asynchrony (SOA) or target duration, and the nature of the task to perform on the target, define which type of effects these cues usually generate (Chica, Martín-Arévalo, Botta, & Lupiáñez, 2014; Posner, 1980). For instance, with the commonly used SOA of less than 300ms, facilitation effects (i.e., speeded and more accurate performance) are usually found on trials in which the location designated by the cue matches that of the actual target; conversely, on situations in which the target appears at an unexpected location, impaired performance is usually obtained. However, if we were to increase the SOA beyond 300ms, this pattern of results would revert to find faster responses on expectation-mismatching location than on expectation-matching ones (IOR; Lupiáñez, Klein, & Bartolomeo, 2006; Posner, Rafal, Choate, & Vaughan, 1985). Furthermore, when the target needs to be discriminated facilitation is observed even at rather longer SOAs.

As the reader will find out on the first experimental series of the present thesis, several of these factors were manipulated here to assess the long-term memory consequences of different ways of orienting attention.

Schema paradigms.

While cueing paradigms use explicit external cues to generate predictions, schema paradigms make use of previous knowledge on associations between items to produce an expectation about forthcoming stimuli. For instance, when walking through a forest we would expect to find a specific subset of animals and plants and that expectation would be based on our previous knowledge of forests and forest life.

It is important to draw attention to the fact that objects often relate to each other forming a semantic schema (Henderson & Hollingworth, 1999) that aids their processing and creates the subjective impression that we do not see isolated objects but rather perceive a continuous scene (Pinker, 2007). Among the different ways in which it is possible to induce semantic-based associations, the ones arising from context to

objects are of most interest for the present work. Specifically, natural real-life images contain a great amount of information regarding not only the structure of the scene itself but also concerning the objects that are usually found in this type of contexts. Literature on scene processing has shown that while the gist of the scene is available from a few hundred milliseconds (Castelhano & Henderson, 2008), accessing information about individual objects can take a little longer (Fei-Fei, Iyer, Koch, & Perona, 2007; VanRullen & Thorpe, 2001). Thus, just a brief glimpse to an image can predispose ourselves to encounter certain objects.

Immediate effects of predictions

When information is presented to our system, a quick and effective response is often required. As it was outlined above, our system is often prepared in advance to deal with incoming inputs. Any deviation from these expectations, whether they appear as a low-level discontinuity (Koch & Ullman, 1987) or as a high-level semantic mismatch (Hollingworth & Henderson, 2000), would capture our attention and bias processing of entire input.

Low-level incongruities can generally be studied by means of *perceptual saliency*, by how different a given stimulus is from its surroundings. The concept of saliency arises as an answer to the question of how can our attentional system be tuned up so quickly toward specific locations when looking at a scene that contains a gigantic amount of information. The answer most models offer is that different feature-maps feed into a common *saliency map* that is independent of the features themselves. Namely, a green square among red circles would be as salient as a red square among green circles. Same goes for features other than color such as shape, orientation, or even motion (Koch & Ullman, 1987). Therefore, perceptual saliency would be used in the present work in the terms of Koch and Ullman as purely bottom-up saliency: not tied to specific features but also independent of top-down influences.

Saliency-based attentional guidance has been supported by a great number of experimental studies; in most of them it is easy to find overt or covert attentional allocation toward the most salient regions of space (Itti & Koch, 2001; Lamy & Zoraris, 2009). These results are in line with predictive models that assign a preferential role to ill-predicted stimuli. In addition, the prioritization of unpredicted stimuli has been

shown to be domain general as it has been found when using visual stimuli (Gordon, 2004; Hollingworth & Henderson, 2000; LaPointe, Lupiáñez, & Milliken, 2013), acoustic deviant sounds (Parmentier et al., 2011) or even purely conceptual low level mismatches (Treisman & Souther, 1985). Numerous investigations have aimed at finding a neural signature of perceptual saliency most of which converge in the crucial implication of the dorsal frontoparietal network (Bogler, Bode, & Haynes, 2011; Constantinidis & Steinmetz, 2005; Koch & Ullman, 1987; Santangelo, 2015; Schall & Hanes, 1993).

However, it is important to note that attention allocation during scene processing is based not only on low-level features (Castelhano & Heaven, 2010; Navalpakkam & Itti, 2005; Peelen & Kastner, 2014; Stirk & Underwood, 2007; Torralba, Oliva, Castelhano, & Henderson, 2006). Semantic information also effectively biases attention allocation by generating its own *semantic-saliency or meaning map* (Henderson & Hayes, 2017), or feeding its characteristics into a *master saliency map* (Itti, Koch, & Niebur, 1998; Koch & Ullman, 1987). Take as an example Gordon's 2004 study. Participants were presented with line drawings depicting real world scenes that contained semantically incongruent objects for a brief period of time (147ms); after the scene disappeared a probe was shown and participants were required to make a discrimination task. The author reported faster response times for probes that appeared at the spatial location of scene-inconsistent objects thus reflecting that attention was effectively drawn to the object specific location (Gordon, 2004). Henderson and Hayes (2017) directly compared the role of both meaning and saliency maps in guiding attention during the exploration of real world scenes and found a larger weight for meaning compared to perceptual saliency, in spite of the two maps were highly correlated.

The idea of high-level semantic information guiding attention has also received support from neuroimaging data which have shown that the presence of semantically inconsistent objects modulated activity in some areas of the ventral frontoparietal network such as the right temporo-parietal junction and the left middle frontal gyrus. This finding is also consistent with recent proposals relating activity in the ventral frontoparietal network with the updating of contextual information based on unpredicted and relevant stimuli (Doricchi, Macci, Silvetti, & Macaluso, 2010; Geng &

Vossel, 2013). This high level semantic incongruity has also been shown to attract attention (LaPointe & Milliken, 2016; Peelen & Kastner, 2014), even beyond perceptual saliency (Henderson & Hayes, 2017), as stated above, and to do so to even override lower-level effects (Santangelo, di Francesco, Mastroberardino, & Macaluso, 2015).

More interestingly for the purpose of the present work, similar advantages are found on change detection paradigms (Hollingworth & Henderson, 2000; Stirk & Underwood, 2007; LaPointe et al., 2013). More specifically, when participants are instructed to detect a change between two versions of the same image that are identical other than for one critical item, either scene inconsistent changes or changes made on scene inconsistent objects are detected faster and more accurately than their corresponding scene consistent ones. Importantly, this result was complemented by LaPointe et al. (2013) by showing that, in spite of being quickly and accurately detected, context-incongruent objects are poorly identified. In other words, identification is rather facilitated by contextual congruity (Bar, 2003; Gorlin et al., 2012), whereas detection is facilitated by contextual incongruity. This interesting dissociation between detection and identification can be easily accommodated by predictive accounts such as the one presented in this introduction: the initial gist of the scene sets a contextual schema within which incorporating schema-consistent objects is straightforward (and thus the eased identification); however, finding a schema-inconsistent object *circuit breaks* the scene construction process and attracts attention toward the object location (and thus the eased detection).

The studies reviewed above are just a small relevant portion of the vast literature on the influences of predictive behavior on immediate performance. A more specific review on the topics addressed in the experimental series can be found at the beginning of each chapter.

Delayed effects of predictions

Of all the information that we efficiently process we are only able to retain a small fraction. What are the defining characteristics of an event that would render it relevant enough to be encoded into memory? Events capable of generating a prediction error signal seem good candidates.

Indeed, many cognitive and neural models have postulated that prediction error can be used by the system as a signal for the need to acquire more information, in contrast with situations that are well predicted in which there is no need for new learning (Rescorla & Wagner, 1972). Take, for instance, Verguts and Notebaert's (2008) model of cognitive control. The authors propose that the co-activation of two or more competing and incompatible representations would trigger learning mechanisms that would release norepinephrine throughout the brain. This hormonal release would end up binding together any active representations by means of Hebbian-like learning.

Another relevant and more memory-focused model is the Predictive, Interactive Multiple Memory Systems model (PIMMS; Henson & Gagnepain, 2010). The authors apply the predictive coding framework to a hierarchical structure of memory in which three systems are described. The higher system, the episodic one, would be in charge of associating items to specific contexts and it would be primarily supported by the hippocampus. The intermediate semantic system would bind combinations of features that tend to occur together in the real world and that define items (i.e., semantic memory); this system would be supported by the anterior temporal cortex. Finally, a lower perceptual system would abstract and represent modality-specific sensory features from stimuli and it would recruit the activity of the higher sensory cortices.

Each level would make predictions about the activity in the level below that would later on be contrasted with the actual activity in that level. The difference between the prediction and actual input received, i.e., the prediction error, would be sent back (via feedforward connections) to upper levels which would update the predictions (via feedback connections to lower levels). The systems would then engage into multiple iterations of this process until the prediction error is minimized. Long lasting synaptic changes (i.e., memory formation) would arise following these repetitive iterations.

One important hypothesis drawn from this model is that larger initial prediction errors would require a greater amount of iterations to be solved and, as a consequence, they would entail greater memory formation. Prediction error is considered, in this model, as a direct proxy for the encoding of new information.

Although the two models described above come initially from very different

fields of research, they both converge into one key assumption: a prediction error ought to be followed by a memory improvement. Recent evidence seems to support this assumption. Take, for instance, Krebs et al.'s (2015). They presented participants with either congruent (e.g., male-male) or incongruent (e.g., male-female) face-word pairs and asked participants to perform a gender discrimination task on the faces while ignoring the words, thus generating a Stroop-like conflict. In addition to obtaining the usual detriment in performance for incongruent pairs, when recognition memory of the faces was tested later on, participants performed better for faces that were studied as part of an incongruent pair than as part of a congruent pair. This result is complimentary to that of Rosner et al. (2016) who showed that incongruent word pairs (e.g., the word *piano* interleaved with the word *truck*) were later on better recognized than congruent word pairs (e.g., the word *piano* interleaved with that same word). Both studies reported memory advantages for information that was presented under incongruent conditions.

In addition to what has been stated before, literature on scene processing also favors the idea of improved memory performance for ill-predicted objects (Pedale & Santangelo, 2015; Friedman, 1979; Goodman, 1980; Hock et al., 1978; Pezdek, et al. 1989). This idea is in line with the research reviewed on the previous section on the immediate effects of prediction errors. Scene-inconsistent objects are assumed to be better encoded as a consequence of attention attraction (Silva, Groeger, & Bradshaw, 2006).

On the work presented below we aim at providing new evidence on the topics reviewed in this introduction that will help clarify the relationships between predictions fulfillment and mismatching and several processes from early perception to eventual memory of the perceived information.

CHAPTER II: MOTIVATION AND MAIN GOAL
OF THE RESEARCH

Among the wide variety of stimuli that we process everyday just a small portion enters our conscious mind, and an even smaller fraction is efficiently encoded into memory and can be later remembered. Which information is selected to be made available to consciousness and how this process is accomplished has been matter of intense debate for decades; nowadays, this issue is still not completely solved. Similarly, it is still unclear whether it is possible to define key stimuli' features that would render specific stimuli relevant enough to be encoded into memory. The present doctoral dissertation aims at expanding current knowledge on these and related issues by taking a predictive coding approach across different stages of visual processing from early perception to eventual memory. This perspective presents a challenging yet a very interesting approach by considering cognition as a stream of processes rather than as isolated actions to be performed on a static point in time. Although considering independent processes in isolation is a very useful and productive approach, integrative attempts such as the present one represent a necessary step in the study of human cognition.

This main goal of the present thesis is, therefore, to assess the immediate and delayed consequences of expectation mismatches across the flow of information processing. Is unexpected information rapidly detected thus being prioritized on its access to consciousness? Is it easier to identify objects that match our predictions? Are surprising events remembered better than well-predicted ones? This main and broad goal is divided into four objectives to be addressed in four different experimental series. First, we attempt at ascertain whether there is such a thing as a learning signal triggered by mere expectation mismatch by using a Posner cueing paradigm, in which the spatial expectation mismatch is independent of meaning. Second, in two experimental series we use semantic congruity/incongruity as another form of expectation fulfillment/violation to assess its impact on conscious detection, object identification and delayed recognition. Lastly, on one last experiment we use brain stimulation to test the causal role of an attentional orienting-related region on detection and identification. The content of these experimental series is described in the following section.

I) Does prediction error always lead to enhanced learning?

Experimental series I

As outlined in the introduction, several models of prediction error as well as some models of cognitive conflict argue that, following a mismatch between anticipations and actual input, a learning signal is triggered. This signal is thought to be domain general and therefore to be measurable following any expectation violation. Whereas it is possible to find studies that show these memory improvements after different unfulfilled expectations, they often include a number of confounding factors (Henson & Gagnepain, 2010; Krebs, Boehler, De Belder, & Egner, 2015; Rosner, D'Angelo, MacLellan, & Milliken, 2015; Rosner, Davis, & Milliken, 2015) that make it difficult to draw strong conclusions regarding prediction error per se. In this experimental series we address this concern by attempting to isolate prediction error from any other surrounding factor by measuring memory performance on the context of the most basic and aperiodic prediction that can be established: an anticipation about the location of an upcoming stimulus based on a previous cue (i.e., a Posner cueing paradigm).

We present our participants with an anticipatory spatial cue that could either signal the correct location of an upcoming target stimulus or a different one. This procedure has been traditionally used to study attentional orienting in space rendering a processing difficulty on trials in which the location of the target stimulus mismatches the location signaled by the cue (usually measured from delayed and less accurate responses). If the models' assumptions were true, we should find better memory on expectation mismatching trials. This is definitively not the case of the observed pattern of results in this experimental series. No differences are found between the remembering of words appearing at the expected and unexpected locations. Across seven different experiments important variables in both the attention and memory literature such as the nature of the cue, the familiarity and the language of the materials or the number of presentations are tested and all fail to explain the null result.

Bayesian statistics are used to ascertain the strength of our evidence. After ruling out a range of most likely alternative accounts and being aware of the caution needed when drawing conclusions from null results, we performed Bayesian analyses to assess how much more likely were our set of results under the null hypothesis versus the

alternative hypothesis. The outcome of the analyses undeniably favored the absence of an effect of validity on memory formation. Then we moved to a different paradigm to test our predictions on rather more ecological scenarios.

II) Do semantic mismatches in ecological scenarios lead to enhance encoding?

Experimental series II

Predictive coding models assume that prediction error would follow not only after the breaking of a straightforward conscious prediction but after any kind of situation in which the system has been set up to respond to the most likely input to be received and a readjustment is needed to account for the actual input. Taking this perspective into consideration, scene processing can be understood as several consecutive anticipations of upcoming information. As noted in the introduction, just a few milliseconds are sufficient to grasp the gist of a given scene or to access some of its basic features such as its openness, whether it depicts a natural or an artificial location, whether it is night or day, etc; however, accessing each object's specific information takes considerably more time (Castelhano & Henderson, 2008; Oliva & Torralba, 2006; Sampanes, Tseng, & Bridgeman, 2008). Therefore, finding a context-mismatching item can be understood as another form of prediction error.

In four experiments we test this assumption by using a flickering change detection task (Rensink, O'Regan, & Clark, 1997) that included ecological natural scenes. Critically, we manipulate the semantic congruity between the to-be-detected target object and the gist of the scenes. Our participants have to detect and identify changing objects in complex natural scenes. Once the change detection task is completed, and after a distracting task, a surprise recognition memory test is administered to assess the impact of semantic congruity on recognition memory. Our results replicate previous online findings by showing that incongruent objects are quickly detected but poorly identified and extended those to show that incongruent objects are remembered worse than congruent ones. Furthermore, we also show that the congruity mediated memory enhancement is specific to the target objects and not to the background scene.

III) What are the mechanism underlying semantic influences across the stream of processing? *Experimental series III*

Three behavioral indexes of the influence of semantic information on different subsequent steps from early perception to eventual memory can be established based on previous literature and on our own results. The paradigm developed in the second experimental series is an appropriate tool to study different steps across the flow of information processing by using the behavioral indexes as proxies for their associated processes. More concretely, this particular set up allows for measuring three behavioral indexes of three different processes (i.e., conscious detection, object identification and delayed recognition) within one experiment and using the very same stimulus set across.

In this third experimental series we aim at using the abovementioned indexes to better characterize their associated processes. On the first two experiments we select two candidate underlying basic cognitive mechanisms, *priming* and *object competition*, and ascertain to which extent conscious detection, object identification and delayed recognition relied on them. The main manipulation on these two experiments was to include a new stimulus set in our paradigm in which most of the competing distracter objects are removed and thus object competition is reduced. Our results revealed that while object competition is a crucial process in conscious detection, it is not so much for object identification or delayed recognition. The third experiment proves that semantic effects on remembering can be independent on the level of conscious identification. The fourth one uses eye movements' measures to find the gaze patterns associated with each of the three studied processes, and to show that scene-incongruent objects indeed capture attention so that they are fixated before earlier on than scene-congruent objects.

IV) Can the dissociation between detection and identification be extended at the neural level? *Experimental series IV*

In this last experimental series we aim at dissociating the detection and identification processes at a neural level. To that end, we apply an inhibitory Transcranial Magnetic Stimulation (TMS) protocol over the right Temporo-Parietal Junction (TPJ) to hinder activity in this region, and asked our participants to perform a simplified version of the procedure used in Experimental series II and III in which the memory test was left out. Because activity in the right TPJ has been traditionally related

to exogenous orienting of attention and in light of the results from the previous experimental series, we expect to find a reduction in the differences in detection efficiency of congruent and incongruent trials following right TPJ stimulation when compared with stimulation over a control region (Vertex). Results confirmed our hypothesis regarding detection performance and uncovered an unexpected interesting finding: the impairment on identification for context-incongruent objects was also reduced following stimulation over right TPJ. This unforeseen finding can be understood under a recently proposed framework which argues that the main function of right TPJ would not be attentional endogenously re-orienting but rather the updating of an established context (Doricchi et al., 2010; Geng & Vossel, 2013) on which attentional orienting might operate.

CHAPTER III: CUE-BASED PREDICTIONS

Does prediction error *always* lead to enhanced learning?

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Attentional influences on memory formation: a tale of a not-so-simple story.

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Abstract.

Is there a learning mechanism triggered by mere expectation-violation? Is there some form of memory enhancement inherent to an event mismatching our predictions? Across seven experiments we explore this issue by means of a validity paradigm. Although our manipulation clearly succeeded in generating an expectation and breaking it, the memory consequences of that expectation-mismatch are not so obvious. We report here evidence of a null effect of expectation on memory formation. Our results 1) show that enhanced memory for unexpected events is not easily achieved and 2) call for a re-evaluation of previous accounts of memory enhancements based on prediction error or difficulty of processing. Limitations of this study and possible implications for the field are discussed in detail.

Introduction.

What are the long-term consequences of encountering an unexpected or conflicting situation? Are those episodes especially salient and encoded into long-term memory? Recent research and cognitive modeling have pointed at some form of cognitive conflict as a learning-inducer (Krebs et al., 2015; Rosner, D'Angelo, et al., 2015; Verguts & Notebaert, 2009). For example, Krebs et al. (2015) presented a group of participants with a gender categorization task in which they had to respond to the gender of human faces with a superimposed word. Critically, the word was a gender label that could be congruent, neutral or incongruent with the response. The authors found impaired performance (i.e., longer response times and higher error rates) for incongruent than congruent word-face pairs. More important, when their participants were later asked to remember previously presented faces in a surprise recognition test, they found better recognition for faces that were part of incongruent than congruent study items (see the full paper for converging neuroimaging findings). In a conceptually similar study, Rosner et al. (2015) asked participants to name aloud a list of target words that were displayed with matching or mismatching distractor words (e.g., the target word *piano* could be interleaved with either that same word or with the word *truck*). The authors reported that on a later surprise recognition memory test, recognition memory was superior (i.e., greater hit rates and fewer false alarms) for items that were part of incongruent word pairs in the study phase. Rosner et al. claimed that conflict detection might have recruited cognitive control which, in turn, may have up-regulated memory encoding for incongruent items. This set of results can easily be accommodated by Verguts and Notebaert's Adaptation by Binding model of conflict mediated learning. According to this model, conflict detection (arguably taking place in the anterior cingulate cortex), releases norepinephrine throughout the brain and thus strengthens the connections between co-active representations.

Another appealing and compatible interpretation of these effects comes from understanding incongruity as a mismatch between the predictions that we make and the outcomes that we actually encounter. Several models of predictive coding have proposed that prediction error can indeed trigger learning

mechanisms that gather new evidence to update previously established associations. These updated representations would, in turn, improve future predictions (Henson & Gagnepain, 2010; van Kesteren, Ruiter, Fernández, & Henson, 2012).

Despite their surface appeal, several factors prove challenging for this set of ideas that map conflict or prediction error to episodic memory encoding. One such factor is that the direct connection between incongruity and prediction error, at least in the studies outlined above, is not straightforward. A second factor of note is that it is relatively easy to find sets of data in the literature that support a putatively contrary principle; that is, that structured, consistent, congruent information is remembered better than incongruent information (Ortiz-Tudela, Milliken, Botta, LaPointe, & Lupiañez, 2016; van Kesteren et al., 2012). Lastly, another factor worth noting is that, in most of the studies described above, the manipulations included at study necessarily imply a processing difficulty that is confounded with the expectation mismatch itself. Indeed, in those studies it is difficult to disentangle the separate contributions of prediction error (or conflict detection, or expectation mismatch) from additional processing that often follows as a consequence of prediction error.

Hence, in light of the inconsistent evidence and lack of a direct correspondence between prediction error and conflict, we developed a paradigm in which recognition memory is assessed as a function of fulfillment (or not) of an expectation, with those expectations realized either through explicit voluntary prediction (experiments 1, 2, 3 and 4) or through bottom-up anticipation from a cue to a target (experiments 5, 6 and 7). In this study we attempt to test directly the assumption that there is a core learning mechanism triggered solely by expectation mismatch. In order to do so, our experimental paradigm equates the conditions of interest in all features other than the expectation fulfillment (see Figure 1). Namely, our expectation matching (i.e., valid) and mismatching (i.e., invalid) trials only differed from one another in that the anticipation about the upcoming location of the stimulus is either met or broken; other variables such as cognitive control exertion, selective attention deployment or cognitive effort cannot be used to explain any differential results between valid and invalid trials

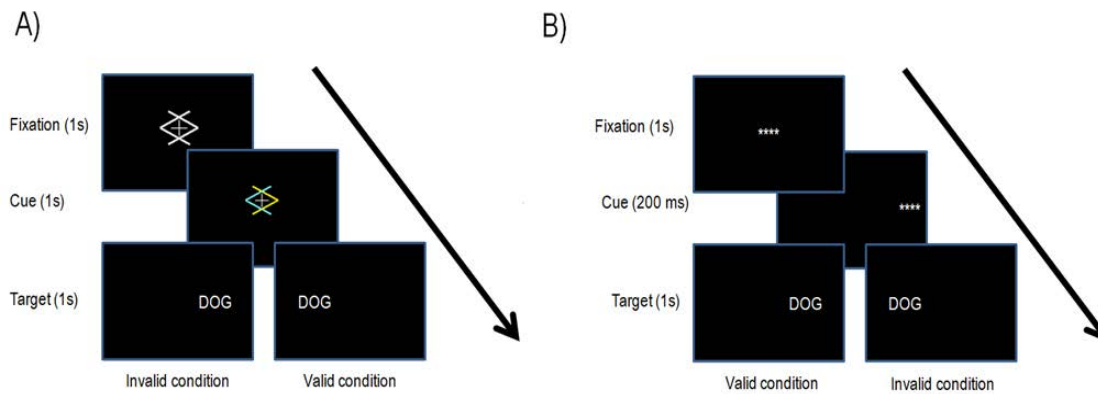


Figure 1. Illustration of the experimental procedure for Experiments 1, 2, 3 and 4 (panel A) and Experiments 5, 6 and 7 (panel B).

since the two conditions of interest rely on those mechanisms equally. According to this approach, and in line with the conceptual overlap between our study and prior studies on conflict and memory encoding (Krebs et al., 2015; Rosner et al., 2015), superior recognition memory ought to occur when an anticipatory cue results in an expectation that is violated. Specifically, our method focuses on cueing the location of an upcoming stimulus, which either matches or mismatches the actual location of that stimulus, and the straightforward prediction is that we should find better recognition memory for the stimuli appearing in an unexpected location. In the following experiments we thoroughly test this intuitive idea that stimuli appearing at unexpected locations are later better remembered, across a variety of manipulations of the standard validity paradigm (Chica et al., 2014; Posner, 1980) and using a recognition memory test.

Generating (and breaking) expectancies.

The most common way of inducing an expectation about a particular stimulus feature (e.g., its category, its color, its location on the screen, etc.) is to validly cue said feature prior to the stimulus' appearance. The standard validity paradigm has been widely used to induce spatial expectancies (Posner, 1980). In its most common form, a visual cue is given prior to the presentation of a peripheral target stimulus. Although the cue always carries some form of spatial information, the extent to which that information relates to the actual location of the target defines the validity of the trial. Namely, on a valid trial the cue correctly anticipates the location of the target; conversely, on an invalid trial the cue directs attention toward a location different from that of the target. On invalid trials, when

attention is misdirected, the appearance of the stimulus at an unexpected location triggers the re-orienting system to disengage attention from the cued location, to shift attention toward the actual target location, and to re-engage attention on the new target (Corbetta, Patel, & Shulman, 2008).

Another key aspect of validity paradigms is the nature of the anticipatory cue. The general consensus is that peripherally presented cues intrinsically carry spatial information (by their mere peripheral appearance) and automatically capture attention at their location, regardless of their informative value (i.e., exogenous orienting). On the other hand, centrally presented cues must contain some form of symbolic information (although see Lambert, Roser, Wells, & Heffer, 2006 for a discussion on symmetrical vs. asymmetrical cues) about a specific location and therefore require conscious and volitional action to properly shift attention (i.e., endogenous orienting). These two ways of orienting attention have different impacts on the processes that take place once the stimulus appears (Chica et al., 2014; Funes, Lupiáñez, & Milliken, 2007; Hauer & MacLeod, 2006; Markant & Amso, 2014).

Our aim was to combine these methods of generating a spatial expectation with a straightforward verbal memory task. To our knowledge, there are only two prior studies that have addressed related issues, although they do so indirectly, with a similar paradigm (Hauer & MacLeod, 2006; Markant & Amso, 2014). In a study by Markant and Amso (2014), the authors showed that spatial cueing effects in a study phase can predict recognition memory in a following test phase. More concretely, they demonstrated that participants who engaged in greater suppression of cued locations showed improved memory performance. Although they did not report individual memory performance separately for valid and invalid trials, their results can be taken broadly as evidence that processes that impact spatial cueing effects can impact memory encoding. In another study, Hauer and MacLeod (2006) used either central symbolic (endogenous) cues or peripheral abrupt onset (exogenous) cues to assess the influence of these two cueing methods at study on later memory performance. Their results indicate that endogenously attended words were remembered better than exogenously attended words. Crucial to our interests, although their study focused only on valid words

(invalid words were to be ignored during the task), they did report a small tendency towards better memory for invalid words in spite of the fact that they were not even attended. The present study builds on this prior work but explicitly requires our participants to attend (and respond) to both validly and invalidly cued words.

The present experiments.

The overall structure of all of the experiments reported here is as follows. First, in a study phase, participants were presented with some variation of a validity paradigm. Namely, an anticipatory visual cue was presented with the purpose of generating an expectation about the location in which a given target word was going to appear. For Experiments 1, 2, 3 and 4 we used informative centrally presented arrows as cues; for Experiment 5 and onwards, we used uninformative peripherally presented asterisks as cues. Following each cue, a word was presented to which participants responded, with the word appearing either at the anticipated location (valid trials) or at the opposite location (invalid trials). The timing parameters were adjusted for each experiment so that the target would appear at a temporal interval following the cue that would be expected to produce facilitation on valid trials (Chica et al., 2014). In a second phase, a distracter task was completed for about 10 minutes consisting of math calculations either on a paper sheet (Experiments 1, 2, 3, 6 and 7) or on a computer display (Experiments 4 and 5). Finally, a surprise recognition test was administered for the words presented during the incidental study phase. The specific details of each experiment are described in the corresponding section.

Indeed, in the study phase, the processing of stimuli presented at cued locations was facilitated (i.e., faster response times and/or higher accuracy) relative to uncued locations in all experiments (see Table 1). As these results were anticipated and not central to our research question, and in order to ease reading of the manuscript, they are not discussed further. However, these basic validity effects did allow us to test our main prediction concerning memory for words as a function of whether or not they appeared at the cued location. For the test phase, we hypothesized that if prediction error triggers better encoding of expectation-mismatching items, then memory performance ought to be better for

invalid location trials than for valid location trials.

We use the term “prediction” to refer to any configuration of the system in response to an internal or external cue that anticipates a given stimulus feature. In other words, a prediction will occur when, in the presence of a cue that signals a given stimulus feature, the system re-configures to efficiently respond to upcoming stimuli. From this perspective, any mismatch between the anticipated input and the actual stimulus will be considered a prediction error (Henson & Gagnepain, 2010). The specific empirical issue addressed in our study is whether such prediction errors regulate learning and memory broadly – will a strictly spatial prediction error regulate learning and memory in a task that has no obvious spatial component? To the extent that spatial information plays an important role

Experiment	Valid	Neutral	Invalid	Stats	p value	η_p^2
1	814	844	893	F(2,78)=28.76	<.000	0.42
2	755	774	803	F(2,56)=23.66	<.000	0.458
3	783	801	822	F(2,26)=3.73	0.037	0.223
4	601	645	675	F(2,38)=26.34	<.000	0.581
5	556	640	685	F(2,38)=84.28	<.000	0.816
6	512	---	666	F(1,29)=88.53	<.000	0.75
7	532	---	692	F(4,68)=3.16	0.019	0.157

Table 1. Summary of RTs (ms) from the Study phases of all 7 experiments reported in this manuscript. For experiments 6 and 7 RTs for the different levels of repetition are collapsed in this table. See Figure 2 for a break down.

in event encoding (Kahneman, Treisman, & Gibbs, 1992), spatial prediction errors may well play a key role in event segmentation processes known to impact both perception and memory (Kurby & Zacks, 2008). If this is the case, then we might also expect spatial prediction errors to impact performance in a simple verbal memory task.

Series A. Endogenous attention.

Experiment 1

Voluntary shifts of attention towards a specific location are often studied with centrally presented symbolic cues. Among the types of cues used, arrows are the most common. Our initial goal was to evaluate the influence of explicit spatial

expectation on memory encoding; as such, this first series of experiments used centrally presented arrows predictive of the target word location.

Participants. In order to meet counterbalancing requirements (see below) forty undergraduate students (36 female; mean age: 22; s.d.: 3.40) from the Universidad de Granada were recruited to participate in the study in exchange for course credits. All participants in this and other experiments reported here signed a consent form approved by the local ethics committee, and the experiments were conducted according to the ethical standards of the 1964 Declaration of Helsinki.

Details of the procedure. All stimuli in both phases were presented and responses were recorded using E-Prime 2.0 software (Psychology Software Tools, 2012).

Study phase. Each trial of the study phase began with an “X” presented in the center of the screen for one second that served as fixation. On 80% of the trials, the fixation cross was replaced by an informative cue; that is, by two colored arrow heads pointing left and right respectively. The two arrow heads were presented in different colors, and participants were instructed to pay attention to only one of them (colors were counterbalanced across participants). Participants were told that the relevant arrow would point to the location at which the upcoming stimulus was most likely to appear. On the rest of the trials (neutral trials), an uninformative cue appeared, in which the fixation cross was replaced by randomly oriented colored lines that provided no directional information (Martín-Arévalo, Lupiáñez, Botta, & Chica, 2015). 500ms after onset of the cue, a colored (red or green) target word appeared in either the valid (75% of the trials) or the invalid (25% of the trials) location; across the entire experimental session, 60% of the trials were valid, 20% were invalid and 20% were neutral. Words subtended approximately 2° vertically and between 5° and 7° horizontally of visual angle. Participants were instructed to use two keys of a standard QWERTY keyboard to categorize the word as either “natural” or “artificial”. The word remained on the screen until participants made a response and speed and accuracy were both encouraged.

A total of 80 Spanish words representing natural objects and 80 words

representing artificial objects were used for the study phase. Words were extracted from the Alameda and Cuetos database (Alameda & Cuetos, 1995) and we tried to equate them as much as possible in frequency and length, resulting however in artificial words being slightly longer (6.4 vs. 5.9) and more frequent (101 vs 19 appearances per million words) than natural words, $t(158) = 1.90$, $p = .059$, Cohen's $d = .297$ and $t(158) = 3.08$, $p = .002$, Cohen's $d = .487$ respectively. In spite of these differences, it is important to note that validity was counterbalanced across participants so that every word would appear in every condition across the entire sample and for every participant half of the words were extracted from each category for each condition.

Test phase. After the study phase, participants completed a surprise recognition test in which they judged centrally presented words as OLD (i.e., already presented in the study phase) or NEW (i.e., not presented in the study phase). The 160 words from the study phase and 40 new words were used in the memory test.

In addition to the OLD/NEW judgment, participants reported the confidence of their responses on a 4-point scale (i.e., “I’m completely sure it is OLD”, “I think it is OLD”, “I think it is NEW” and “I’m completely sure it is NEW”). After judging whether each test word was old or new, participants reported their memory for the color and location of the words presented in the study phase, again on a 4-point scale (i.e., “I’m completely sure the word was presented in red”, “I think it was presented in red”, “I think it was presented in green” and “I’m completely sure the word was presented in green”; and a corresponding judgment about left-right location). As none of the results from these 4-point scales offered any useful information in this or any of the other experiments (in fact, memory for location and color responses was always at chance), these results are not discussed further¹.

¹Confidence ratings were analyzed on independent ANOVAs and collapsed after not finding any differences between these measures. “I’m completely sure” and “I think” responses were collapsed together for both old and new words.

Results and discussion. Separate repeated measures ANOVAs were conducted for study and test phases. Both analyses included Validity (valid vs. neutral vs. invalid) as a within-participants factor. For the study phase, response times to categorize the words served as the dependent variable; for the test phase, as it was impossible to assess independent false alarm rates for valid, neutral and invalid trials, hit rates were used as our measure of memory performance.

Study phase. The percentage of correct responses for valid, neutral and invalid trials was 96%, and did not differ across conditions. However, a strong expectation effect for target location was reflected in the pattern of response times for valid (814ms), neutral (844 ms) and invalid (893ms) words, $F(2,78)=28.76$, $p<.001$, $\eta_p^2 = .42$.

Test phase. Overall d' (1.70) indicated that participants accurately discriminated between OLD and NEW words; overall hit rate was .61 and overall false alarm (FA) rate was .10. Unexpectedly, there was no significant difference between the hit rate for words presented at valid (.62), neutral (.62), and invalid (.58) locations, $F(2,78) = 2.85$, $p=.064$, $\eta_p^2 = .068$.

Experiment 2

Despite the expected difference in response times between valid and invalid trials in the study phase, recognition did not differ for valid and invalid trials in the test phase. This unexpected result is inconsistent with our initial hypothesis, and surprising in light of the results of several previous studies. In these studies, an attentional manipulation during the study phase produced superior memory performance for the condition with higher attention demands at study (Krebs et al., 2015; Mulligan, Spataro, & Picklesimer, 2014; Rosner, D'Angelo, et al., 2015; Rosner, Davis, et al., 2015; Swallow & Jiang, 2010a). For example, consider the study of Krebs et al. (2015). They found better memory for faces presented in the context of incongruent than congruent face-word Stroop stimuli. A potentially important aspect of their procedure was the pre-exposure of all the materials before the study phase as a way to equate the subjective familiarity of all the stimuli. Although words from our stimulus set all had an intermediate normative frequency, small variations in perceived familiarity could have increased noise in

our results, thus making it more difficult to find a true effect. In Experiment 2, we mimicked Krebs et al.'s procedure to reduce variation in the familiarity of our items.

Participants. In order to optimize resources, but still complete the six counterbalancing cycles, we reduced the total sample to thirty participants; all of them were undergraduate students from the Universidad de Granada and volunteered to participate in the study in exchange for course credits. One participant did not complete the entire experimental session so the final sample was composed of twenty-nine students (25 female; mean age: 22.9; s.d.: 3.92).

Details of the procedure. The procedure and stimuli used in Experiment 2 were similar to Experiment 1 with the exception of an initial phase in which we pre-exposed all stimuli to participants. This initial phase consisted of the same categorization task used for the following study phase, but now involving all words that appeared later either as study words in the study and test phases, or as lures in the test phase only. In this initial phase, the words were presented centrally in black. The rest of the procedure was identical to Experiment 1. During the test phase participants were instructed to consider as old only those words that appeared in color, to the left or right of fixation, during the study phase.

Results and discussion. As expected, pre-exposing the words in the initial phase led to a large increase in false alarms in this experiment (.50) compared to Experiment 1. At the same time, pre-exposing the words prior to the study phase had no appreciable influence on the results of primary interest.

In the study phase, there was a validity effect of 47ms in the response time analysis, $F(2,56)=23.66$, $p<.001$, $\eta_p^2 = .458$, but no effect of validity in the accuracy analysis (95% correct responses for each of the three conditions). Recognition sensitivity in the test phase was somewhat lower in this experiment than Experiment 1, with overall hit and FA rates of .70 and .49, respectively. Nonetheless, the mean d' of .6 was significantly different from 0, $t(28)= 8.60$, $p<.001$, Cohen's $d_s = 2.26$. Importantly, however, the effect of Validity on hit rates was not significant, $F<1$, with hit rates not differing for valid (.70), neutral (.72) and invalid (.70) words.

Experiment 3

The absence of a validity effect in the memory tests of Experiments 1 and 2 was puzzling. However, it has been shown that when a single retrieval cue is associated with many memories, the cue can lose its utility in activating particular memories. This phenomenon is often found in the literature under the name of *cue-overload* (Watkins & Watkins, 1975). As Experiments 1 and 2 displayed words in just two locations on the screen (i.e., left and right), and a total of 160 different words were presented, the word-location ratio was 1:80. Ratios this large might diminish the distinctiveness of available cues, and thereby hurt memory performance (Logan, 1998).

In Experiment 3, we addressed this issue by presenting target words in four different locations (i.e., left, right, up and down with respect to the fixation point) and by reducing the number of words to 80 in order to decrease the word-location ratio (note that d' was much reduced in Experiment 2, with 160 words).

Details of the procedure. The procedure of Experiment 3 was identical to Experiment 2 except for the following details. Instead of one out of two possible arrow cues we now presented one out of four possible arrow cues on each trial (i.e., pointing up, pointing down, pointing left, or pointing right). On half of the trials (i.e., valid trials), the target words appeared in the location indicated by the arrow cue, on 25% of the trials (i.e., invalid trials) the target word appeared in a location randomly chosen from among the three not-cued locations, and on the rest of the trials the same neutral cues from Experiments 1 and 2 were used (i.e., neutral trials). In addition, from the original pool of 160 words, we randomly selected a total 80 words. This method reduced the number of words presented at a single location from 80 to 20.

Participants. Due to the changes in the proportions of trials in each category, a sample size that was a multiple of four would produce complete counterbalancing of items across conditions. We aimed for a sample size of 16 but fell short by two, ending up with a final sample of fourteen undergraduate students (13 female; mean age: 22.43; s.d.: 3.99) from the Universidad de Granada who also participated in the study in exchange for course credits.

Results and discussion. Reducing the cue load did not influence the results in any important way. We observed a validity effect for RTs in the study phase (39ms, $F(2,26)=3.73$, $p=.04$, $\eta_p^2 = .223$), but not for accuracy (95% for invalid, 96% for neutral and 97% for valid). Overall memory sensitivity in the test phase ($d'=.87$) was significantly greater than zero, $t(13)=6.36$, $p<.001$, Cohen's $d_s =2.40$, hits $=.75$, FA $= .54$. However, memory performance was not affected by Validity, $F< 1$; hit rates were similar for the valid (.77), neutral (.72), and invalid (.76) conditions.

Discussion of Series A

To this point, the results suggest that enhancement of memory due to a mismatch between target expectation and actual target appearance is not easy to observe. However, being aware of the problems of drawing conclusions from null results, and also being confident of the very straightforward prediction outlined in the Introduction, we decided to explore the issue further.

Several factors might have been driving the null effects found in Series A. One of the factors responsible for the null effects in this series of experiments may be the depth of processing of the words during the study phase. It has been shown that deep, semantic processing of stimuli usually leads to better encoding and remembering than shallow, structural processing (i.e., the Levels of processing effect; Craik & Lockhart, 1972). In the prior experiments, relatively deep processing (natural vs. artificial) during the study phase may have made it difficult to observe an effect related to mismatches with expectation. In the following series we addressed this issue by changing the encoding task during the study phase to one with less emphasis on meaning.

Series B. Task and cue type.

Rosner et al. (2015) required participants to name words in the study phase, a shallow encoding task. In contrast, in the experiments in Series A, participants categorized words as “natural” or “artificial”, a deeper encoding task that requires access to semantic representations. These two types of encoding do produce a levels of processing effect, with better memory following semantic categorization than naming (Craik & Lockhart, 1972). It seemed possible that the semantic

categorization task used in the experiments in Series A incidentally improved memory for all of our stimuli to a level at which the expectation manipulation was unable to boost memory any further. In the present series we addressed this issue.

Experiment 4

To equate our procedure with that of Rosner et al. (2015) as much as possible, we conducted a spatial cueing study like that in Series A, but in the same lab, using the same task, and also the very same stimulus set as Rosner et al. (2015).

Details of the procedure. The procedure used for Experiment 4 was identical to that of Experiment 1 except for the following. Instead of categorizing the words, upon presentation participants were required to name aloud the words as quickly as possible. The onsets of vocal responses were detected by a microphone and coded online by the experimenter as “correct” or “incorrect”. Note, however, that most (above 96%) of the words were read correctly and the few coded errors were caused by coughs or other extraneous noises. In addition, instead of Spanish words, a total of 240 high frequency English (borrowed from Rosner et al., 2015) words were used; 120 were presented in both the study and test phases and 120 served as lures for the test phase only. Additionally, in this experiment, as in the study of Rosner et al. (2015), instead of presenting words until response, words were displayed for 1s regardless of participants’ response times. Stimuli were presented and responses were recorded using Psychopy software (Peirce, 2007). Lastly, all of the words included were counterbalanced not only in the study phase, but also between study and test phase across participants.

Participants. The new counterbalancing conditions required sample size multiples of ten. 20 undergraduate students (12 female; mean age: 18.85; s.d.: 1.63) from McMaster University voluntarily participated in the study in exchange for course credits.

Results and discussion. The pattern of results obtained in this experiment corresponded closely to that found in previous experiments. A validity effect of 74ms was observed for RTs, $F(2,38)=26.34$, $p<.001$, $\eta_p^2=.581$, while accuracy was

similar across conditions (99% correct on valid and 98% correct on neutral and invalid trials). Overall recognition sensitivity in the test phase was well above chance (hits= .56, FAs= .23 and $d' = 1.06$) and there were no differences in memory performance for words presented at the valid (.56), neutral (.57) and invalid (.54) locations, $F < 1$. The only difference between these results and those reported previously was an expected decrease in overall hit rates, arguably due to naming rather than categorizing the target words – a successful LOP manipulation. In summary, level of processing, language differences, and other parameters that differed between this and prior experiments do not appear to explain the differences between our null result (no memory difference for the valid and invalid conditions) and that of Rosner et al. (2015; better memory for the incongruent than congruent condition).

Experiment 5

Having set aside the task as responsible for the null results reported above, we explored further the underlying rationale for our prediction. As noted in the Introduction, different ways of orienting attention might have different impacts on the processing of subsequent stimuli (Chica et al., 2014; Hauer & MacLeod, 2006; Markant & Amso, 2014). Indeed, with a paradigm very similar to the one we used, Hauer and MacLeod showed that endogenous and exogenous orienting had very different impacts on later remembering of cued stimuli. The authors reported that endogenous orienting facilitated stimulus encoding and improved memory (Hauer & MacLeod, 2006). Therefore, it seemed possible that the null effects in our experiments result from an enhancement of memory due to endogenous cues that overrides the effect of expectation-mismatching, thus rendering a null cue validity effect on memory. If this is the case, then forcing an automatic shift of attention, by means of an exogenous cue, might reveal an underlying validity effect. In Experiment 5, we addressed this hypothesis by using an exogenous cueing paradigm.

Details of the procedure. There were only two differences between the current and previous experiment. First, on each trial, instead of a centrally presented arrow, a row of three asterisks was presented at the center, to the left of center, or to the right of center of the screen for 200ms. Second, this anticipatory

cue was unpredictable of the location of the following target word, which appeared equally often to the left and right of center. All other details as well as the stimulus set used were the same as in the preceding experiment.

Participants. Although a complete counterbalancing cycle in Experiment 5 required six participants, a sample size of 20 was used to match that in Experiment 4. 20 undergraduate students (18 female; mean age: 20.25; s.d.: 3.93) from McMaster University participated in the study in exchange for course credits.

Results and discussion. Shifting from an endogenous to an exogenous cueing paradigm did not change the previous pattern of results. Once again, we obtained a validity effect on RT, 129ms, $F(2,38)=84.28$, $p<.001$, $\eta_p^2=.816$, no validity effect on accuracy (99% on valid, neutral and invalid trials), better than chance memory sensitivity (hits= .48, FAs= .21 and $d'=.8$, $t(19)=8.69$, $p<.001$, Cohen's $d_s=2.75$), but no recognition difference between words presented at the valid (.46), neutral (.50), and invalid (.47) locations, $F<1$. Note that the overall hit rate decreased in this experiment (.48) relative to Experiment 4 (.55); however, this decrease did not reach statistical significance, $t(20)=2.41$, $p=.055$, Cohen's $d=.40$. This result is consistent with previous literature, which has shown better overall memory performance when endogenous rather than exogenous attentional cueing is involved (Hauer & MacLeod, 2006). However, and importantly, there was no difference observed between the valid and invalid conditions.

Discussion of Series B

Neither the depth of processing of the target words nor the nature of the cueing manipulation could account for the absence of a validity effect obtained so far. Also, these experiments rule out the attribution of the null validity effect to some idiosyncrasy of our Spanish stimulus materials or our population of Spanish students. Indeed, Spanish and English are very different languages with respect to reading. Although Spanish is an almost completely transparent language, the structure of English requires readers to access the proper lexical representation to read words correctly (Bajo, Burton, Burton, & Canas, 1994). Yet, we find null validity effects with both Spanish and English stimulus materials and participants.

Although none of the variables manipulated to this point changed our results, we considered another possibility. Krebs et al. (2015) tested a similar hypothesis with faces as stimuli and they obtained a benefit for encoding on incongruent trials. One of the differences between their procedure and ours is the number of presentations of the stimuli during the study phase. They presented each of their faces up to three times, whereas we have relied on a single presentation approach. It may be that a single presentation of the target words did not allow an enhancement in encoding for invalid trials to be captured by our memory test. In the last experimental series, we explored whether repeated presentation of the target words, and also the valid/invalid status of those words, could result in a cumulative enhancement of the effect.

Series C. Number of presentations.

Here we tested the effect of repeated presentation of words during the study phase. The number of presentations of words varied from 1 to 5. We expected memory performance to improve with increased presentations of the words at study. More important, if encoding enhancement on invalid trials accrues with increased presentations at study, then we ought to find that learning curves across repeated presentation differ for valid and invalid trials.

Experiment 6

This experiment included repetition of study words as a variable to explore whether the learning curves for valid and invalid words differed.

Details of the procedure. The procedure of this experiment was similar to that in Experiment 5 in that we used peripheral cues and a naming task. The only changes were the following. First, we used Spanish words with Spanish participants; a list of 120 high frequency words was selected in accord with LEXESP (Sebastián-Gallés, 2000). Second, and more important, the stimulus list was divided in five sets so that each set of 24 words was presented one, two, three, four or five times in the study phase. As a consequence, the total number of trials was 360. Importantly, trial sequences were generated so that word repetitions were distributed relatively evenly across the entire sequence. That is, if a word was presented, for example, three times, the first presentation always took place

within the first third of the stimulus list, the second presentation took place during the second third of the stimulus list, and the third presentation took place in the final third. This procedure prevented words being clustered together for a given participant in a specific part of the experiment. Both the validity and location of each word were held constant across word repetitions within each participant, but the assignment of the words to each of the repetition conditions, each of the validity conditions, and each location on the screen was counterbalanced across participants. No neutral trials were included in this experiment. The study phase duration increased from approximately 10 minutes in previous experiments to almost 30 minutes in this experiment.

Participants. The repetitions of the words in this experiment required a sample size multiple of 15, and therefore, for Experiments 6 and 7, 30 undergraduate students (26 female; mean age: 22.16; s.d.: 3.83) were recruited from the Universidad de Granada to participate in the study in exchange for course credits.

Results and discussion. We conducted a 5 (Presentations) by 2 (Validity) repeated measures ANOVA on the RTs from the study phase. The main effect of Validity was again highly significant, $F(1,29)=88.53$, $p<.001$, $\eta_p^2 = .75$. The interaction between Presentation and Validity was also significant, $F(4,116)=4.65$, $p=.001$, $\eta_p^2 = .14$, showing that the validity effect, although significant, $F(1,29)=6.09$, $p=.019$, $\eta_p^2 = .17$, was smaller for words presented 5 times (81ms) than for words presented only once (158ms).

Importantly, the test phase results were similar to those found in previous experiments. Memory sensitivity was again significantly different from zero (hits=.79, FAs=.17, $d'=1.92$, $t(29)=17.10$, $p<.001$, Cohen's $d_s = 4.42$), and higher than in previous experiments, as expected given that words were repeated several times in this experiment. To test our predictions, we conducted a 2-way repeated measures ANOVA on hit rates with Presentations (1 to 5) and Validity (valid vs. invalid) as within-subject factors. The repetition manipulation proved to be effective, as there was a significant main effect of repetition, $F(4,116)=10.58$, $p<.001$, $\eta_p^2=.267$; words presented more times were recognized better than words presented fewer times. This result was, of course, not surprising, but it was

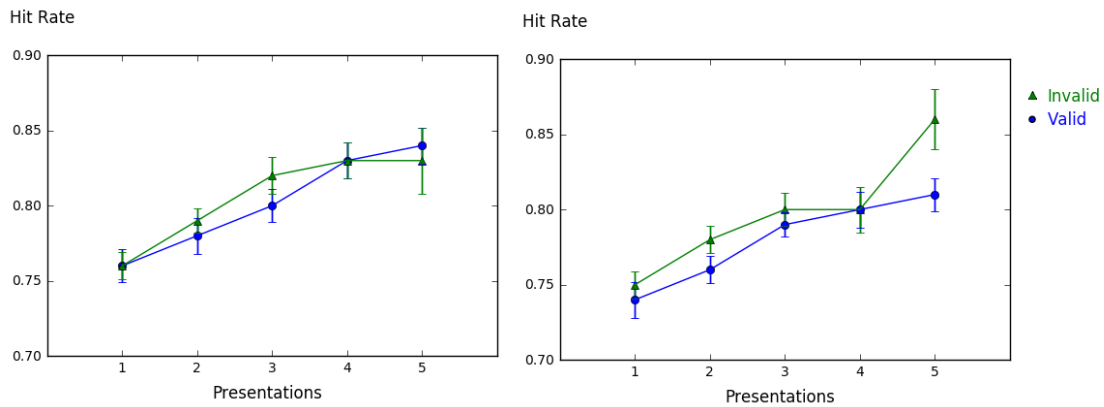


Figure 2. Mean HIT rates for Experiments 6 and 7 across the number of presentations (from 1 to 5). Data from Experiment 6 are plotted in the left panel and data from Experiment 7 in the right panel. Error bars displaying standard error of the variance with between-subjects differences removed (Cousineau & O'Brien, 2014)

crucial to allow us to test whether the repetition manipulation influenced the validity effect on memory. The Validity X Presentations interaction was far from significance (see Figure 2), $F < 1$. The main effect of Validity was also not significant, $F < 1$. Therefore, once again, the breaking of an expectation (in this case a bottom-up expectation produced by an exogenous cue) produced a strong validity effect on RTs for words presented in the study phase, but did not affect memory for those words in the test phase, even when expectation was broken up to five times.

Experiment 7

Although repeating target words several times did improve memory in Experiment 6, this method did not produce a benefit for invalid trials relative to valid trials. Nevertheless, we deemed it possible that participants' recognition judgments may have hinged more on familiarity rather than on recollection, in particular given the length of the study phase. Indeed, other similar effects have been found to be sensitive to this distinction (Krebs et al., 2015). In addition, repeatedly cuing invalid locations might have an impact on the way the word-location compound is encoded. Specifically, the increased number of expectation mismatches might strengthen memory for the location of invalidly cued words.

We aimed to load the task heavily toward recollection of episodic details by testing our participants not only on the identity of the words but also on the location at which the words appeared during the study phase. Although prior

experiments had shown performance in this type of task to be at chance, here we tested the idea that multiple study presentations might lift performance in this source task off floor. It was also an aim in this experiment to ensure that participants' recognition strategy at test was biased toward recollection of source information.

Details of the procedure. The procedure of the present experiment was identical to that of Experiment 6 except for the critical change in the memory test. On each trial, and after having judged each word as “OLD” or “NEW”, participants were asked to report the location (i.e., left or right) in which the word had been presented.

Participants. 30 undergraduate students from the Universidad de Granada volunteered to participate in the study in exchange for course credit. One of them was unable to finish the experimental session so the final sample size was 29 (27 female; mean age: 21.66; s.d.: 3.39).

Results and discussion. As in Experiment 6, we conducted a 5 (Presentation) by 2 (Validity) repeated measures ANOVA on the study phase naming times. The interaction between Presentation and Validity was not significant this time, $F < 1$, but, importantly, both main effects of Presentation and Validity were significant, $F(4,68)=3.16$, $p=.019$, $\eta_p^2 = .157$ and $F(1,17)^2=67.24$, $p<.001$, $\eta_p^2 = .798$, respectively. Invalidly cued words were always responded to more slowly than validly cued words and response times increased with repetitions (from 562ms with 1 presentation up to 638ms with 5 presentations). Memory sensitivity was again significantly different from zero (hits=.77, FAs=.15 and $d'=2.10$, $t(28)=16.94$, $p<.001$, Cohen's $d_s = 5.24$). As in Experiment 6, we submitted the hit rates to a 2-way ANOVA. The main effect of presentation was again significant, $F(4,112)=16$, $p<.001$, $\eta_p^2 = .363$. Neither the main effect of Validity, $F(1,28)=2.18$, $p=.15$, $\eta_p^2 = .072$, nor the interaction between Presentation and Validity, $F < 1$, were significant. Memory for the location of the words was again at chance. Therefore, increasing the emphasis on recollection of episodic (or source) details did not affect the results.

²Due to a microphone malfunction, response times of 11 participants were not recorded.

Discussion of Series C

Repeated presentation of the target words up to five times in the study phase, with repeated words occurring in the same validity condition across the repetitions, did not improve the encoding of invalid words relative to valid words, in spite of producing a general improvement in memory. This result replicates and extends findings from our previous series, and rules out the possibility that a single exposure at study produces a weak boost in memory encoding that would be cumulative and measureable with multiple stimulus presentations.

Overall analyses of all experiments.

Unexpectedly, none of the manipulations introduced across the experiments produced a validity effect on the memory for target words. Indeed, evidence from the analyses we conducted on the seven experiments points to an absence of influence of a mismatch between expected and actual location on memory sensitivity. Nevertheless, being aware that one cannot assume *evidence of absence* from *absence of evidence*, we used a Bayesian approach to reanalyze our data (Wagenmakers, 2007). The Bayesian approach to statistics has two critical advantages over traditional null hypothesis significance testing (NHST). First, the output of the analyses has a more straightforward interpretation than that of a standard p value, which has often been subject to misinterpretation (Dienes, 2011; Fisher, Anderson, Peng, & Leek, 2014). Second, and particularly important with patterns of data such as the one described in this manuscript, Bayesian statistics easily allow for assessment of how much support we have for the null hypothesis. More specifically, most Bayesian analyses output a value often called Bayes Factor (BF_{10}), which represents a ratio between the likelihood of two hypotheses given a set of data (i.e., how strongly a specific piece of evidence supports one hypothesis over the other). In this case, we compared our initial hypothesis (i.e., better memory for invalid trials, H_1) against the standard null hypothesis (i.e., no difference between valid and invalid trials, H_0). BF_{10} ranges from 0 to infinity and its common interpretation is as follows: i) when BF_{10} is greater than 1, the greater its value, the stronger is the evidence for H_1 when compared with H_0 and ii) BF_{10} values ranging from 0 to 1 indicate evidence in favor of H_0 with smaller values indicating stronger evidence for H_0 (Wagenmakers, 2007). The standard

practice is to use two thresholds that define three ranges of values for BF_{10} : values from 0 to .33 can be considered as evidence favoring the absence of an effect, values ranging from .33 up to 3 are indicators of inconclusive evidence (e.g., low statistical power), and values above 3 should be interpreted as considerable evidence of the existence of an effect (i.e., a similar interpretation to that made from a p value smaller than .05 on traditional NHST; Jarosz & Wiley, 2014).

Table 2 summarizes the BFs for the seven experiments reported in this paper. All Bayesian analyses were conducted with JASP software (JASPTEAM, 2016). As one can easily see, most of the experiments offer substantial evidence for a null effect. Take, for instance, Experiment 1. The BF_{10} for the t test on the validity effect is .052. Since this value falls below .33 we must interpret it as reflecting that our data strongly supports H_0 . In contrast, consider Experiment 7. The BF_{10} value for that validity comparison is .728. According to the interpretation commonly accepted, we can conclude that evidence in this particular case is not informative of whether H_1 or H_0 is true.

Moreover, another important feature of Bayes' theorem is that it is relatively easy to combine sets of results to draw a broader picture. In its basic formulation, Bayes' theorem states that the posterior probability (i.e., how much we should change our beliefs over a given phenomenon after having collected the data) can be obtained by multiplying the prior probability (i.e., our beliefs regarding the phenomenon before any evidence is gathered) by the likelihood ratio (i.e., the BF). When no prior beliefs are assumed about the possible outcome of a given experiment, the prior probability is 1 and therefore the posterior probability and the BF are equivalent. This is a conservative but fair assumption to make when

Experiment	Valid	Invalid	NHST	BF_{10}	Interpretation	Posterior Odds ₀₁
1	.62	.58	$F(2,78) = 2.85$	.052	<i>Support for H_0.</i>	19.23
2	.70	.70	$F < 1$	.169	<i>Support for H_0.</i>	113.79
3	.77	.76	$F < 1$	.447	<i>Inconclusive evidence.</i>	254.57
4	.56	.54	$F < 1$	.152	<i>Support for H_0.</i>	1674.78
5	.46	.47	$F < 1$	.414	<i>Inconclusive evidence</i>	4045.37
6	.79	.79	$F < 1$	.196	<i>Support for H_0.</i>	20639.65
7	.79	.77	$F(1,28) = 2.18$	.728	<i>Inconclusive evidence</i>	28351.17

Table 2. Summary of the analyses from the analyses of the HIT rates in the 7 experiments. Both NHST and Bayesian analyses are reported. Interpretations are based on Jarosz & Wiley (2014). Note that, although evidence from some of the experiments is tagged as inconclusive, the continuous nature of the BF and the combined analyses clearly supports the absence of an effect.

considering either an isolated experiment or the first one in a series of experiments.

However, prior probability can be updated to incorporate results of a new experiment that explores the same phenomenon (Ly, Etz, Marsman, & Wagenmakers, 2017); that is, we can use what we have learnt from Experiment 1 as a prior belief for Experiment 2. More concretely, the BF_{10} for Experiment 1 was .052 meaning that, if we would assume an equal prior probability for H_0 and H_1 , H_1 was .052 times more likely than H_0 , or conversely, H_0 was 19.23 times more likely than H_1 . For Experiment 2, the evidence gathered rendered a BF_{10} of .169; however, we now know that H_0 is more likely than H_1 . When the obtained BF_{10} is multiplied by our updated beliefs from Experiment 1, the likelihood of H_0 being true grows to 113.79 times larger than the likelihood of H_1 . Subsequent steps can be taken to incorporate results from the rest of the experiments (see Table 2). As can be seen in Figure 3, the gathered evidence increases support for the null hypothesis exponentially. It is therefore evident that the data reported here clearly favor the absence of an effect.

In conclusion, with the current set up, namely, an anticipatory cue in the study phase, a 10 minute distracter interval and a recognition memory test, one can strongly conclude that there are no differences in memory sensitivity for valid and invalid trials (Hauer & MacLeod, 2006).

General discussion.

The main objective of this study was to assess whether memory encoding is enhanced as a consequence of a mismatch between the expected location (either as straightforward top-down prediction or as bottom-up anticipation from cue to target) of a stimulus and its actual location. Expectation mismatch in our study is defined broadly to refer to any form of prediction error; that is, any divergence between how the system was set up to encode and what it actually encounters. This definition of prediction error is domain general and ought to be applicable across a range of very different paradigms that would include manipulations of proportion congruity, oddball paradigms, as well as the spatial cueing procedures. To explore this idea, we used a spatial validity paradigm in which we presented a

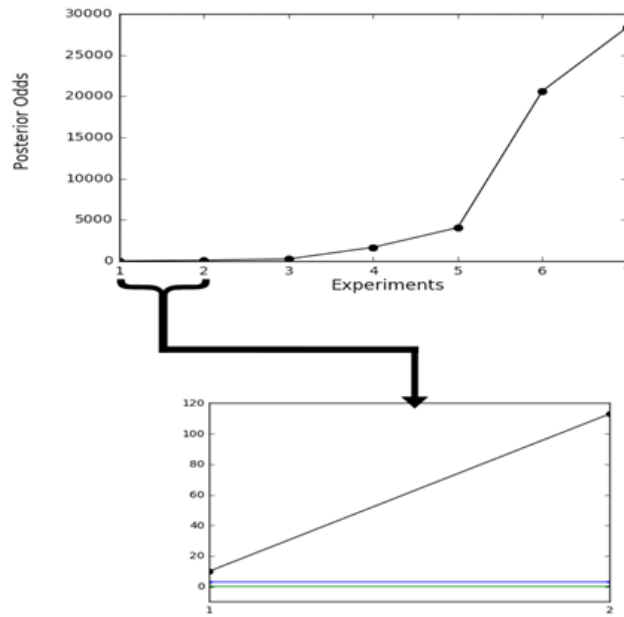


Figure 3. Graphic representation of the evolution of the posterior odds across the experimental series (upper panel) and a zoom in depiction of the analyses of Experiments 1 and 2 for illustration purposes. Colored lines reflect the usually accepted likelihood ratio decision boundaries: 3 for accepting the null hypothesis (blue line) and .3 for substantial evidence in favor of the alternative (green line). Note that the likelihood of the null hypothesis being true has been plotted here against the likelihood of the alternative hypothesis being true rather than the opposite; it should be interpreted then as higher values reflect stronger support for the null hypothesis.

word peripherally preceded by a cue that validly or invalidly signaled the location of the target word; by doing so, we were able to generate an expectation that was completely independent of the nature of the tested materials. Across seven different experiments we explored the nature of the cue and its orienting properties, the task participants had to accomplish once the word had appeared, the number of repetitions of the words during the study phase, and many other variables.

The results of the seven experiments converged on the same result: a mere spatial expectation mismatch does not trigger an enhancement in recognition memory. This surprising finding is not well accounted for by predictive coding or conflict-driven learning theories (Henson & Gagnepain, 2010; Krebs et al., 2015; Verguts & Notebaert, 2009). Likewise, accounts of attention that hinge on

resource allocation would also have problems explaining why we found no encoding benefits for items that were correctly predicted and attended when compared with those in which attention was initially misdirected and then had to be re-focused. Across the set of experiments, a great deal of evidence was collected that explored many nuances of the orienting paradigm; none of those many variations of the basic orienting method changed the results in a meaningful way, in spite of all of them producing the expected spatial attentional orienting effects. Moreover, in addition to the independent results from each experiment revealing no difference between memory for validly and invalidly cued words, the combined analysis with updated Bayesian a priori probabilities across all experiments offered a very clear finding – the results here undeniably favor the absence of an effect of validity on memory.

Van Kesteren et al. (2012) describe a framework for how encoding of objects might be impacted positively both by matches with schemas and by novelty. Although the paradigm described in Van Kesteren et al. (2012) is very different from the one used in our research, both share the idea that encoding might be impacted by a mismatch between the input the system expects and that which it actually encounters. Many different cognitive processes may precede and follow this mismatch in processing. For instance, when using visual scenes to establish a schema, the system is tuned to receive a visual representation of the upcoming stimulus and, when it eventually appears, this particular set of the system needs to be modified and updated to account for the new stimulus. Likewise, once the new stimulus has been processed, a readjustment of the beliefs about the general structure of stimulus presentation is required; some rumination about what has just happened most surely also takes place. Although any particular experimental paradigms will rely more heavily on some processes than others, all such experimental paradigms share the commonality that the stimulus the system was prepared for does not match the stimulus that actually occurs. This is the broad notion of expectation-mismatch that we refer to here, rather than the narrower notion associated with the conscious experience of an unfulfilled belief.

Previous studies that have found memory to be affected by some form of

expectation mismatch or conflict may have differed in some critical way from the method used in our study. Namely, those studies may have included not only an expectation mismatch or cognitive conflict but also some associated increase in processing difficulty. For instance, in the study of Krebs et al. (2015) participants were required to perform a gender categorization task on face-word stroop-like stimuli. Responding to this sort of stimulus entails exerting some form of cognitive control to solve the incompatibility that arises when two incompatible representations are active at the same time. This putative up-regulation in cognitive control may make this method a poor one for measuring the isolated contribution of expectation mismatch to memory encoding. Likewise, stimuli in the study of Rosner et al. (2015) were constructed by combining either two instances of the same word (i.e., congruent pairs) or two different words (i.e., incongruent pairs). Responding to incongruent words may also involve an up-regulation in cognitive control, or may involve other processes that are distinct in nature from those involved in responding to congruent words (e.g., increased elaboration; Craik & Lockhart, 1972). Once again, the important point here is that this method also may be a poor one for measuring the isolated effect of expectation mismatch – the results of our seven experiments demonstrate that expectation mismatch on its own does not modulate recognition.

Of course, the above comments are not meant to imply that the memory encoding effects observed in the above studies are uninteresting. Differential elaboration of encoding in response to conflict implies an interesting link between transient shifts in cognitive control (Botvinick et al., 2001) and memory encoding. Moreover, further research on this topic may help to add some specificity to the *desirable difficulty principle*. Bjork and Bjork (1992) have noted a range of well studied cognitive phenomena that appear to fit the notion that processing difficulty enhances retention. What is critically needed for this principle to be of practical use in guiding new research is an accepted and non-circular definition of the “types” of difficulty that enhance retention. As illustrated in the present study, if difficulty is defined simply as measurably worse performance in one condition than another in a study phase, then it is quite clear that processing difficulty does not always enhance memory encoding. However, additional research on links between conflict-induced control adaptations and memory encoding may point to

a more restricted and process-specific definition of difficulty that does reliably predict when memory encoding will be enhanced.

In any case, it seems reasonable to conclude that expectation mismatches in the study phase of the present experiments were very likely produced by mechanisms that are qualitatively different from the mechanisms that produced processing difficulty effects on memory in other studies (e.g., Krebs et al., 2015; Rosner et al., 2015). Valid and invalid trials in our study differ specifically and solely in terms of whether an expectation generated by the cue is fulfilled or broken by a following target. It is this isolation of the influence of expectation mismatches from other more complex forms of cognitive control adjustment that we view to be a merit of the present study. The results reported here make it clear that the readjustment of the system in response to a target that mismatches the prediction set up in response to a prior spatial cue does not lead to enhanced memory encoding of that target.

Conclusions and future directions.

We find the pattern of results uncovered by this line of research interesting for both empirical and theoretical reasons. From an empirical perspective, several recent studies have demonstrated ways in which attentional manipulations at study impact memory significantly at test. Across these studies, memory performance has been shown to be sensitive to selective attention congruency (Krebs et al., 2015; Rosner, D'Angelo, et al., 2015), perceptual encoding difficulty (Rosner, Davis, et al., 2015), and to transient shifts in temporal attention (Swallow & Jiang, 2010a). A quick look at the literature gives one the impression that it is a fairly simple exercise to impact memory encoding with attentional manipulations. Furthermore, there is a relatively straightforward mapping between several of those manipulations, the cue validity method used in the present study, and several cognitive and neural models (Henson & Gagnepain, 2010; Verguts & Notebaert, 2008) that would lead us to predict superior memory performance for invalid trials in our study. Clearly, this prediction was not supported in a straightforward manner by the results of our experiments. As such, our results point to a broad empirical issue worthy of further study. From a theoretical perspective, models of prediction error-based learning need to more exhaustively

define what counts as a prediction and what counts as a prediction error. It appears from the present study that not every anticipatory cue will produce prediction error that up-regulates memory encoding in spite of affecting performance considerably. Does the task relevance of the stimulus feature associated with the anticipatory cue matter? Does the processing level (e.g., semantic versus non-semantic) of the prediction matter? Does increasing the number of instances of a specific prediction error impact memory encoding (Henson & Gagnepain, 2010; van Kesteren et al., 2012)? At the same time, accounts of memory performance that focus on encoding difficulty (e.g., the desirable difficulty principle) must address how it is that two conditions, valid and invalid, with clearly different impacts on response outcome, produce no difference whatsoever in recognition memory – a clear definition of *difficulty* itself is needed (Bjork & Bjork, 1992; de Winstanley & Bjork, 1997).

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CHAPTER IV: SCHEMA-BASED PREDICTIONS

Do semantic mismatches in ecological scenarios lead to
enhance encoding?

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A cow on the prairie vs. a cow on the street: long-term consequences of semantic conflict on episodic encoding

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Abstract:

Long-term effects of cognitive conflict on performance are not as well understood as immediate effects. We used a change detection task to explore long-term consequences of cognitive conflict by manipulating the congruity between a changing object and a background scene. According to conflict-based accounts of memory formation, incongruent trials (e.g., a cow on the street), in spite of hindering immediate performance, should promote stronger encoding than congruent trials (e.g., a cow on a prairie). Surprisingly, across three experiments we show that semantic incongruity actually impairs remembering of the information presented during scene processing. This set of results is incompatible with the frequently accepted hypothesis of conflict-triggered learning. Rather, we discuss the present data and other studies previously reported in the literature in the light of two much older hypotheses of memory formation: the desirable difficulty and the levels of processing principles.

Introduction.

Processing associated with conflict has been shown to have immediate as well as distant consequences on behavior. The former are usually assessed through widely studied interference effects, such as Stroop (Stroop, 1935), flanker (Eriksen & Eriksen, 1974) or Simon (Simon & Small, 1969) and through sequential effects, such as the *Sequential Congruency effect* (Gratton, Coles, & Donchin, 1992) or post-error slowing (Laming, 1968). On the other hand, distant consequences on future behavior are usually assessed through later memory for the stimuli that produced the conflict (Chiu & Egner, 2014; Krebs et al., 2015; Rosner, D'Angelo, et al., 2015). These distant consequences can be measured via a memory test either right after the offset of the entire stimulus set or including some form of delay between the presentation and the test. Although in the literature these two types of memory tests are often referred to as immediate and delayed tests, here we use the term *immediate effects* for the differences that can be measured *online* (i.e., while the stimulus is displayed) and *long-term effects* for *offline* measures (i.e., once the stimulus has disappeared). One cognitive model that can account for both, immediate and long-term effects, is Verguts and Notebaert's Adaptation by Binding proposal (Verguts & Notebaert, 2009). The model assumes that detection of cognitive conflict serves as a triggering signal for learning mechanisms; conflict detection leads to the release of norepinephrine throughout the brain, thus facilitating the adjustment of previously established associations and the formation of new ones (Verguts & Notebaert, 2008, 2009).

Although short term effects of conflict resolution have been widely explored (Crump, Gong, & Milliken, 2006; Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Egner, 2007; Egner, Ely, & Grinband, 2010; Gratton et al., 1992; Torres-Quesada, Funes, & Lupiáñez, 2013; Torres-Quesada, Milliken, Lupiáñez, & Funes, 2013), it has only been recently that long term consequences have been the object of study (Chiu & Egner, 2014; Krebs et al., 2015; Rosner, D'Angelo, et al., 2015). For example, Krebs and colleagues (2013) used a face-word Stroop task in which participants were asked to judge the gender of a face while ignoring a superimposed word. Memory for the faces was later assessed as a function of whether the distracter word was congruent, neutral, or incongruent with the gender of the face. Their results showed enhanced memory for faces presented on incongruent trials, where conflict

occurred (Krebs et al., 2013). Similar results were obtained by Rosner and colleagues using a naming task. They asked participants to read aloud words that were interleaved with either a second presentation of the same word (congruent trial) or a different word (incongruent trial). When a surprise recognition test was administered, participants showed better memory for target words presented on incongruent trials (Rosner et al., 2014).

Both sets of results can easily be accounted for by the Adaptation by Binding model. Detecting the co-activation of two incompatible representations in conflicting trials would have increased the attention devoted to relevant information and thus enhanced the encoding of the target stimuli; that enhanced encoding would then result in better memory for conflicting stimuli at the later test. The most relevant aspect of these two studies is that they found support for the idea that cognitive conflict, in spite of hindering current performance, can in fact have beneficial long-term effects by means of eliciting memory formation.

Nevertheless, the two studies discussed above focused on relatively low-level conflicts in tasks that did not require participants to generate a mental model of the event to solve the task: in Krebs et al. (2013) the conflict arose at the response level when two competing representations were active; in Rosner et al. (2014) only two stimuli were presented and conflict could be solved by simple perceptual analysis of target features against those of the distractor (on the basis of color). In addition, in the tasks used in both studies responses to conflicting trials were always slower than those to non-conflicting trials. Hence, stimuli presented on conflicting conditions may have been actively processed for a longer period of time, which may have contributed to improve their encoding.

In the following experiments we aimed to address these issues by exploring whether this conflict-driven encoding enhancement also occurs when conflict arises at a higher level (i.e., semantic congruency between elements of a scene) and when exposure times are controlled for. Also, we used a more ecological task in which participants were presented with naturalistic images that could more easily map onto real-life situations. Importantly, it has been shown that natural scene viewing has some idiosyncratic features that can interact with attentional processes (Peelen & Kastner, 2014).

The present experiment

In the present study we used a change detection (CD) task. In this particular paradigm, when manipulating the semantic congruity between the to-be-detected target object and the scene context, change detection has been shown to be faster and more accurate for incongruent changes (e.g., a cow in a street) than for congruent changes (e.g., a cow in a field) (Hollingworth & Henderson, 2000; LaPointe et al., 2013). The fact that a larger proportion of congruent changes go unnoticed and that incongruent changes are quickly detected implies that semantic conflict may actually attract attention.

In addition to the attentional consequences of semantic congruity, the CD task has two other interesting features for our purpose. First, as opposed to visual search tasks, on CD tasks incongruent trials are reliably responded to faster than are congruent trials (LaPointe & Milliken, 2016), which means that processing time is reduced for the trials that are expected to produce better memory (i.e., the conflicting ones); this is a critical factor to control for in memory studies since longer processing time has been shown to improve the encoding of information into memory (Tversky & Sherman, 1975; Craik & Tulving, 1975). Second, the task structure allows for a wide variety of naturalistic stimuli, which increases the ecological validity of results. Furthermore, the types of naturalistic scenes used in CD tasks make it possible to assess memory for the primary source of conflict (i.e., the changing object) but also for surrounding information (i.e., the background scene context). The representation of the target object and the representation of the background scene context are presumably activated and maintained in working memory at the same time (Rensink, 1997). These representations can create either a coherent mental model of a scene (congruent trials) or an incoherent model (incongruent trials). Incoherent mental models may then be subject to detection by the conflict monitoring system (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Following Verguts and Notebaert's model, some kind of binding operation may be triggered when incongruity is detected, leading to up-regulated associative learning. However, the precise nature of this up-regulated learning is unclear. It may be the target object, the background scene context, or the pairing of the target object with a particular scene context that is targeted for up-regulated associative learning. Although the *Adaptation by Binding* model does not specifically

state that strengthening of these bindings should lead to better episodic encoding of the event, we think it is a fair assumption to make in the light of previous work showing similar results (Krebs et al., 2013; Rosner et al., 2014).

For all the reasons described above, the CD task seems an apt tool to test for the long-term encoding consequences of semantic conflict in a naturalistic environment. Therefore, we presented participants with a CD task similar to that used by LaPointe and colleagues (2013) and, after a short delay, we assessed memory for the different types of information using a surprise recognition task. Specifically, we tested the target-context pairs (Experiment 1), as well as the target and its background in isolation (Experiment 2). Finally, we conducted a third experiment to replicate the findings uncovered in the first two, as well as to test for guessing behavior in the memory test.

Experiment 1

The aim of Experiment 1 was to assess whether memory of target-context associations depend on their mutual congruency. To address that goal, participants first completed a study phase consisting of a CD task. On each trial in the CD task, participants were to detect a changing object between two otherwise exact images. Participants were then confronted with a surprise recognition test. We hypothesized that when simultaneously activated representations conflict they are affected by Hebbian learning and bound together (Verguts & Notebaert, 2009). Therefore, we expected to find better memory for incongruent than for congruent object-scene pairs.

Materials and methods

Participants. Thirty undergraduate students (6 male; mean age: 21 years old) from the University of Granada participated in the study. All participants in this and the other experiments reported here signed a consent form approved by the local ethics committee.

Design and procedure. In each experimental session participants completed three different phases. The study phase, which consisted of a change detection task, was followed by a distracter task for ten minutes and, finally, a surprise recognition memory test.

Study phase: Change detection task. Stimuli were selected from the original data set of LaPointe and colleagues (2013)³. The images were constructed by taking a picture of a naturalistic scene and then digitally adding an object that was either consistent or inconsistent with the image context. Perceptual salience of the changing object, assessed with the SUN algorithm (L. Zhang, Tong, Marks, Shan, & Cottrell, 2008a), was held constant across conditions for each participant individually as well as for the whole sample of participants.

On each trial, the background-only and the background-plus-target images were presented in a rapidly alternating sequence. Between the images, a blank screen was introduced to generate the standard flickering appearance (Rensink et al., 1997). The scene images as well as the blank screens were all displayed for 250ms each (Figure 1a). One cycle of the entire loop, from the presentation of the first image to the final blank screen, lasted one second. If participants did not respond within nineteen cycles of the sequence, that trial was coded as a *Miss* and the next trial was presented.

Our procedure and that used by LaPointe et al. (2013) differed in the following details. In their procedure participants saw each target twice: once embedded in a congruent background and once in an incongruent background. In contrast, we presented each target just once in order to be able to later assess memory for the target objects as a function of whether the target had been encountered in a congruent or an incongruent condition. Thus, target-background congruity was counterbalanced between participants so that across the entire sample each target was seen in both a congruent and an incongruent scene.

Another minor difference between the method used by LaPointe et al. (2013) and that used here concerns the specific task instructions. Since target-context incongruity appears to have its primary effect on target detection processes (LaPointe et al., 2013), we encouraged participants to respond even if they had not identified the changing object. Specifically, they were given the following instruction: ‘Press the SPACE BAR as soon as you realize that there is something different from one picture to the other

³From the original stimulus set, images displaying the exact same background scene (regardless of the target object) were removed and not used in this experiment to avoid recognition problems caused by image similarity.

EVEN if you DO NOT know WHAT it is'. When participants pressed the space bar the image was removed from the screen. Participants were then asked to use a few words to identify the changing object, in cases in which they knew what the object was, or to report its location on the screen, in cases in which they did not.

Trials were then coded offline regarding whether the changing object had been correctly *identified* or just correctly *located*. This coding allowed us to separate two sets of trials: those in which a change was detected but no identification was possible (from now on, *located object* trials) and those in which the target objects were correctly detected and then accurately identified (from now on, *identified object* trials).

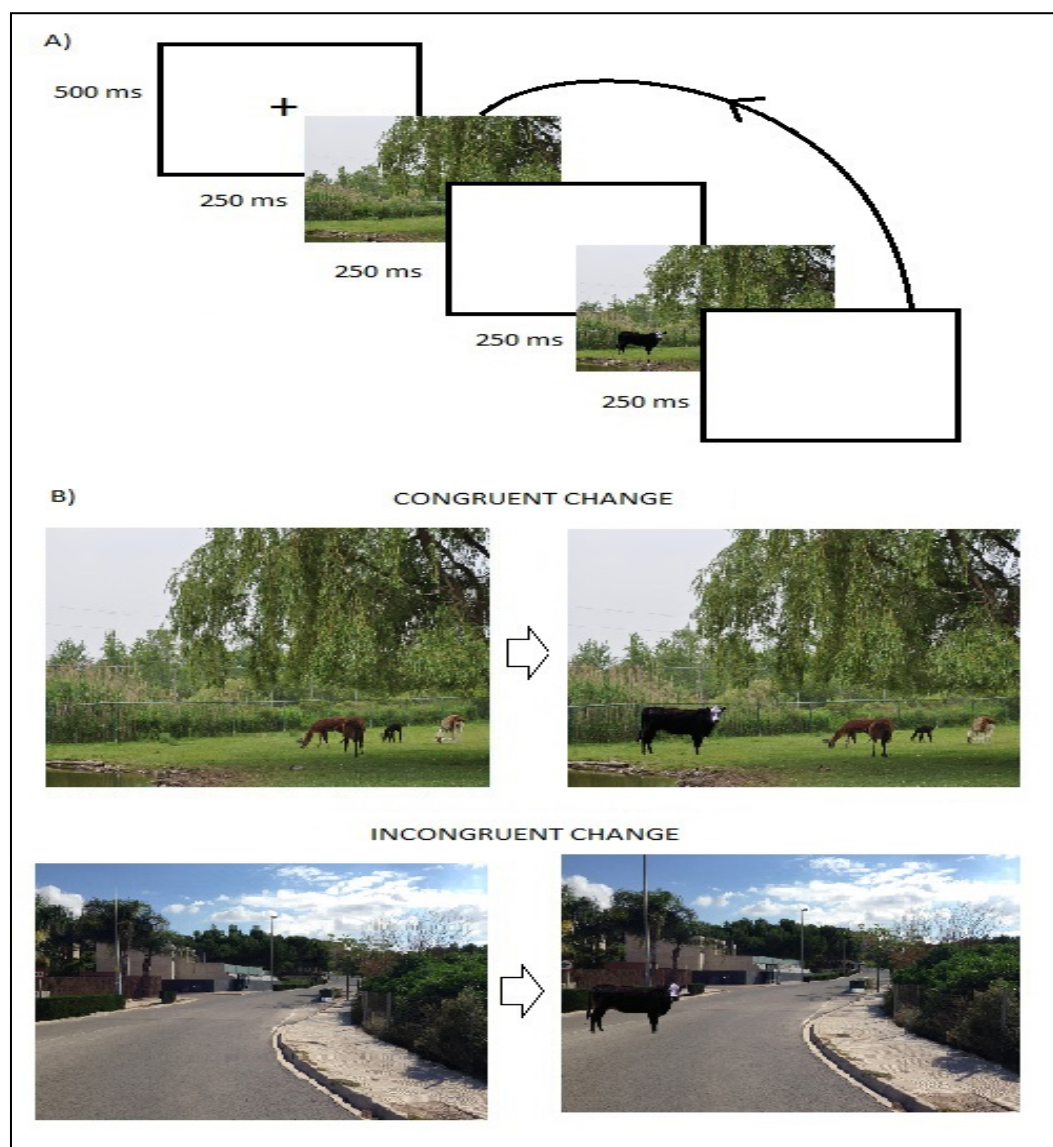


Figure 1. A) Procedure for the study phase of the three experiments reported here. B) Example of two pairs of images used in the study phase displaying a congruent change (upper panel) and an incongruent change (bottom panel).

A total of 60 trials were administered to each participant. On half of those trials the target object was consistent with the background scene (congruent trials; e.g., a boat on a river), whereas on the other half of trials the target object appeared embedded in an inappropriate background scene (incongruent trials; e.g., a boat on a road). See Figure 1b for an example of the images used.

Distracter task. Following the CD task (the study phase) and prior to the test phase, participants completed a visual working memory task (Luck & Vogel, 1997) of about 10 minutes in duration. In this task, participants compared two consecutive presentations of similar rectangle arrays. For each pair of arrays, participants were asked to judge the second one as being SAME or DIFFERENT compared to the first one.

Test phase. On each trial of the memory test participants were presented with a scene that they had to judge as OLD (seen in the study phase) or NEW (never seen before). Scenes consisted of combinations of targets and backgrounds. OLD scenes were just a reinstatement of the background-plus-target images presented in the study phase. NEW scenes were constructed by embedding old target objects in never seen before contexts. Each target was seen twice, such that in half of the trials the object was embedded in the same context as in the study phase (e.g., a cow in a congruent context), and in the other half of trials the target was presented with a new background (e.g., a cow in an incongruent context). Across the whole sample, all target objects were seen in all conditions (OLD-congruent; OLD-incongruent; NEW-congruent; NEW-incongruent)⁴.

Responses were registered on a QWERTY keyboard and reminders were placed on the screen on every trial indicating the key-response mappings.

Results

Change detection task. A t-test was conducted on mean response times. As

⁴Participants were instructed in the remember/know (RK) distinction (Rajaram, 1993) and, for OLD responses, they were asked to report whether their response was based on a feeling of remembering or on a feeling of knowing. Nevertheless, posterior analyses revealed that this distinction did not affect in any way the pattern of results and thus it will not be reported for this experiment, nor for any other experiment in the present study.

expected from previous studies, the effect of congruency was significant with responses to congruent trials being slower (3289ms) than responses to incongruent trials (2680ms), $t(29)= 5.23$, $p<.05$, $d=1.22$ (Table 1). This effect of poorer detection performance was also found in the percentage of missed trials: 12% for congruent and 4% for incongruent trials, $t(29)=5.16$, $p<.05$, $d=1.92$.

Similar to the results presented by LaPointe and colleagues (2013), for the targets that were detected, those presented in a congruent context were identified more accurately (.74) than those presented in an incongruent context (.63), $t(29)=6.96$, $p<.05$, $d=2.58$.

Binding recognition. As an overall index of discriminability, d' was computed using hits (HITs = .82) and false alarms (FAs = .21). Overall d' (1.87) was significantly greater than zero, $t(29)=19.66$, $p<.05$. More interestingly, separate d' s were computed for both congruent and incongruent trials. Contrary to our hypothesis, memory for congruent trials (2.05) was numerically better than memory for incongruent trials (1.89), although a t -test revealed this difference not to be significant, $t(29)=1.37$, $p=.20$, $d=.51$.

Discussion

A conflict-based account for learning predicts that memory should be strengthened in conflicting situations (Verguts & Notebaert, 2009). The results of Experiment 1 clearly do not support this prediction, as the observed non-significant tendency was opposite to this hypothesis. Nevertheless, the recognition scores assessed

Experiments	Study phase				Memory test					
	Detection		Identification		Binding recognition		Target recognition		Context recognition	
	C	I	C	I	C	I	C	I	C	I
1	3289 (.12)	2680 (.04)	.74	.63	.82	.79	--	--	--	--
2	3072 (.14)	2407 (.06)	.78	.70	--	--	.72	.65	.60	.59
3	4018 (.25)	3691 (.04)	.82	.71	--	--	.85	.74	.61	.60

Table 1. Summary of the results from the three experiments reported here. C stands for Congruent and I for Incongruent. Mean change detection times are measured in ms, with proportion of misses presented in parentheses. Change detection identification is measured as the proportion of trials correctly identified. The recognition scores are HIT rates in the memory test.

in Experiment 1 could be affected by the retrieval of memories for two different types of information: namely, memory for the target object and memory for the background image. These two sources of memory could be competing with each other or interacting in some way that would render no difference in our memory test. Therefore, before discussing further the unexpected result observed in Experiment 1, we carried out Experiment 2 to further investigate the effect of scene-object semantic congruency at encoding on later memory for the object and for the scene.

Experiment 2

The recognition test in Experiment 1 could have measured either or both of two independent types of memory: memory for the target objects and memory for the background images. Also, it is worth noting that each target was presented twice in the memory test, once with a congruent context and once with an incongruent context; however, each background image was presented only once. This particular task set-up could have biased participants to ignore the target objects since remembering the background images was sufficient to complete the task. In other words, the combination of backgrounds and target objects for Experiment 1 might have encouraged participants to neglect their memories for the target objects, thus making use only of their memories for the backgrounds to solve the task. Another possibility is that semantic conflict could affect memory for target objects and background scenes in opposite directions, thus rendering no difference in overall performance. To address these issues in Experiment 2, during the memory test we separated the stimuli into target only and background context only images, and tested memory for target and background context in separate blocks.

Materials and methods

Participants. Twenty-eight undergraduate students (6 male; mean age: 22 years old) from the University of Granada volunteered to participate in the study in exchange for partial course credit.

Design and procedure. Both the study phase and the distracter task were identical to those in Experiment 1. At test, we presented participants with two independent blocks: a target recognition block followed by a context recognition block.

Test phase I: Target recognition. On each trial, an isolated object was displayed in the center of the screen. All 60 target objects from the study phase were presented along with another 60 objects never seen before. Participants were asked to judge whether the object was OLD (previously seen object) or NEW (never seen before object). Also as in Experiment 1, reminders of the key-response mappings were present on this block.

Test phase II: Context recognition. Following the target recognition block, we presented participants with the background images shown in the study phase and 60 never seen before images. Critically, displayed images did not include the corresponding target object to avoid responses based on recognition of the target. As in the previous block, participants had to judge whether the image was OLD or NEW. Reminders of the key-response mappings were also present on this block.

Results

Change detection task. As in Experiment 1, a t-test was conducted on response times to assess the significance of the difference between congruent and incongruent trials. Responses to congruent trials were slower (3072ms) than responses to incongruent trials (2407ms), $t(27)=4.73$, $p<.05$, $d=1.82$. The percentage of missed trials was also larger for congruent (14%) than incongruent (6%) trials, $t(27)=6.08$, $p<.05$, $d=2.34$, whereas identification was more accurate for congruent (.78) than for incongruent (.70) trials, $t(27)=3.64$, $p<.05$, $d=1.40$. All told, the results closely replicate those from Experiment 1.

Target recognition. Overall HIT and FA rates were assessed as an indicator of memory performance. Both reached appropriate levels (.62 and .23, respectively). The mean d' value of 1.17 was significantly different than zero, $t(27)=10.93$, $p<.05$, $d=4.20$. As it was not possible to measure independent FA rates for congruent and incongruent trials, from now on, we use HIT rates as recognition scores.

A single t-test was conducted on recognition scores. Although the difference between conditions was significant, $t(27)=2.51$, $p<.05$, $d=.96$, the direction of the difference was opposite to the original prediction – memory was better for congruent (.72) than for incongruent trials (.65).

Better memory for congruent trials in the present study could be driven by the longer total exposure time for congruent than for incongruent trials (see also Krebs et al., 2013; Rosner et al., 2014). To address this issue, we computed a Pearson correlation across participants between the congruity effect in RT and recognition scores (see Krebs et al., 2013 for a similar procedure). This correlation did not reach significance, $r=-.006$, $t<1$, suggesting that longer “time-on-task” for congruent trials does not underlie the superior recognition performance for congruent trials.

Finally, to explore this result further, we analyzed recognition scores as a function of whether or not participants successfully identified the target. We conducted a repeated measures ANOVA on recognition scores with Congruity (Congruent vs. Incongruent) and Identification (Identified vs. Located) as within-participants factors. Although the interaction was not significant, $F(1, 26)=1.01$, $p=.33$, $\eta_p^2=.04$, both main effects of Identification and Congruity were close to significance $F(1,26)=3.05$, $p=.09$, $\eta_p^2=.11$ and $F(1,26)=4.11$, $p=.05$, $\eta_p^2=.14$, respectively. Not surprisingly, and in support of the two process view of CD performance (LaPointe et al., 2013), identified items were remembered better (.71) than located items (.63), $t(27)=2.37$, $p<.05$, $d=.91$ (Figure2). This result is consistent with the view that identifying an item allows deeper processing and, consequently, better encoding of said item (Craik & Lockhart, 1972).

Context recognition. Overall HIT and FA rates as well as d' again demonstrated above

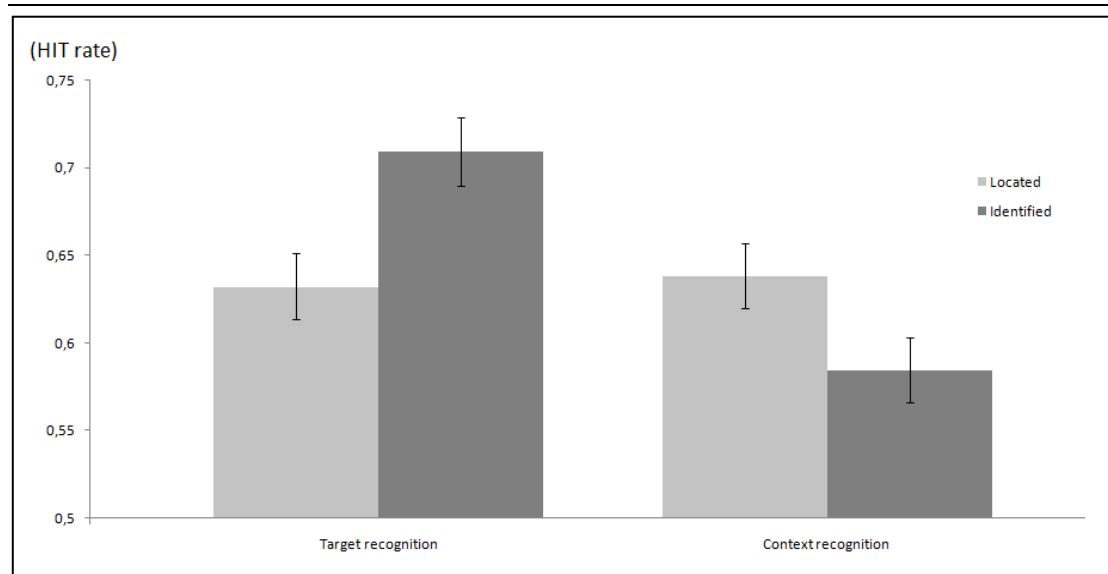


Figure 2. Recognition scores as a function of identification in Experiment 2. Error bars displaying standard error of the variance with between-subjects differences removed (Cousineau & O’Brien, 2014).

chance level performance (.60, .31 and .81, respectively), $t(27)= 9.20$, $p < .05$, $d=3.54$. In the analysis of HIT rates, there was no effect of Congruity on the recognition of context images ($t < 1$). To address the issue of ‘time-on-task’ we computed a Pearson correlation across participants between the congruity effect in RT and recognition scores. Again, the correlation was not significant, $t < 1$.

To explore the impact of the target identification process on context recognition we assessed memory for the background image as a function of whether the target that was originally embedded in that context was correctly identified or not. Interestingly, we found a close to significant trend in the opposite direction to the one found for target recognition. Memory was poorer for those backgrounds in which participants were able to identify the target (.58) than for background images in which the target object was only located (.63), $t(27)=1.89$, $p=.07$, $d=.73$ (Figure2). This result is compatible with the intuitive explanation that identifying a target object actually hurts the encoding of the corresponding background image by diverting attentional resources from its encoding (Kahneman, 1973). According to this view, when the target was correctly identified, no further post-processing of the background scene was done and thus later remembering was poor, whereas when identification of the item was not possible, participants might have engaged in additional processing of the image.

Discussion

The purpose of Experiment 2 was to test whether the mismatch between expected and actual objects found in a scene enhances memory selectively for target objects or for context images. To that end we presented participants with a CD task in which we manipulated the congruity between the to-be-detected object and the background scene and then tested memory for both in separate blocks. Contrary to the predictions derived from accounts focused on conflict as a triggering signal for learning, our results show that conflict between the target and background itself does not up-regulate encoding of targets. In fact, the results were in direct opposition to this prediction: better memory was found for trials in which no conflict was present (i.e., congruent trials). In addition, this enhancement in memory was evident for the target objects but not for the background images.

The better memory for congruent targets was indeed a very surprising finding in

part because it contradicted the intuitive idea that an unpredicted event (such as a cow in the middle of the street) would be better stored in memory than predicted event (such as a car in the middle of the street). It was also a surprising finding because it is in clear opposition to models in which conflict, novelty, or prediction failure, serves as a trigger for learning (Henson & Gagnepain, 2010; Rescorla & Wagner, 1972; Verguts & Notebaert, 2009), and to results of empirical studies that have found beneficial effects of conflict on memory (Krebs et al., 2013; Rosner et al., 2014). The pattern of results observed here implies that the ubiquitous assumption that learning is initiated by surprise requires additional study.

However, prior to accepting the finding of Experiment 2 at face value, an alternative account for the better memory for congruent items had to be addressed. Specifically, as recognition for background images was quite good, we were concerned that retrieval of these memories for the background images might be used by participants to *guess* whether a given target object was presented or not in the study phase. For instance, if participants remembered having seen the picture of a prairie it is more likely that, at test, they would judge as OLD a cow rather than a toaster. Thus, this kind of guessing could result in better (false) memory scores selective for objects that are congruent with presented backgrounds. We addressed this issue in Experiment 3.

Experiment 3

It is possible that memories for the background images could have biased participants' responses about the presence or absence of certain targets in the study phase of Experiment 2. To control for this potential confound we replicated the previous experiment but included a set of trials in which no change was presented in the study phase. In other words, some trials in the CD task presented the background image followed by the exact background image repeatedly rather than alternating a background image with a background image plus target object. Adding some trials in which there was no target object in the flickering sequence allowed us to compute a false alarm rate for objects never presented at study for each participant, but that were either congruent or incongruent with background contexts that were presented at study. If biased guessing was responsible for the results in Experiment 2, we ought to observe a larger false alarm rate for congruent trials.

Materials and methods

Participants. Twenty-three students from the University of Granada (1 male; mean age: 20 years old) volunteered to participate in the study in exchange for partial course credit.

Design and procedure. The study phase was identical to those described for previous experiments except for the following: in half of the trials no changing object was included in the flickering sequence. Thus, for those trials, the correct response was to withhold response throughout the display sequence. Half of these catch trials were constructed from items that were congruent in the previous experiments and the other half from items that were incongruent in previous experiments. The assignment of each target to congruent, incongruent, congruent-catch, or incongruent-catch trials was counterbalanced across participants.

The distracter phase and the test phase were also identical to those in Experiment 2, with the following exceptions. Targets presented in the target recognition block were coded as OLD (presented at study), NEW (never presented before) or CATCH (never presented before but considered a contextual match to one of the background images presented at study). OLD and CATCH trials were in turn coded as congruent and incongruent (note that CATCH trials are dummy coded as *congruent* and *incongruent* since no target object was actually presented in the study phase; the labels refer to the object that originally belonged to that context). The present experiment aimed not only to control for guessing behavior but also to test the impact of the inclusion of catch trials on the CD task results. Neither in the original study (LaPointe et al., 2013) nor in the first two experiments presented here were trials included in which no target was presented. Including trials without a changing object ought to make participants' responses more conservative.

Results

Change detection task. Three participants were removed from the analyses for having responded on more than 20% of the Catch trials (92%, 31% and 62% respectively). Only RTs for correctly detected trials were included in the analyses. As in previous experiments, a t-test was conducted on RT between congruent and incongruent trials. Although the t-test did not reach significance, $t < 1$, responses to

congruent trials were still numerically slower (4018ms) than responses to incongruent trials (3691ms). The proportion of misses was larger for congruent (.25) than incongruent (.07) trials, $t(19)=4.27$, $p<.05$, $d=1.95$. In fact, the difference in proportion of misses in this experiment was greater (.25 vs. .07) than that in Experiment 1 (.12 vs. .04) and in Experiment 2 (.14 vs. .06). In addition, mean RTs were slower in Experiment 3 (3730 ms) than in both Experiment 1 (3261 ms) and Experiment 2 (2989 ms). Taken together, these results suggest that the inclusion of Catch trials biased participants' responses toward a more conservative approach (i.e., responding only on the most salient change trials), but that detection performance was again better for incongruent than for congruent trials. In addition, it is worth noting that the relatively smaller sample size in this study compared to the previous ones could have contributed to the lack of significance of the t test on RTs. Finally, and in line with prior studies, identification scores were more accurate for congruent (.82) than for incongruent (.71) trials, $t(19)=2.47$, $p<.05$, $d=1.13$.

Target recognition. OLD responses to OLD targets were coded as HITS. OLD responses to NEW targets were coded as False Alarms. OLD responses to CATCH targets were coded as Guesses. HIT and FA rates were similar to prior experiments (.78 and .27, respectively). The mean d' value of 1.5 was significantly different than zero, $t(19)= 17.33$, $p < .05$, $d=7.95$. The overall proportion of Guesses was .44.

Analysis of the proportion of HITS for congruent and incongruent trials led to the same pattern of results as reported for Experiment 2; congruent objects were remembered better (.85) than incongruent objects (.74), $t(19)=2.72$, $p<.05$, $d=1.25$. The smaller proportion of trials available in this experiment (a target object was presented in only half of the trials) did not allow us to properly test for statistical significance of the distinction between identified and located object trials. Nevertheless, the numerical pattern was similar to that in Experiment 2, with a benefit for identified (.70) when compared to located trials (.50).

More interestingly, there was no difference in the proportion of Guesses for congruent (.44) and for incongruent (.43) trials, $t<1$. To further explore this result, we assessed a difference score between HITS and Guesses for congruent and incongruent trials to see whether, once corrected for Guesses, participants' memory was still better for congruent than for incongruent trials. Indeed, corrected memory for congruent targets

was better (.40) than corrected memory for incongruent targets (.29), $t(19)=2.07$, $p=.053$, $d=.95$, although this result did not quite reach significance⁵. This result and the null difference between Guess scores for congruent and incongruent trials, suggest that memory for congruent background images did not spuriously cause the superior memory performance for congruent than for incongruent target objects.

Context recognition. Overall HIT (.65) and FA (.43) rates were again assessed to measure discriminability. The mean d' value of .68 was significantly different from zero, $t(19)= 5.60$, $p < .05$, $d=1.78$. Replicating previous results, the HIT rate was not affected by target-image congruity (.61 for congruent vs. .60 for incongruent), $t < 1$.

Similarly, as in Experiment 2, memory for the background context was better for trials in which the target was merely located (.75) than for trials in which the target was also correctly identified (.57), $t(19)=3.65$, $p<.05$, $d=1.67$. Following the same procedure as in Experiment 2, we computed a Pearson correlation across participants between the differences for located and identified trials in memory for the background image and in RT for the CD task. The correlation was again far from significant, $t<1$, thus ruling out any explanation for the difference in memory in terms of different exposure times.

Therefore, these results, which are similar to those observed in Experiment 2, strongly support the idea of less processing of the background image when a target object is found. Attention appears to be diverted from the background so that encoding of the target object is favored over encoding of the background.

Discussion.

The primary purpose of this experiment was to control for participants' guessing behavior in evaluating the effect of congruity on memory for target objects. In particular, we were concerned that superior memory for congruent target objects in Experiment 2 could have resulted from participants responding old to congruent target objects because of memory for a congruent background scene rather than because of memory for that particular target object. To rule out this explanation, we removed

⁵In a similar experiment run as a follow up of the present findings with a sample size of 36 participants we replicated the results from the study phase and the memory test with satisfactory significance levels ($p<.05$). Thus we can safely assume that equating the sample sizes from Experiment 3 to that of Experiment 1 will likely render the numerical differences found here statistically significant.

the target for half of the trials in the study phase and then included those targets in the memory test. If memory for context images biases memory performance for now dummy-coded congruent and incongruent target objects, then we should expect to find a higher proportion of OLD responses for congruent targets (target objects that are congruent with a background context presented in the study phase) than for incongruent targets (targets that are incongruent with a background context presented in the study phase). In contrast, if the memory enhancement for congruent targets is due specifically to the congruity manipulation in the study phase, then the proportion of old responses for the dummy coded congruent and incongruent trials should be the same. Indeed, this is the result that was observed; presentation of a context only at study did not increase the likelihood of participants judging as OLD the associated congruent target when that congruent target was not presented at study.

Another goal of the present experiment was to replicate the results obtained in Experiment 2 with a procedure in which participants were more conservative in their responses due to the presence of catch trials in the CD task. As in Experiment 1, target-context congruity selectively enhanced memory for the target objects but not for the context images in which they were embedded.

General discussion.

A variety of models from different research areas converge in predicting that conflicting situations may serve as a trigger for new learning to occur. Across diverse frameworks (e.g., cognitive conflict, prediction error, novelty) researchers have proposed the idea that a mismatch between co-active representations is used by our cognitive system to up-regulate encoding mechanisms (Henson & Gagnepain, 2010; Rescorla & Wagner, 1972; Verguts & Notebaert, 2009).

In three experiments we tested this prediction using a behavioral task, namely a CD task, which has some idiosyncratic and convenient features: it allows for the use of naturalistic real-life images; it can be used to study high-level semantic conflict; and it produces an unusual pattern of results, with faster and more accurate detection for target-context incongruent than congruent trials (Hollingworth & Henderson, 2000; Hollingworth, Schrock, & Henderson, 2001; LaPointe et al., 2013; Stirk & Underwood, 2007). Our study phase successfully replicated previous results with semantic congruity

manipulations for the CD task. Nevertheless, contrary to the initial prediction for the memory results, the mismatch between the target objects and the context images did not produce a benefit on a later memory test. In fact, the opposite was observed: memory for congruent target-context combinations presented in the encoding phase was better than memory for incongruent combinations. In the following section this unexpected result is discussed in the light of two possible accounts: the Desirable Difficulty principle and the Levels of Processing effect.

Applying the Desirable Difficulty principle.

Difficulty at the time of encoding has also been proposed as a mediator in the formation of new memories. In other words, information processed under difficult circumstances is usually remembered better than information more fluently processed (Bjork & Bjork, 1992; de Winstanley & Bjork, 1997, 2004). This odd finding is opposite to the more intuitive idea that if a task is easier to accomplish it should leave more resources available to encode the information presented. Instead, difficult processing appears to trigger mechanisms that cause more efficient encoding (Bjork & Bjork, 1992; see Bjork & Bjork, 2011 for a recent review).

Interestingly, recent studies that have aimed at exploring the impact of conflict at study on a later memory test all have shared the same confound: in their tasks, conflicting information was always more difficult to process (Krebs et al, 2013; Rosner et al., 2014). Hence, it seems possible that the memory benefits attributed to the detection of conflict might be due simply to an increase in the cognitive effort devoted to the task. If we apply the principle of desirable difficulty to our CD task, in which congruent changes led to longer RTs and higher proportion of misses than incongruent changes, we ought to expect better memory for congruent trials. That is, within the structure of the CD task used here, congruent trials are measurably more difficult to detect than incongruent trials and thus memory should be boosted for them. Our results clearly match this hypothesis. We observed recognition scores that were higher for the more difficult-to-detect changes (i.e., congruent target-context combinations) when compared with changes detected in a more effortless manner (incongruent target-context combinations).

It is worth noting, however, that the congruity manipulation may interact

differently with the two processes taking place in the CD task. Namely, semantic incongruity appears to render objects easier to detect but more difficult to identify. Yet, we have constrained our interpretation of the memory advantage for congruent items to difficulty in detection only. We must acknowledge that difficulty of identification could, in principle, also impact memory encoding in a task such as ours, but several considerations lead us to believe that detection difficulty predominated in our study. For instance, overt goal-driven identification of the target object takes place after its detection in the current task. As a result, any potential byproduct of identification processes will always be contaminated by what has already happened during the detection phase of each trial. Moreover, even if a mechanistic explanation of the desirable difficulty principle is adopted for both detection and discrimination, and we assume that difficulty in both detection and identification triggers some compensatory process that enhances encoding, it may not make sense to apply this principle to processing that occurs after a stimulus is offset (note that our identification task was performed after the stimulus disappeared). In other words, at the moment at which participants experienced the difficulty on the identification task, there was no longer a visual stimulus whose encoding could be boosted. Nevertheless, the interaction between the desirable difficulty principle and the two process view of the CD task is a very interesting issue that future research with a more suitable experimental design ought to explore.

Depth of processing.

This last point leads to another body of literature that could offer an account for the unexpected better memory for congruent trials we see here. Information that matches our previous knowledge of the world is usually more easily processed, integrated and remembered (Craik & Lockhart, 1972; Petersson, Sandblom, Elfgrén, & Ingvar, 2003; van Kesteren, Rijpkema, Ruiter, & Fernández, 2010). It has been proposed that the number of associations that can be made between any new information and information previously stored determines the durability of that memory trace. The number and strength of the possible associations are by definition greater for coherent information (Craik & Lockhart, 1972). In our task, semantic congruity between the objects and the backgrounds allows for the creation of a coherent mental model of a situation in which all the details would match our previous knowledge of the

world. Therefore all the details would be more easily integrated at a deeper level and, as a consequence, congruent target-context combinations would be better encoded and later remembered.

In summary, differences in depth of processing for congruent and incongruent trials might offer an explanation of the better remembering of objects embedded in congruent than incongruent backgrounds observed here. At the same time, this account does not explain why no differences were found for the recognition of contexts (Experiments 2 and 3) or object-context pairs (Experiment 1). In addition, it is also difficult to reconcile this account with the previous sets of results discussed above in which inconsistent information was remembered better than more consistent information (Krebs et al., 2013; Rosner et al., 2014).

In light of the data obtained and the literature reviewed in this paper, we propose that introducing conflict at encoding is one of a number of ways of inducing additional encoding that leads to better remembering, but that it is not the conflict itself that produces the better remembering. In fact, other attentional non-conflict related manipulations at encoding, such as withholding a response in the context of a Go/No-Go task (Chiu & Egner, 2014) or monitoring for a secondary stimulus (Swallow & Jiang, 2010b), may lead to similar findings regarding memory for the information presented. We thus argue that conflict may be one of many processing manipulations that increase encoding difficulty, and the general concept of up-regulated processing in response to encoding difficulty may provide a more accurate account for the present results. Moreover, to our knowledge, all of the attempts to explore the influence of conflict on encoding have confounded conflict and difficulty (Krebs et al. 2013; Rosner et al., 2014). In those experimental designs the independent contributions of conflict and difficulty could not be disentangled as incongruent conditions were always more difficult. Hence, we argue that the desirable difficulty hypothesis in and of itself can account for all of these results. However, we acknowledge that the accounts reviewed above are not mutually exclusive. In fact, we think that it is worth noting that when it comes to memory formation there are many different principles that take place at the same time (Craik & Lockhart, 1972; Henson & Gagnepain, 2010; Rescorla & Wagner, 1972; Verguts & Notebaert, 2009); therefore circumscribing our interpretations to only one of them will likely only capture a small portion of the big picture.

Conclusion

Across three experiments the impact of semantic conflict on memory formation using a CD task was examined. The idiosyncratic features of this task allows the disentanglement of conflict and difficulty (Hollingworth & Henderson, 2000; Hollingworth et al., 2001; LaPointe et al., 2013), which highlights the idea that these are not equivalent constructs. Accordingly, a recent study conducted using fMRI has revealed that difficulty and cognitive conflict elicit activity in different brain regions in spite of having similar behavioral outcomes (Robertson, Hiebert, Seergobin, Owen, & MacDonald, 2015). By means of that separation, we can conclude that conflict itself, understood as the co-activation of competing representations (Botvinick et al., 2001), is neither sufficient nor necessary to trigger learning mechanisms. Rather, we argue that any kind of interplay between the stimulus features and peoples' responses making performance less fluent is a much better candidate mechanism to trigger learning. We propose this tentative definition of disfluency aiming at reconciling a wide range of commonly used constructs (Botvinick et al., 2001; Russo & Doshier, 1983; Bjork, 1994).

In conclusion, in light of the present results we argue that learning mechanisms can be triggered by any stimulus-response interaction, which may or may not include conflict (Botvinick et al., 2001), that is perceived as a difficulty (Bjork, 1994) and that requires more cognitive effort (Russo & Doshier, 1983).

Compliance with Ethical Standards

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Conflict of interest. The authors declare that they have no conflict of interest.

Ethical approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent. Informed consent was obtained from all individual

participants included in the study.

What are the mechanism underlying semantic influences
across the stream of processing?

Under review as:

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Consequences of scene-object semantic incongruity across stages of processing: from
detection to identification and memory

Consequences of scene-object semantic incongruity across stages of processing: from detection to identification and memory.

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Abstract:

Studying processing of information across different steps of the stream of processing is a very interesting yet not a very often used approach. In this study we selected three behavioral indexes as proxies for three commonly studied processes: conscious detection, object identification and delayed object recognition. These indexes reflect a modulation of the aforementioned processes by semantic information on objects, scenes and their relationships. Namely, semantically incongruent objects are quickly detected but poorly identified and remembered. We used these three indexes and behavioral and eye tracking measures to study to which extent detection, identification and recognition rely on different mechanisms such as object competition and priming. Our results reveal i) that whereas object competition plays a key role in conscious detection it is not so important for identification and posterior recognition, ii) that longer and delayed fixation latencies support the detection cost of scene-congruent objects and iii) that, although better identified objects are better remembered, the recognition cost of scene-incongruent objects is independent of the level of identification. The combined and transversal approach taken on the present line of research represents a challenging but very exciting perspective by building bridges over theory-seemingly different fields (i.e., conscious perception, attentional orienting, semantic processing and memory formation) but on-practice much related processes.

Keywords: *Information processing; semantic congruity; recognition memory; conscious perception; object identification.*

Introduction

The amount of information with which our system is faced on a regular day is overwhelming. Of all the information that gets through our senses only a small portion reaches a state in which we become actually aware of it. In turn, an even smaller fraction of that information is stored in memory and can eventually be remembered. Understanding what happens with that information across the stream of processing is crucial to deepen our knowledge of human cognition.

Interestingly, it has been shown that semantic features can be a key modulator of this information filter. For instance, previous knowledge of the world can bias the type of information that gets access to our system by anticipating the most likely stimulus, given a set of priors (Rao & Ballard, 1999; Summerfield et al., 2006), or meaning maps that guide attention similar to saliency maps (Henderson & Hayes, 2017). Likewise, this previous knowledge can help us to interpret and give meaning to seemingly meaningless stimuli (Gorlin et al., 2012; Mooney, 1957) and it can even adjust which information gets stored and which does not (Henson & Gagnepain, 2010; van Kesteren et al., 2012).

On this research paper we will use prior semantic knowledge of real-world visual scenes to characterize three key stages in the processing of information: detection, identification and retrieval.

Object detection

The unspecific report of the detection of a visual stimulus can be studied with many different paradigms. Most of them require participants to press a given key to the appearance of a stimulus independently of some specific features such as its location, its color, or its identity. These seemingly unimportant features are often used as independent variables to either speed up or slow down detection times, or even to facilitate or impair detection accuracy, leading to positive and negative effects like priming (Kroll & Potter, 1984), change blindness (Simons & Rensink, 2005) or inhibition of return, interpreted as a detection cost (Lupiañez, Martín-Arévalo, & Chica, 2013).

The semantic features of an image are also thought to bias detection responses in

a very interesting way during scene viewing. For instance, Hollingworth and Henderson (2000) showed that change detection is improved when the to-be-detected object is embedded in a semantically incongruent context (Hollingworth & Henderson, 2000). This effect, which has been replicated several times afterwards (Hollingworth et al., 2001; LaPointe et al., 2013), seems to be in line with neuropsychological data from extinction patients. This subset of neglect patients shows a specific impairment in noticing two objects presented one on each hemifield when their meanings overlap (e.g., a wooden fork and a metal fork); however, when the two objects have clearly different meanings (e.g., a fork and a pencil) patients are more likely to report both of them (Baylis, Driver, & Rafal, 1993). It seems, thus, as if having similar co-active semantic representations, either via two analogous objects or via the gist of a scene and a given object, hinders our ability to segregate them apart so that we can consciously report both; that is, it generates a congruity-mediated detection cost (CDC). The CDC refers to a cost in detecting objects embedded in a congruent scene.

It is worth noting that the opposite effect has also been reported. Using a breaking-continuous flash suppression paradigm (b-CFS; Tsuchiya & Koch, n.d.), Stein & Peelen (2015b), showed that cuing a stimulus' category in advance reduced participants suppression times when they were to detect validly cued items (Stein & Peelen, 2015b). However one major difference between Stein and Peelen's paradigm and those noted above lies on the fact that Stein and Peelen presented their objects in isolation, and participants' task was to differentiate them from a noisy mask. Under these specific conditions, mechanisms such as priming (Kroll & Potter, 1984) or top-down inferences over ambiguous stimuli (Bar, 2003; Gorlin et al., 2012) are most likely responsible for guiding participants' behavior. In other words, whereas in b-CFS paradigms detection rather refers to noise interpretation, in change detection paradigms detection refers to the conscious isolation of a unique target object among other distracting objects.

Object identification

Interestingly, LaPointe et al. (2013) showed that semantic information can also be used to dissociate object detection from object identification by impacting both processes in opposite ways (LaPointe et al., 2013). More specifically, they used a change detection task in which the identity of the object either mismatched the gist of

the surrounding scene or not, and they asked participants to detect and subsequently to identify the changing object. Their results showed the previously reported CDC and, at the same time, a congruity-mediated identification benefit (CIB). The CIB refers to facilitation in the conscious access to semantic information for context-congruent objects. In other words, objects that are presented embedded on a congruent background are generally identified more accurately than those that are presented on an incongruent one (LaPointe et al., 2013; LaPointe & Milliken, 2016; Ortiz-Tudela et al., 2016). This finding is in line with previous research on prior knowledge and expectations which has shown that object identification is improved when the visual input matches what is expected (Eger, Henson, Driver, & Dolan, 2007; Esterman & Yantis, 2010).

It is worth noting, however, that the strong behavioral dissociation between detection and identification proposed by LaPointe et al. has been later nuanced by showing that the neural overlap between the two processes is higher than anticipated based on behavioral data, as both CDC and CIB were reduced after inhibitory stimulation of the right Temporo-Parietal Junction (Ortiz-Tudela, Martín-Arévalo, Chica, & Lupiáñez, n.d.).

Object retrieval

Taken both, the CDC and the CIB as a starting point, Ortiz-Tudela et al. extended these results by showing that the influence of semantic processing can be also measured in delayed recognition memory tests (Ortiz-Tudela et al., 2016). They presented participants with a surprise recognition memory test following a change detection task and found a congruity-mediated delayed recognition benefit (CRB). In other words, they found heightened remembering of context-congruent objects compared to context-incongruent ones when memory was later measured via a recognition memory test.

In summary, congruity between a new object and the scene context in which it is presented seems to be harmful for the detection of the object but, at the same time, it facilitates its identification and its ulterior recognition.

The present study

Although much research has been conducted on the abovementioned three

processes separately, it remains largely unknown whether they share some underlying mechanisms or whether they are based on different principles. In order to explore this question, we will focus on two basic mechanisms that have been shown to underlie many cognitive processes: priming and object competition. Priming refers to the propagation of activation from one representation to another such that the processing of the latter is biased as a function of the former (Palmer, 1975; Schvaneveldt & Meyer, 1973); in contrast, competition refers to a sort of race between two or more co-active representations to reach a level of activation such that, eventually, only one of them is selected over the others (Desimone & Duncan, 1995). In the visual domain, priming helps giving sense to visual noise by pre-activating semantic representations which can in turn ease the interpretation of rather ambiguous visual stimuli. This propagation of activation can occur, for example, from an anticipatory cue to an object, between objects within a scene, or from the background scene to a target object. Likewise, object competition, which can only take place between activated objects, determines which stimuli are selected (Desimone & Duncan, 1995) and therefore prioritized to access awareness. For instance, as discussed above, semantically meaningful objects capture attention and thus they can be rapidly noticed. It is important to note that these two opposite mechanisms are in no way mutually exclusive, and in fact they most likely often interact with each other. However, processes of detection, identification, and memory might probably rely on different combinations of competition and priming mechanisms. Across a series of four experiments we attempted to offer new insight into how semantic information impacts these three processing stages by characterizing the mechanisms underlying the CDC, CIB and CRB (Experiment 1A and 1B), as well as by more clearly isolating object identification from the other two processes (Experiment 2) and by assessing the gaze patterns associated with each one of these functions (Experiment 3).

Experiment 1

Whether the aforementioned semantic effects (i.e., CDC, CIB and CRB) are a consequence of priming or of object competition mechanisms is still unsolved. As noted above, Stein and Peelen (2015) recreated an extreme situation in which competition from other objects was absent (i.e., the target was presented alone in the context of visual noise), but in which a categorical cue might prime the detection of an

object presented under b-CFS conditions. With this paradigm, the authors showed a benefit from the congruency of the cue, rather than a CDC. Conversely, LaPointe et al. (2013) used what can be considered as the opposite situation: their change detection task with cluttered images relied heavily on object competition, since participants' goal was to selectively detect a changing target among many distracters; this situation rendered an advantage in detection for context-incongruent target objects (or, what amounts to the same, the CDC). In Experiment 1 of the present study, we attempted at recreating an intermediate situation, using LaPointe et al.'s task, but reducing the presence of distracters, in order to prevent competition. We presented participants with two types of natural scenes: the cluttered ones, in which the images included many non-target objects together with the target one, and the sparse ones, in which only the target object was presented against a background image.

If semantic effects take place as a consequence of priming-like or top-down inferential mechanisms, they ought to be present in both types of trials, since the propagation of the semantic properties from the scenes to the individual objects can equally occur in both conditions. Conversely, if the aforementioned effects arise as a consequence of stimulus competition, they should appear selectively in cluttered trials, where there are many objects that compete with each other. More specifically: given that the CDC has been shown to disappear or even to revert in conditions without object competition (Stein & Peelen, 2015b), we hypothesized that the CDC ought to be present only for cluttered trials. In opposition, the CIB, which arguably relies on spreading activation from the context image to the object's semantics (Davenport & Potter, 2004; Eger et al., 2007; Palmer, 1975), ought to be present in both cluttered and sparse trial types. Lastly, given that the CIB and the CRB have been previously shown to take the same form (Ortiz-Tudela et al., 2016), we hypothesized that the CRB could also be observed in both stimulus types.

Because including qualitatively different sets of images in a task might entail not only the differential processing of those images but an overall change in participants' mindset and strategies, we conducted two separate but complementary experiments. In Experiment 1A, the order of presentation of the two stimulus types was randomized so that it was impossible to anticipate the nature of the upcoming trial and to be specifically prepared for it in advance. In Experiment 1B, stimuli from the same set

(i.e., cluttered vs. sparse) were grouped into blocks, so that all of the trials from one group were presented together and therefore participants would be able to adopt an optimal strategy before the onset of the trial.

Materials and method

Participants. Twenty students (18 female; mean age: 21.84; s.d.: 6.30) from the Universidad de Granada participated in Experiment 1A; another twenty students (18 female; mean age: 20.45; s.d.: 5.65), extracted from the same pool, participated in Experiment 1B. All of them volunteered in exchange for course credit and signed informed consents approved by the local ethics committee. All experiments in this paper, which are part of a larger research project approved by the Universidad de Granada Ethical Committee (175/CEIH/2017), were conducted according to the ethical standards of the 1964 Declaration of Helsinki (last update: Seoul, 2008).

Procedure. Each participant completed three sequential phases: the first one consisted of a change detection task; this phase was followed by 10 minutes of mathematical operations that served as distracter task. Finally, memory of the presented targets was assessed through a surprise recognition test.

The overall structure of the session was identical for Experiment 1A and 1B with the sole exception of the order of presentation of the different trial types (i.e., randomized for Experiment 1A and blocked for Experiment 1B). For Experiment 1B randomization was applied within each block so that the exact sequence of trials was different for each participant. The order of the blocks was counterbalanced across participants.

Change detection task. Each trial consisted in a rapid alternation of two versions of the same image. The two versions represented scenes which were identical to each other except for the presence or absence of an extra object. Participants were required to press the space bar on a QWERTY keyboard as soon as they noticed any detail that was different between the two versions of the scene. To prevent the changing object to pop-out, an intervening blank screen was included between the two presentations which rendered the standard flickering appearance (Rensink, O'Regan, & Clark, 1997), and made object detection rather difficult. Importantly, we manipulated the congruity between the to-be-detected object and the background scene. On half of

the trials the target identity matched the gist of the scene (i.e., congruent trials) and on the other half it corresponded to an object that was not expected or frequent in that context (i.e., incongruent trials). After the detection response, or after 9 alternation cycles, the sequence stopped and a new screen prompted participants to identify the changing object with a few words (e.g., black dog) or by locating it on the screen (e.g., bottom-left) if identification was not possible (Figure 1). To assure participants' engagement in the task, a 10% of trials with no change were included (i.e., catch trials). A total of 90 object-image combinations were used. More importantly for our purposes, we included two sets of trials. The cluttered set was built so that the target object (i.e., the changing one) was one among many other presented objects. Conversely, in the scenes of the sparse set the target object was presented roughly in isolation against an open background image (Figure 2).

Distracter task. Participants completed 10 minutes of paper and pencil math operations.

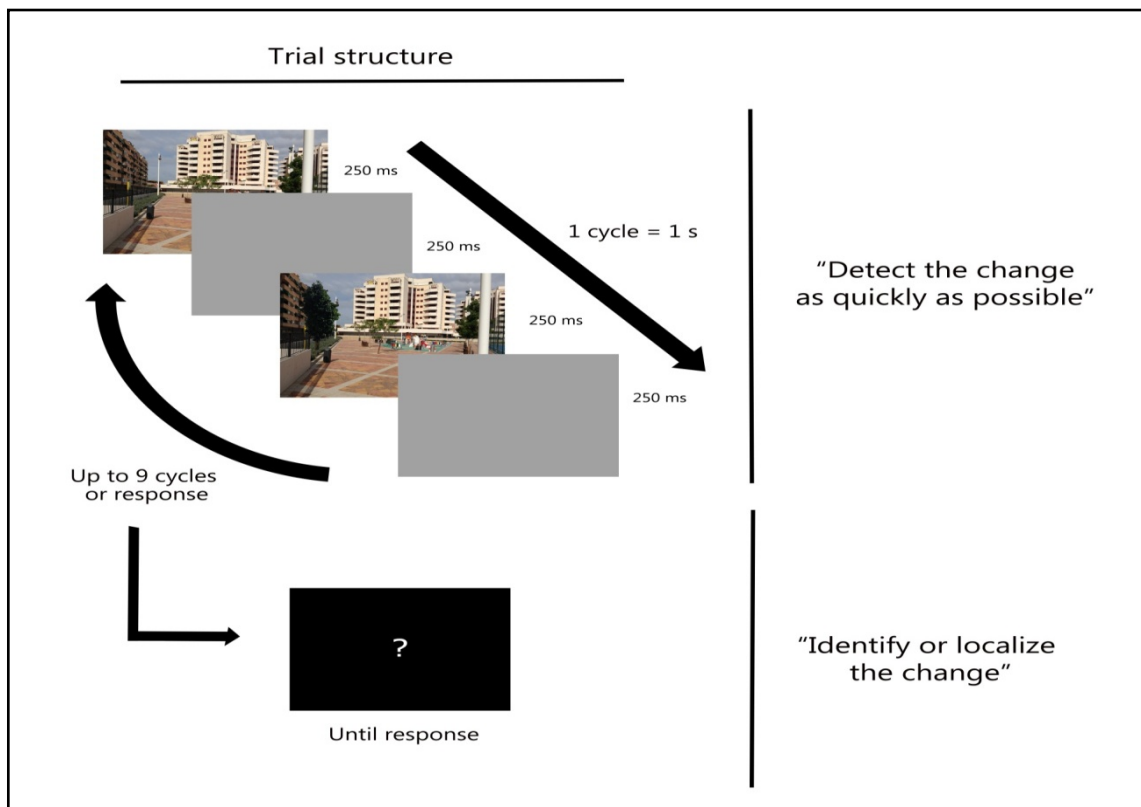


Figure 1. Trial structure for the change detection task in Experiments 1A, 1B and 3. Participants sequentially performed a detection task followed by an identification task (see Ortiz-Tudela et al., 2016, for a similar procedure).

Recognition memory test. All of the target objects from the change detection task, together with 90 new objects, were used in the memory test. Each object was presented alone (i.e., stripped from any scene context), and participants were required to perform an OLD vs NEW judgment in response to those objects. Correct responses to OLD objects were coded as HITS and incorrect responses to OLD objects were coded as False Alarms (FAs).

Results

Experiment 1A. Participants with detection accuracy below 80% (N=6) were excluded from the analyses. The three dependent variables of interest were analyzed separately using 2x2 repeated measures ANOVAs with scene-object congruity (congruent vs. incongruent) and trial type (cluttered vs. sparse) as within-subjects factors.

Detection. The analyses of the proportion of correct detection responses revealed a significant two-way interaction between background-object congruity and trial type, $F(1,13)=8.23$, $p=.013$, $\eta^2=.39$. The interactive pattern showed that the previously reported CDC was present on the cluttered set, $F(1,13)=14$, $p=.002$, $\eta^2=.52$, but completely absent on the sparse one, $F<1$. The analyses of raw detection times to correctly responded trials revealed that neither the interaction, $F<1$, nor the main effect of congruity reached significance, $F(1,13)=2.11$, $p=.170$. Nevertheless, when detection

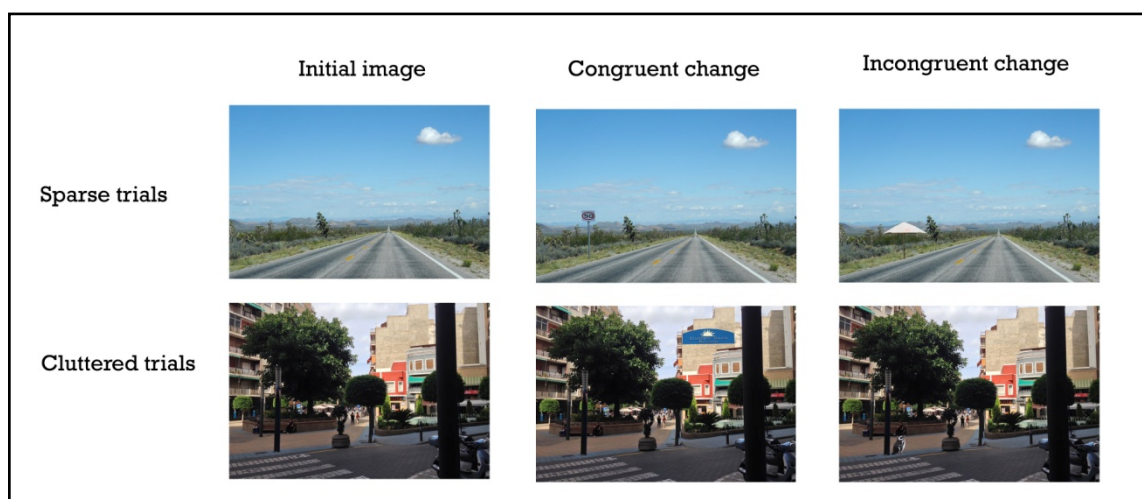


Figure 2. Example of stimuli used in Experiment 1A and 1B. Scenes in the cluttered set were taken from Ortiz-Tudela et al., (2016); for the sparse set, scenes with none or just a few non-target objects were selected.

times were corrected according to a procedure that has proved to be useful in conditions in which there is great overall variability in the sample (Ortiz-Tudela et al., *n.d.*), either by combining detection times with proportion of correct responses to make an overall detection index (detection times/proportion of correct responses); or by recoding non-detected object times with the value corresponding to the maximum available deadline (9s), the statistical patterns both revealed a significant trial type by congruity interaction, $F(1,13)=8.67$, $p=.011$, $\eta^2=.40$ and $F(1,13)=9.23$, $p=.010$, $\eta^2=.42$. Both of these corrected measures showed that responding to congruent targets was more difficult than responding to incongruent targets on the cluttered set, $F(1,13)=9.69$, $p=.008$, $\eta^2=.43$ and $F(1,13)=12.19$, $p=.004$, $\eta^2=.48$, respectively, but that they were not different in the sparse set, both $F_s < 1$.

Identification. Only correctly detected objects were included in the following analyses. The results of the analysis of the proportion of correctly identified objects appropriately replicated previous findings of higher identification scores for congruent objects, $F(1,13)=11.54$, $p=.005$, $\eta^2=.47$. Importantly, the trial type by scene-object congruity interaction was far from significance in this measure, $F < 1$, showing that the CIB was present in both trial types, for the cluttered ones, $F(1,13)=8.16$, $p=.013$, $\eta^2=.36$, and for the sparse ones $F(1,13)=9.90$, $p=.007$, $\eta^2=.43$.

Recognition. Those trials which were correctly detected and correctly identified were submitted into the recognition analyses. Overall d' was 1.27 and beta 1.84. Since it was not possible to assess independent FA rates for congruent and incongruent trials, overall HIT rates were used as a measure of memory performance. The analyses just failed to show a significant effect of trial type, $F(1,13)=4.40$, $p=.056$, $\eta^2=.25$, even though it showed numerically higher recognition scores for objects in the sparse set (.74) compared to those in the cluttered set (.67). The numerical pattern also showed higher memory rates for congruent than for incongruent objects, at least for the cluttered scenes (see Table 1), but neither this difference, nor the two-way congruity x trial type interaction were close to statistical significance, $F_s < 1$.

Experiment 1B. Participants with detection accuracy below 80% ($N=4$) were excluded from the analyses. The same approach as in Experiment 1A was adopted for the analyses of Experiment 1B.

Detection. Analysis of detection times and detection accuracy replicated those of Experiment 1A. The trial type by congruity interaction was significant for detection accuracy, $F(1,16)=10.81, p=.005, \eta^2=.42$, but did not reach significance for raw detection times, $F(1,16)=1.34, p=.27, \eta^2=.08$. When these times were corrected by combining them with detection accuracy in a detection efficiency index, or by substituting incorrect response times with the response deadline, these two corrected indices showed an interaction between trial type and congruity which was close to significance for the detection index, $F(1,15)=4.45, p=.052, \eta^2=.23$, and was clearly significant in the substitution index, $F(1,16)=7.38, p=.016, \eta^2=.33$. In other words, again more efficient responses were made on incongruent than on congruent trials for cluttered trials, $F(1,15)=7.05, p=.018, \eta^2=.32$ and $F(1,15)=11.44, p=.004, \eta^2=.43$, but the effect of congruity did not arise in any of these two indices for sparse trials, both $F_s < 1$.

Identification. The pattern of the identification scores for Experiment 1B mimicked that of Experiment 1A, even though the statistical effect missed significance. According to the CIB effect, congruent target objects tended to be identified better than incongruent objects, but the main effect of congruity did not reach significance, $F(1,16)=3.64, p=.076, \eta^2=.21$. There was no indication of an effect of trial type, or of an interaction between stimulus type and congruity, $F < 1$.

Recognition. The memory pattern in Experiment 1B also resembles that of Experiment 1A. Overall d' was 1.35 and overall beta was 2.05. The main effect of trial type was significant, $F(1,15)=4.60, p=.049, \eta^2=.23$, with better memory for objects in the sparse trials (.75) than in the cluttered ones (.66). No significant effect of congruity nor an interaction between trial type and congruity were observed, both $F_s < 1$.

Combined analyses. Because the paradigms and the results of Experiments 1A and 1B are similar to each other, and to gain some more power to detect some potential effects not revealed due to the sample sizes of each individual experiment, we conducted a combined analysis of both experiments. We used a 2(trial type) x 2(congruity) x 2(Experiment) repeated measures ANOVA with Experiment as a between-participants factor to independently analyze the three variables of interest.

Detection. Analyses of detection accuracy revealed a two-way interaction

between trial type and congruity, $F(1,28)=18.88$, $p<.001$, $\eta^2=.40$, with incongruent objects being more accurately detected than congruent ones in the cluttered set, $F(1,28)=26.98$, $p<.001$, $\eta^2=.49$, but not in the sparse one, $F<1$. Analyses of detection index and corrected RTs uncovered the same pattern as before: we observed a significant interaction for both detection index, $F(1,28)=7.96$, $p=.009$, $\eta^2=.22$ and corrected RTs, $F(1,28)=15.86$, $p<.001$, $\eta^2=.36$. Exploration of the interaction revealed more efficient detection responses for incongruent than congruent trials in the cluttered set, $F(1,28)=11.27$, $p=.002$, $\eta^2=.29$ for detection index and $F(1,28)=22.97$, $p<.001$, $\eta^2=.45$ for corrected RTs, and no differences between incongruent and congruent trials in the sparse one, both $F_s<1$.

Identification. The combined analysis accurately replicated the individual ones. No significant interactions were found nor a main effect of trial type, all $F_s<1$. Nevertheless, a significant CIB was obtained, $F(1,28)=14.26$, $p<.001$, $\eta^2=.34$, reflecting that the CIB was present for both the cluttered trials, $F(1,29)=8.07$, $p=.008$ and the sparse ones, $F(1,29)=13$, $p=.001$.

Recognition. The analyses revealed no effects of Experiment, congruity or any of the interactions, all $F_s<1$. Only a main effect of trial type was found, $F(28,1)=8.66$, $p=.006$, $\eta^2=.24$, with better memory for objects on sparse trials.

Discussion

The aim of Experiments 1A and 1B was to test whether the congruity effects reported in the literature on detection, identification and delayed recognition of changing objects from a scene could rely on different combinations of priming and competition. To that end, we used a change detection paradigm, that has reliably rendered the CDC, CIB and CRB (Ortiz-Tudela et al., 2016; Ortiz-Tudela et al., *in press*), and we compared two sets of context stimuli which either included the target among many other distracter objects, or presented the target in a scene showing a plain background. Because we reasoned that participants' responses can be affected by the adoption of a specific mindset provoked by the previously experienced trials, Experiment 1A and 1B also explored the potential effect induced by including these two types of sparse vs. cluttered contexts either randomly on each trial (Experiment 1A) or grouped into blocks (Experiment 1B).

The results of both Experiments showed that while the CIB is present for both cluttered and sparse stimuli, the CDC is only found in the presence of stimulus competition. This result suggests that the detection cost arises only when there is a number of coactive stimuli competing for attentional resources, whereas the benefits found for identification seem to depend on mechanisms of priming which might arise either from the activation of a group of semantically related objects, or from the overall meaning of the context scene (Eger et al., 2007; Esterman & Yantis, 2010). It is worth noting that the absence of differences in responding to congruent and incongruent trials is consistent with the idea that sparse scene contexts represent an intermediate situation between Stein and Peelen's advantage of semantically cued objects in noisy preparations, and the CDC effect observed in LaPointe et al.'s (2013) paradigm.

Finally, in Experiment 1A we were unable to obtain a CRB even in the cluttered trials where it has been previously observed (Ortiz-Tudela et al., 2016). The aim of Experiment 1B was two-fold: first, we wanted to test whether the lack of CRB even on cluttered trials from Experiment 1A could be due to the random inclusion of sparse trials during the study phase; second, we intended to explore whether the CDC and the CIB could be also observed on the sparse set when a specific anticipation could be established prior to the onset of the trial. The results of Experiment 1B clearly showed that blocking the order of presentation of each trial type did not change the results from Experiment 1A. That is, the CDC was again absent in sparse trials, even when it was possible to establish an appropriate task set; at the same time, the CIB was again present in both cluttered and sparse trials. Lastly, and still surprisingly, we were not able to obtain a CRB in spite of having arranged very similar study conditions, and a sample size (in the combined analyses) twice as large as those used in previous reports of this effect (Ortiz-Tudela et al., 2016).

However, one may argue that, even if the encoding situation was virtually the same in Experiment 1B as that used in previous reports of CRB, the recognition test took place under a situation that was considerably different: the pool of plausible objects from which each item needed to be compared in the memory test was not only larger in the current experiment, but it also included a subset of items (i.e., the objects from sparse trials) that were different in nature, and were better remembered in general. Having qualitatively different types of trials, and particularly having a subgroup of

target objects with a stronger memory trace can arguably interfere with memory for the less salient stimuli (Kaufman & Bolles, 1981; Mackintosh, 1971). It is therefore possible that some form of interference is taking place here from the objects presented in sparse trials, which might prevent the effect of congruity to affect recognition in this context. Before jumping to this speculative conclusion, we set to replicate CRB without the interfering objects from the sparse set.

Experiment 2 was conducted with the goal of improving our understanding of the nature of the CRB by attempting to measure it in conditions in which 1) any potential interference provoked by the inclusion of sparse trials was removed, and 2) any possible effect of the identification task on memory results was equally controlled.

Experiment 2.

LaPointe et al. (2013) used the CDC and the CIB to claim that a clear dissociation could be behaviorally established between the detection and identification processes. Ortiz-Tudela et al.'s (2016) later report of the CRB followed the same direction as the CIB. However, the dual task conditions arranged in this latter study, in which participants were required to detect and then to identify the changing object, made it impossible to separate the influence of each of these two tasks in the memory results. Indeed, it was possible that the CRB arose as a consequence of the offline elaboration required to respond to the identification question.

Therefore, in Experiment 2 we returned to the exclusive use of cluttered scenes, to ensure the CDC, and arguably to improve the chances of obtaining the CRB effect, but we also eliminated the identification question altogether, to minimize any impact of the identification process, and to avoid any effects of this task on later recognition.

Materials and methods.

Participants. Forty participants (37 female; mean age: 20.7; s.d.:1.6) from the Universidad de Granada volunteered to participate in the study in exchange for course credit. All of them signed informed consents approved by the local ethics committee. Four of them were unable to complete the entire experimental session and therefore were eliminated from the final sample.

Procedure. The overall procedure was the same as those described for Experiment 1A and 1B except for the following: in order to eliminate interference from the sparse set on memory, we only used stimuli from the cluttered set. In addition, the identification question was also removed, so that participants only had to perform the detection task that required them to respond as soon as they noticed any sort of change. Following their response, the alternation of images stopped and it was replaced by a fixation point which indicated the beginning of the next trial after 1000ms. Proper task performance was assessed from accuracy in responding to both change and no-change trials.

Results

All participants reached the required threshold of 80% detection accuracy. We did not conduct a specific comparison between experiments concerning this result, but the absence of any participant below threshold suggests that the inclusion of trials in which change detection was easier (i.e., the sparse trials) may have biased participants in Experiment 1 against reporting more subtle changes in cluttered trials.

Detection.

Analysis of detection responses revealed more accurate and faster response times for incongruent than congruent trials, $t(35)=6.28$, $p<.001$, Cohen's $d=1.04$, and $t(35)=6.03$, $p<.001$, Cohen's $d =1$, respectively. Same as before, combining both, detection accuracy and RTs, in a detection efficiency index, rendered the expected results of more efficient responses for incongruent than congruent trials, $t(35)=8.05$, $p<.001$, Cohen's $d=1.34$.

Recognition.

Overall d' and beta were .80 and 2.35, respectively. Analysis of HIT rates showed the expected CRB. Targets from congruent scenes were remembered better than those from incongruent ones, $t(35)=2.21$, $p=.034$, Cohen's $d =.34$.

Discussion.

Experiment 2 aimed at replicating the previously reported CRB, which was surprisingly absent in Experiment 1A and 1B, and at testing whether CRB would

appear in conditions in which identification was not required. According to our predictions, participants in this experiment showed the standard CRB, even though recognition scores were considerably lower in this case (38%) as compared to that found in previous studies when an identification task was included after detection (e.g., 62 %, in Ortiz-Tudela et al., 2016). This lower recognition rate is most likely due to shallower processing of the stimulus (Craik & Lockhart, 1972). Finding CRB in the absence of an identification task rules out the possibility that the CRB reflects the impact of post-detection processes triggered by these explicit identification requirements. Of course, one cannot claim that identification processes are completely absent when the task is removed, but it is fair to assume that they must be reduced in these conditions. Moreover, given that the procedure of Experiment 2 closely resembled that of Experiment 1B, with the specific stimuli being taken from the cluttered set from Experiment 1B, it appears that the observation of CRB in this case, together with the lack of this effect obtained in Experiment 1A and 1B, tend to reinforce the conclusion that it was the presence of a subset of highly remembered items, taken from the sparse trials, which hindered the observation of congruity effects on recognition on the overall test.

The results of Experiment 2 have proven that the CRB arises independently of the identification task, and that it is more clearly observed when all trials have a certain complexity (i.e., when targets are presented on a cluttered context). However, the nature of this memory effect is still puzzling. Indeed, congruent trials are generally displayed for longer periods of time (Hollingworth & Henderson, 2000; LaPointe et al., 2013; Ortiz-Tudela et al., 2016), but incongruent objects tend to attract eye gaze and to be looked at longer than congruent ones (Henderson, Weeks, & Hollingworth, 1999; LaPointe & Milliken, 2016). The literature on mere exposure effect shows that extended exposure strengthen memory effects simply by virtue of longer processing time. What happens then under the circumstances in which the CRB is produced? Are incongruent targets looked at longer than the congruent ones, but still they got more poorly remembered? Or it might be the case that, under these particular conditions, congruent targets produced longer dwelling times, and CRB arises as a by-product of this extended exposure? Some post-exposure analyses have been conducted before as tentative attempts at controlling these and related issues (Krebs et al., 2015; Ortiz-Tudela et al., 2016; Rosner, D'Angelo, et al., 2015), but no study to date aimed at

ruling out this possibility by exploring gaze patterns.

On Experiment 3 we used a high temporal resolution eye tracking system to 1) explore the relationship between dwell time and memory performance and 2) to characterize the gaze patterns associated with each of these three effects (i.e., CDC, CIB and CRB).

Experiment 3

Building up on previous studies recording eye movements in change detection tasks (Henderson et al., 1999; Hollingworth et al., 2001; LaPointe & Milliken, 2016), on Experiment 3 we intended to further extend their findings to include memory results. More specifically, we aimed at characterizing the gaze patterns associated respectively with the CDC, the CIB and the CRB. Besides, this characterization would allow us to explore whether the CRB can be taken as a consequence of extended dwell time for congruent trials.

Materials and method.

Participants. Twenty students (15 female; mean age: 20.65; s.d.: 3.8) from the Universidad de Granada volunteered to take part in the study. All of them signed informed consents according to the local ethics committee.

Procedure. The overall structure of the experiment resembles that of the previous studies in the present paper: a change detection phase was followed by a distracter task, and then by a surprising recognition test. As in Experiment 2, we only used stimuli from the cluttered set, but we included the identification task, to be able to explore the gaze patterns associated with each of the processing effects described above.

Eye movement recording.

A high frequency (250 Hz) SMI system was used to record participants' eye movements. Participants' heads were placed on a chinrest 60cm away from the monitor to avoid unwanted movements and allow for a more comfortable posture. The obtained raw data were filtered and preprocessed with SMI's BeGaze software.

Results.

Two participants were removed from the analyses due to an eye tracking malfunction which caused the loss of all the session data.

The change detection analyses adequately reproduced the expected results. Namely, we obtained the usual CDC both in accuracy and response times, $t(17)=8.44$, $p<.001$, Cohen's $d=1.99$ and $t(17)=6.28$, $p<.001$, Cohen's $d=1.48$, respectively; combining both measures also rendered more efficient detections for incongruent trials, $t(17)=9.34$, $p<.001$, Cohen's $d=2.20$, for the detection index. We were also able to measure the CIB, $t(17)=4.82$, $p<.001$, Cohen's $d=1.14$, and the CRB, $t(17)=3.06$, $p=.007$, Cohen's $d=.72$ (see Table 1 and Figure 3 for a graphic representation).

Eye movement measures. To analyze eye movements from the study phase we took a step by step approach. First, we analyzed the three measures of interest (i.e., target first fixation latency, target dwell time and pupil dilation) for all correctly detected trials, separately for congruent and incongruent targets. Then, we performed the same analyses for the subset of these correctly detected trials that corresponded to correctly identified targets. Finally, we examined the same variables of interest for the subset of these correctly identified trials that were also correctly remembered. It is

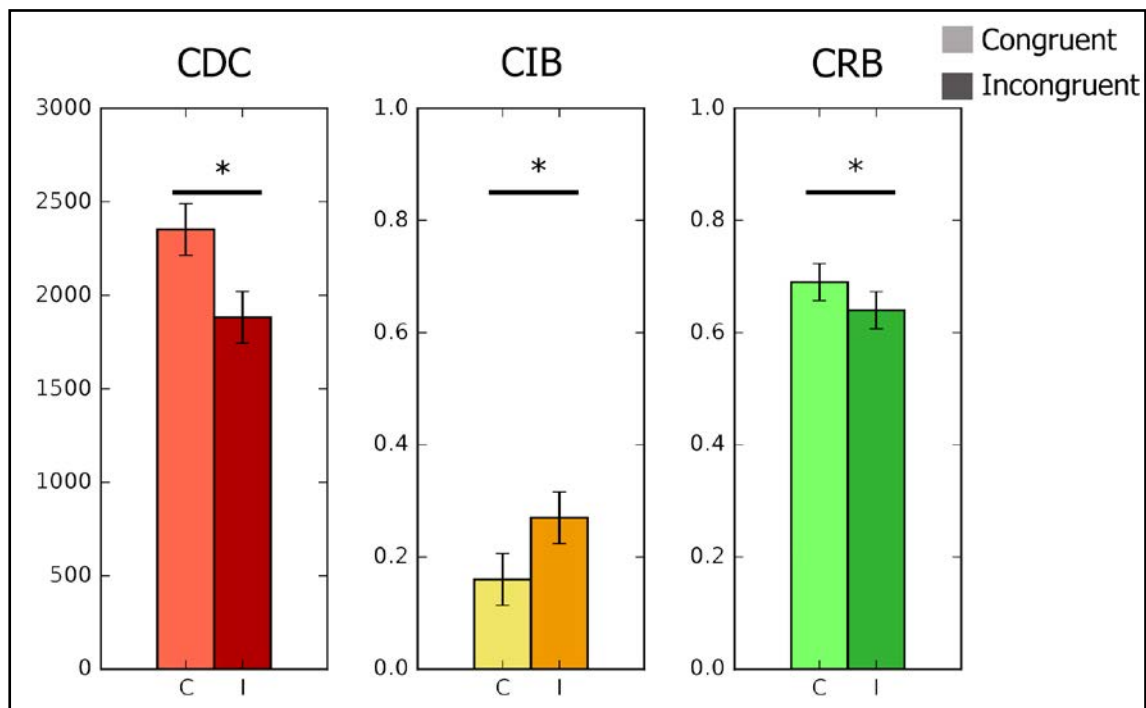


Figure 3. Graphic representation of the three semantic indexes. From left to right: Congruency Detection Cost (CDC), Congruency Identification Benefit (CIB) and Congruency Recognition Benefit (CRB).

important to note that for all these three analyses, including those involving the memory results, the eye-movements of interest were those gathered at the time of study.

Detection

Target first fixation latency. We analyzed target first fixation latency for successfully detected congruent and incongruent objects. Fixation latency was shorter for incongruent objects (1419ms) than for congruent ones (1755ms), $t(17)=5.13$, $p<.001$, Cohen’s $d=1.21$.

To further explore this result and its relation with the CDC, we run a correlation between the congruity effect on response times and on-target first fixation latency, and found a high correlation of $r=.69$, $t(16)=3.76$, $p=.002$, Cohen’s $d=.89$., suggesting that shorter first fixation latencies could be at the basis of the CDC. Besides, we also assessed the probability of fixating the target as a function of the number of fixations which has also been used as a measure of early attention attraction (LaPointe and Milliken, 2016). The cumulative probability of fixating the target object within the first 4 fixations on the scene reached 10% and was equally probable for congruent and incongruent targets, $t<1$. However, from the 5th fixation and on the probability of fixating the target object started growing faster for incongruent than congruent targets (see Figure 4).

Target dwell time (ms). Target dwell time represents the amount of total time spent in the target area and has also been used as a measure of time required to successfully process a given object. No differences were found on the time spent looking at the target once fixated for congruent (1899ms) or incongruent objects

Table 1. Mean RT and percentage of accurate detection responses (in parenthesis) for object detection, and percentage of accurate responses for object identification and delayed recognition, for each of the four experiments.

Experiment	Object Detection				Object Identification				Object Recognition			
	Cluttered		Sparse		Cluttered		Sparse		Cluttered		Sparse	
	C	I	C	I	C	I	C	I	C	I	C	I
1A	2784 (.7)	2757 (.84)	2049 (.94)	2072 (.95)	.87	.72	.83	.73	.70	.65	.74	.74
1B	2423 (.75)	2539 (.87)	1891 (.97)	1783 (.96)	.83	.76	.84	.78	.67	.65	.74	.76
2	2393 (.83)	1883 (.94)	--	--	--	--	--	--	.41	.35	--	--
3	2351 (.87)	1882 (.96)	--	--	.84	.73	--	--	.69	.64	--	--

Note: C (Congruent), I (Incongruent)

(1867ms), $t < 1$.

Pupil dilation. Pupil size has been used as a proxy for cognitive effort (Kahneman & Beatty, 1966; Peavler, 1974) with larger pupil diameter for effortful responses. In our experiment, we found larger average pupil dilation for those trials in which the target was detected (3.49mm) compared to trials in which participants were unable to detect any change (2.48), $t(17)=6.13$, $p < .001$, Cohen's $d = 1.44$. However, in order to ascertain whether increased pupil dilation is either cause or consequence of detecting the change, we compared mean pupil dilation before and after the target was found. The comparison revealed that pupil dilation following a properly detected target was shorter before (3.79 mm) than after (3.85) target detection, $t(17)=2.91$, $p = .009$, Cohen's $d = .69$. This result suggests that increased pupil dilation can be a direct consequence of consciously detecting the target object (Braem, Coenen, Bombeke, van Bochove, & Notebaert, 2015; Critchley, Tang, Glaser, Butterworth, & Dolan, 2005; Wessel & Aron, 2017). In any case, among the detected trials, no differences were found between congruent and incongruent objects, $t < 1$.

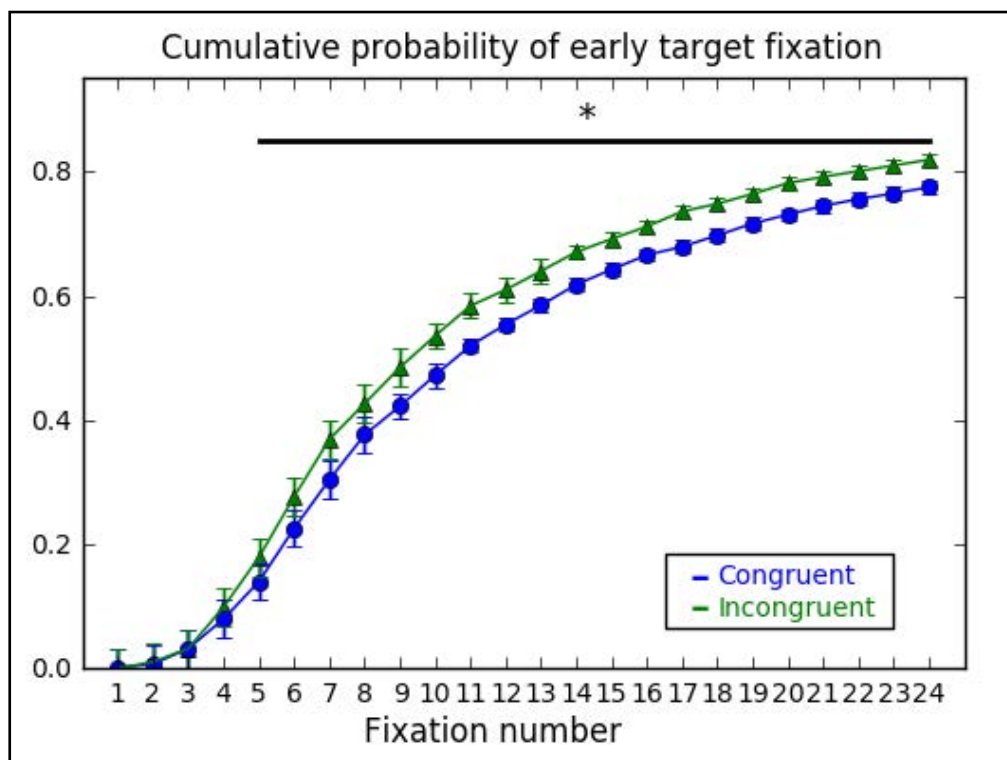


Figure 4. Cumulative probability of early target fixation for congruent and incongruent trials. Probability of having fixated the target as a function of ordinal fixation number.

Identification

Target first fixation latency. The latencies of the first fixations for those targets that were correctly identified and those that were not did not differ from one another, $t < 1$. However, among the identified ones we measured shorter latencies for incongruent objects (1406ms) than for congruent objects (1748ms), $t(17) = 4.66$, $p < .001$, Cohen's $d = 1.10$.

Target dwell time (ms). Total target dwell time for identified (1927ms) and unidentified (1869ms), did not differ significantly, $t(17) = 1.01$, $p = .324$, Cohen's $d = .24$. When we considered only correctly identified objects, target dwell time did not differ between congruent (1929ms) and incongruent objects (1802ms), $t < 1$.

Pupil dilation. No differences in average pupil size were found either between identified and unidentified, $t < 1$, or between congruent and incongruent objects when these were identified, $t(17) = 1.20$, $p = .24$, Cohen's $d = .28$.

Retrieval

Target first fixation latency. No differences in target first fixation latencies were found between remembered and forgotten items, $t < 1$, among those that were correctly detected and identified. As in the previous analyses, when we took into consideration exclusively correctly remembered items, we also found the same pattern of shorter latencies for incongruent targets (1441ms) than for congruent ones (1750ms), $t(17) = 4.78$, $p < .001$, Cohen's $d = 1.13$.

Target dwell time (ms). No differences in dwell time were found either between remembered (1886ms) and forgotten (1874ms) items, $t(17) = 1.17$, $p = .258$, Cohen's $d = .28$, or between congruent (1880ms) and incongruent (1822ms) remembered items, $t(17) = 1.26$, $p = .22$, Cohen's $d = .30$.

Pupil dilation. Average pupil size in the change detection phase varied between later remembered and later forgotten trials with smaller pupil dilation for the former ones (3.81mm) than for the latter ones (3.85mm). However, this small difference was small and it does not reach statistical significance, $t(17) = 2.06$, $p = .055$, Cohen's $d = .49$, so caution is required when interpreting this trend. In addition, no differences were found

between congruent and incongruent later remembered objects, $t(17)=1.19$, $p=.25$, Cohen's $d=.28$,

Discussion.

Experiment 3 aimed at characterizing the gaze patterns associated with the three effects provoked by semantic congruity on detection, identification and recognition, namely the CDC, CIB and CRB. We showed that shorter latencies for first fixations on the target were obtained for incongruent trials, and that this difference was highly correlated with the strength of the CDC. Moreover, we also showed that the cumulative probability of fixating the target over the first n -fixations grew faster for incongruent than for congruent targets, which is also an indicator of this early gaze (and arguably attention)-attraction toward the target region (LaPointe & Milliken, 2016). This result suggests that the shorter time required to fixate an incongruent target, due to the attraction provoked by semantic mismatch, is responsible for the CDC. It has been shown that scene viewing is guided by meaning maps even more strongly than by saliency maps (Henderson & Hayes, 2017). Thus, when viewing the scenes of our paradigm attention would be guided endogenously by meaning in a search for a change; however, whenever a mismatch between the meaning map and the bottom-up semantic information of the incongruent object occurs attention would be attracted toward this object.

In addition, we showed that no differences in dwell time were found for congruent and incongruent targets, which suggests that longer dwell time is not responsible for the CIB. Rather, eased accesses to objects' semantic properties is most likely due to semantic pre-activation by priming from context or from neighboring objects (Davenport & Potter, 2004; Eger et al., 2007; Henderson & Hayes, 2017). Likewise, none of the other explored gaze measures was related to the CRB and therefore we argue that it reflects enhanced encoding of information that is schema-consistent. It has been proposed before that, upon appearance, this type of information resonates with our previous schemas about the world and thus the pre-existing connections are strengthened (van Kesteren et al., 2012).

General discussion.

Meaning maps have been shown to guide attention in scene viewing even more

clearly than saliency maps (Henderson and Hayes, 2017), as semantic information can be a useful tool when our system needs to select which type of information to prioritize. Nevertheless, it is not clear which processes and when and how are affected by semantic information in scene processing. Thus, previous studies have offered mixed findings when it comes to object detection, identification and remembering (Henson & Gagnepain, 2010; LaPointe et al., 2013; Stein & Peelen, 2015a; Stein, Siebold, & van Zoest, 2016; van Kesteren et al., 2010). Although extensive research has been conducted on these three processes, very few studies have attempted at pursuing the flow of processing from early perception to remembering. In this study we aimed at characterizing the influence of semantic congruity on these three key steps across the stream of processing; namely, from the moment in which one becomes aware of the presence of an object (i.e., detection), through that in which we gain access to its identity (i.e., identification) to that in which one is confronted with the need to retrieve it from memory (i.e., delayed recognition).

To approach these three sequential steps we have made use of three behavioral indices which result from the semantic relationship established between selected objects and the natural scenes in which they are embedded. The first of these three indices, the CDC, is defined as impaired detection of certain objects when their semantic properties overlap with their surrounding scenes. The second one, the CIB, refers to an improved identification of certain objects precisely when they are embedded in congruent scenes. Finally, the CRB reflects a relative advantage in retrieving those objects when they were presented within a congruent background. In order to deepen our knowledge of the processes underlying those effects, we conducted four experiments in which we explored their underlying mechanisms (Experiments 1A and 1B), the relationship between them (Experiment 2), and the particular gaze patterns associated with each of them (Experiment 3).

Experiment 1A and 1B showed that using scenes involving a large number of objects (i.e., cluttered scenes) was a condition to obtain the CDC. From this pattern of results, it is fair to conclude that object competition could be a crucial mechanism underlying the congruity costs observed in this paradigm in object detection. The change detection task requires participants to explore different objects in the search for a changing one; the CDC effect indicates that such an exploration does not take place

randomly, but it tends to prioritize the processing of incongruent objects. Indeed, even if this exploration is performed on the basis of semantic maps (Henderson & Hayes, 2017) and congruity is guiding standard search, incongruent objects act as a circuit-breaker and capture attention. In other words, this is what could be expected if, against a process of semantic competition between neighboring objects, relatively incongruent objects would tend to win the race for attention. In addition to the implications for the detection process, Experiments 1A and 1B also showed that object competition is not needed to measure the CIB. Our identification results did not differ when object competition was removed by using sparse scenes. Although many different mechanisms can be held responsible for the CIB, some form of propagation of activation from the gist of the scene to the identity of the target could probably be part of the explanation underlying the observed benefit in identification obtained in congruent conditions. However, without a neutral condition, it is hard to ascertain whether the CIB could actually reflect an absolute benefit for the processing of congruent targets, or rather an impairment produced in the identification of incongruent targets (see Ortiz-Tudela et al., *in press*, for a discussion in favor of the latter account).

Experiments 1A and 1B pointed at yet another interesting hypothesis: that object recognition of a group of target items is performed differently depending on the presence of another group of target items which are presented under qualitatively different conditions. Specifically, the CRB that had been reported in a series of previous experiments (Ortiz-Tudela et al., 2016) was completely absent even in the combined analysis performed jointly for Experiments 1A and 2B, with a sample size that doubled those previously used to measure the effect. We reasoned that the inclusion of targets presented in sparse contexts, that produced better memory, could have negatively affected recognition of the remaining targets, thus resulting in the observed absence of CRB. In Experiment 2 we removed these sparse contexts, and the results successfully reproduced the CRB. Even though cautiousness is needed to extract conclusions from both null results and between experiments comparisons, the pattern of results is at least consistent with this encoding competition reasoning (Kaufman & Bolles, 1981; Mackintosh, 1971). Extensive replication of this pattern, as well as new experiments, perhaps measuring delayed object recognition with only sparse conditions, would be needed to strengthen this finding.

Another relevant addition of Experiment 2 was the analysis of memory effects in these conditions, removing the requirement of performing an identification task after the change detection task. Previous studies that have shown the CRB effect could not distinguish whether the effect was due either to processes occurring while participants were trying to detect the target change, or rather if it arose later on, as a byproduct of the subsequent identification task. By removing this latter task, and by observing that the CRB effect survived this removal, one can safely rule out that such explicit requirements were responsible for the CRB effects. Even though one surely cannot claim that target identification processes were completely absent from Experiment 2, identifying those targets was not part of the explicit requirements, and thus surely their import was reduced with respect to previous experiments (Ortiz-Tudela et al., 2016). Indeed, compared to previous studies, experiment 2 produced a much lower recognition rate (38%, compared to an average of 62 % in the experiments reported in Ortiz-Tudela et al., 2016). This result attest to the shallower processing promoted by the conditions arranged in Experiment 2 (Craik & Lockhart, 1972), and therefore indicate that the CRB does not require the deep semantic elaboration brought about by the explicit requirement to identify the target.

Experiment 3 characterized the gaze patterns associated with each of the three main effects studied in this article. We found that the CDC is mostly driven by shorter first fixation latencies and fewer saccades required to detect an incongruent target. Indeed, previous reports of the effect focused exclusively on response times were unable to clarify whether faster detection of a change in incongruent trials could be due either to faster attraction of attention, or to a faster decision produced afterwards. In other words, faster detection times in response to an incongruent trial may be produced because, once detected, participants responded right away, whereas responding to a congruent target might require them to wait until the next display is shown, in order to ascertain that this is precisely the object that is undergoing the change. However, our data point otherwise. The shorter latencies to fixate incongruent targets, together with the higher cumulative probability of early target fixation for incongruent targets, and the lack of significant differences in dwell time between congruent and incongruent targets, all suggest that incongruent objects act as efficient attractors of attention (Hollingworth & Henderson, 2000; LaPointe & Milliken, 2016). Future studies restricting eye movements could further extend this finding and reveal whether shorter

first fixation latencies are a necessary requirement for the CDC or are just one of many other components.

In contrast to what has been observed for the CDC, neither the CRB nor the CIB seem to be strongly related to any of the eye gaze measures considered. Interestingly, our findings are in agreement with LaPointe and Milliken (2016) which also found no differences in dwell time between congruent and incongruent items in a change detection paradigm. They aimed at testing two major accounts proposed for explaining differences in object detection times. One of them, the attention attraction hypothesis, states that context-incongruent objects effectively draw attention and therefore speed detection responses; the other one, the attention disengagement hypothesis, proposes that while the scanning of an image would take place randomly, incongruent objects, when found, force attention to linger on them as a mean of extracting more information and when the change occurs attention is already at the appropriate location. Both LaPointe and Milliken (2016)'s results and the present ones seem to be more consistent with the former claim.

It is worth noting that in our stimulus set, somehow reflecting the real world, there is a marked asymmetry between the amount of congruent and incongruent objects. Indeed, in complex ecological scenes, incongruent objects are, by definition, less frequent than congruent ones. One may argue that this asymmetry could be biasing participants' strategies and affecting some of the processes that we are measuring here. However, removing this asymmetry to equate the number of congruent and incongruent objects is impossible, as congruent objects are part of the scene's nature and therefore largely increasing the number of incongruent objects would change the scene itself; in other words, it would change the meaning map that guides the search (Henderson and Hayes, 2017). Some intermediate attempts can nonetheless be taken, for instance adding a few incongruent non-target objects, to reduce the efficiency of a *search-for-incongruity* strategy.

In the next section, we summarize the major implications of our findings for object detection, object identification and delayed object recognition processes.

Object detection.

Conscious detection of a stimulus is arguably the first gate into awareness.

Although still controversial, evidence in favor of pre-conscious semantic influences on detection has been continuously increasing. Here we have shown new evidence suggesting that object competition is one of the key mechanisms underlying conscious detection. When there is competition among a set of objects that are potential targets, this selection process is not randomly performed, but it is by default guided by semantic congruity (Henderson & Hayes, 2017; Peelen & Kastner, 2014) and it tends to prioritize elements that convey more informational value (i.e., incongruent objects; Santangelo, di Francesco, Mastroberardino, & Macaluso, 2015), and to direct both gaze and selective attention towards those more informative items. Whether object selection occurs first and causes attentional allocation, or the other way round, is a matter for further research. What can be safely assumed so far is that semantic processing (at least at the category level) leads to conscious detection by accordingly biasing attentional allocation and object selection (Mudrik, Breska, Lamy, & Deouell, 2011; Stein & Peelen, 2015a).

Nevertheless, it is worth noting that, although Stein & Peelen's (2015) results reflected influences of semantic information on the access to awareness, their manipulation seemed to exert its influence in the opposite direction. In their paradigm, an anticipatory cue was given to participants in the context of a bCFS task; when the category of the object to be found matched that of the cue, shorter suppression times were measured. In other words, prior semantic knowledge improved its detection. This result is opposite to the CDC reported here. One might claim that the presence vs. absence of object competition could account for the different results obtained in these two paradigms. However, it is important to note that in our sparse conditions, when most competing objects were eliminated, we removed the CDC, but failed to find any benefit from congruity on detection responses. Hence, another line of argument is needed to fully explain the overall pattern.

Finding a cost of congruity on cluttered scenes, no effect of congruity on sparse scenes, and a congruity benefit when the target appears surrounded by random noise, can all be understood as points in a continuum of detection complexity, that probably require the contribution of different priming and competition processes. For instance, in the bCFS paradigm participants need to report the appearance of any object under a gradually fading mask. Under these circumstances, the ability of differentiating a

portion of the display as a meaningful object might be crucial, and thus semantic cues that help to grasp its "objectness" could be seen as an aid to the detection process. By way of analogy, consider the scenario of looking for shapes in the clouds with a partner. If your partner tells you to see a dog, it is not difficult to understand that you would find a dog more easily than something else. On the other side of the continuum, looking for changes in a cluttered scene makes perceiving the *objectness* of an item clearly irrelevant for the task at hand, since a lot of different objects are clearly presented in the area. In these conditions, competition among semantically related objects, or preferential selection of highly informative, or incongruent targets, can bias the process to produce the CDC. Halfway through, from segregating one object from noise to selecting one among different candidates, is the sparse condition. The sparse scene scenario, in which neither visual noise nor alternative objects compete for the detection of the changing object, will constitute an intermediate case in which neither the cost of competition nor the benefit of cueing will be expected (either for the absence of the two or for both mechanisms cancelling each other across different trials).

Object identification.

If one needs to produce a fast and unspecific response whenever something changes, prioritizing the novelty seems in order. However, if the task requires rather to identify a target, then it seems much more appropriate to make use of all available information, including the background image, and the semantic properties of all neighboring objects, in order to help disambiguate the properties of the to-be-identified targets (Biederman, 1972; Eger et al., 2007; Esterman & Yantis, 2010; Gorlin et al., 2012). As early as in 1972, Biederman showed that when an object was surrounded by a congruent context, its identification was better than when participants were cued about what to look for, but they had fewer context information (Biederman, 1972). Thus, it seems that the identification process is not negatively affected by object competition, but instead is positively affected by the priming-like mechanisms that are propagated to the target both from their neighboring objects, and from the overall background. Moreover, these priming processes could be likely related to Stein and Peelen's results and they could reflect improved identification based on prior partial identification by a semantic map-guided search (Henderson & Hayes, 2017).

Delayed object recognition.

Many different factors determine which information is finally remembered or forgotten. Here we explored recognition just as one of the many different ways in which it is possible to assess memory performance. Our results indicate that obtaining a CRB effect for a subset of items may depend, in an integral way, on the full set of items with which this subset was presented. Indeed, the evidence indicates that: 1) For virtually the same subset of items (i.e., comparing Experiment 1B and Experiment 2), the CRB can be present or absent as a function of whether this subset was presented together with another set of items which, as a group, produced better recognition effects (i.e., those presented under the sparse-scene conditions); 2) the CRB is observed even under shallow encoding circumstances, not requiring the identification of each object (Experiment 2); and 3) it is not associated with any of the most commonly used eye movement measures at encoding (Experiment 3). Although more research is needed to further explore these memory results, especially regarding the competition effects obtained when sparse contexts were included, we hypothesize that competing stored representations could interfere with each other at retrieval, and could therefore prevent the expression of contextual influences. It is worth noting that similar effects such as *overshadowing* (Kaufman & Bolles, 1981; Mackintosh, 1971), *verbal overshadowing* (Meissner & Brigham, 2001; Schooler & Engstler-Schooler, 1990) or *retrieval induced forgetting* (M. C. Anderson, Bjork, & Bjork, 1994) have been reported before, and have been argued to be a consequence of a change in the response criterion rather than the result of a difference at the time of encoding (M. C. Anderson, Bjork, & Bjork, 2000; Clare & Lewandowsky, 2004; Storm, Bjork, Bjork, & Nestojko, 2006).

Conclusions.

Across four experiments using a change detection paradigm we explored the influence of semantic congruity on three key stages in the stream of object visual processing. This stream ranges from detection to identification and eventual remembering and we used three semantic effects of congruity, namely CDC, CIB and CRB, as empirical proxies to analyze the dependency of these processes with respect to the semantic factor. We combined online and offline behavioral measures together with eye movements' recordings to characterize the gaze patterns associated with each of these three processes. Our results provide some relevant new evidence on the nature of

these important components of visual cognition, and illustrate the ways in which semantic support and competition can modulate these successive stages in the flow of information processing. The data encapsulated in the present study not only provides important insights into the mechanisms underlying key processes in the stream of visual processing but it also presents a challenging yet very promising approach by studying the same information across different stages of processing rather than by attempting at isolating processes that in the real world are very likely to interact with each other.

Acknowledgments

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Can the dissociation between detection and identification be
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Semantic incongruity attracts attention at a pre-conscious level:

Evidence from a TMS study

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Abstract

Unpredicted objects, i.e., those that do not fit in a specific context, have been shown to quickly attract attention as a mean of extracting more information about potentially relevant items. Whether the required semantic processing triggering the attraction of attention can occur independently of participants' awareness of the object is still a highly debated topic. In the present study we make use of a change detection task in which we manipulate the semantic congruity between the to-be-detected object and the background scene. We applied inhibitory repetitive Transcranial Magnetic Stimulation (rTMS) over the right temporo-parietal junction (right TPJ) and a control location (vertex) to test the causal role of the former in the processing of objects at a pre-conscious level. Our results clearly show that semantic congruity can impact detection and identification processes in opposite ways, even when low level features are controlled for. Incongruent objects are quickly detected but poorly identified. rTMS over the right TPJ effectively diminishes semantic effects on object detection. These results suggest that at least some high order category processing takes place before conscious detection to direct attention towards the most informative regions of space. Moreover, rTMS over right TPJ also impacts object identification, which calls for a re-evaluation of right TPJ's role on object processing.

Introduction

When walking down a street on a regular day, our attention is drawn to certain locations of space based on our previous knowledge of the world, on our current goals, as well as on features of the context in which we find ourselves. Our attention gets oriented without our willingness to do so and, most of the time, without even consciously noticing it. Perceptually salient objects such as those with a strong contrast against the surrounding background, or abrupt onsets, easily capture our attention (Corbetta & Shulman, 2002; Ruz & Lupiáñez, 2002; Theeuwes, 1991, 1992). However, objects can be salient not only perceptually but also because they do not fit in their environment. Surprising and unexpected objects are very easily noticeable even when they do not have a sudden appearance or when they do not perceptually pop out from their context. For instance, coming across a tiger in our backyard is a highly salient event that will certainly catch our eye, whereas finding that very same tiger on a zoo cage will not do so as prominently. What makes this experience even more interesting is that the *surpriseness* of that object is due to its *semantic* relationship with the context in which it is embedded. Why would a tiger-like object be more surprising in a backyard than in a zoo if not because of our previous knowledge of tigers, backyards, and zoos?

Interestingly, a similar life-like situation can be recreated in the lab by means of a change detection task (Rensink et al., 1997), wherein it has been shown that semantically incongruent changes are detected faster than semantically congruent ones (Hollingworth & Henderson, 2000). For instance, and following the example outlined earlier, when looking at the picture of a backyard, detecting a *dog* takes longer and entails a higher probability of missing it than detecting a *tiger*. This surprising finding shows that some properties of these context-mismatching objects capture attention and ease detection. This result was further extended by LaPointe and colleagues, to show that two processes can be dissociated with this paradigm: context congruent changes impair detection, producing detection costs, though, at the same time, favor discrimination, producing discrimination benefits (LaPointe et al., 2013). LaPointe et al.'s dissociation provides a very useful tool to explore the relationship between several object features (from low-level perceptual ones to high-level semantic ones) as well as visual processes such as visual search (Wolfe, 1994; Yantis & Jonides, 1984), attention

allocation (Folk, Remington, & Johnston, 1992; Theeuwes, 1991), or scene encoding (Greene, Botros, Beck, & Fei-Fei, 2015; Peelen & Kastner, 2014).

To date, however, the idea of semantic mismatches attracting attention and biasing access to awareness is still a very hot topic (see e.g., Gray, Adams, Hedger, Newton, & Garner, 2013; Lupyan & Ward, 2013; Rabovsky, Stein, & Abdel Rahman, 2016; Stein, Reeder, & Peelen, 2016; Stein, Siebold, & van Zoest, 2016; Stein & Sterzer, 2012). The existence of these effects somehow demonstrates that semantic processing modulates attentional orienting and, in turn, access to awareness, rather than awareness taking place in the first place, appropriately biasing attention and finally leading to conscious semantic processing.

A widely used model in the study of attentional orienting dynamics is Corbetta and Shulman's (2002) proposal. In their model, the authors argue that while a fronto-parietal dorsal network is in charge of orienting of attention in space, the fronto-parietal ventral network would be responsible for re-orienting attention towards unexpected targets once attention has already been placed somewhere else (see also Corbetta, Patel, & Shulman, 2008; Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005; Macaluso & Doricchi, 2013; Vossel, Geng, & Fink, 2014, for more recent updates of this framework). In particular, within the fronto-parietal ventral network, a specific sub-region of the right posterior parietal cortex (PPC) – the right temporo-parietal junction (right TPJ) – is engaged in processing task-relevant stimuli, particularly when they are unexpected (Geng & Mangun, 2011; Polich, 2007; Verleger, Jaskowski, & Wascher, 2005) or in encoding expectations related to the current environmental and task context (Serences et al., 2005; Vossel, Weidner, Thiel, & Fink, 2009). The right TPJ seems to be more responsive to behavioral/task relevance of stimuli rather than sensory salience *per se* (Indovina & Macaluso, 2007; Kincade et al., 2005). Additionally, right TPJ's activity has been also related to the efficient detection of changes across multiple domains (Downar, Crawley, Mikulis, & Davis, 2000, 2001). Taken together, this evidence suggests that the right TPJ would be implicated not only in the re-orienting of attention by salient objects but generally in the updating of the current context by unexpected and relevant stimuli (Doricchi et al., 2010; Geng & Vossel, 2013).

The present study

In the present study, we further expand our previous work (Ortiz-Tudela et al., 2016) to the neural level to test the causal role of the right TPJ in the processing of categories at a pre-conscious level. We do so by means of the detection/identification dissociation in which context-incongruent objects are detected faster than context-congruent objects but poorly identified. We hypothesize that applying repetitive Transcranial Magnetic Stimulation (rTMS) over the right TPJ would impair participants' ability to quickly re-direct attention in space based on contextual cues, whereas it would not affect discrimination benefits. Our aim is to address two major questions: (1) what is the role of the right TPJ on the unconscious guidance of attention when searching through real-world scenes? and (2) do detection and identification processes involve different cognitive mechanisms with different neural substrates? More specifically, if *detection costs* and *identification benefits* produced by scene semantic congruency are mediated by different systems, recruiting different underlying neural substrates, we would expect the detection cost to be reduced or even eliminated after disrupting activity on the right TPJ (as compared to the vertex disruption), while the identification benefit would remain unaffected.

Methods

Participants

A total of twenty-four healthy volunteers, twelve in each group (TPJ group: 7 female, mean age: 26.2 years old; SD= 3.7; Vertex group: 4 female, mean age: 26.8 years old; SD=4.1) from the University of Granada participated in the study in exchange for a monetary compensation (10 Euros/hour). All of them completed security protocols for both the Magnetic resonance imaging (MRI) and the TMS (Rossi, Hallett, Rossini, & Pascual-Leone, 2009), and signed a consent form approved by the local ethics committee. None of the participants had a history of head injury or physical, neurological, or psychiatric illness. The experiment was conducted according to the ethical standards of the 1964 Declaration of Helsinki (last update: Seoul, 2008). The experiment is part of a larger research project approved by the University of Granada Ethical Committee (175/CEIH/2017).

Behavioral task

On each trial, a rapid alternation of two versions of the same image was presented occupying the totality of the screen. The two versions of the image were identical except for one target object that was digitally added. In between the scenes, a blank screen was included to render the standard flickering appearance (Rensink et al., 1997). Each event (i.e., the two versions of the images and the interleaved blank screens) was presented for 250ms (see Figure 1A). Crucially, the identity of the target object could either match (i.e., congruent trials) or mismatch (i.e., incongruent trials) the gist of the surrounding scene. The scenes used were taken from the pool of images used in previous studies (Ortiz-Tudela et al., 2016), and were constructed so that congruent and incongruent objects did not differ in perceptual saliency (L. Zhang, Tong, Marks, Shan, & Cottrell, 2008b). A total of 240 object-plus-background combinations were used throughout the experiment. Half of the entire set (N=120) was assigned to be used for a given participant (60 for the pre-stimulation block and 60 for the post-stimulation block); the other half of the combinations, which was composed of the complimentary versions of the former half, was used for other participants. In other words, for a given

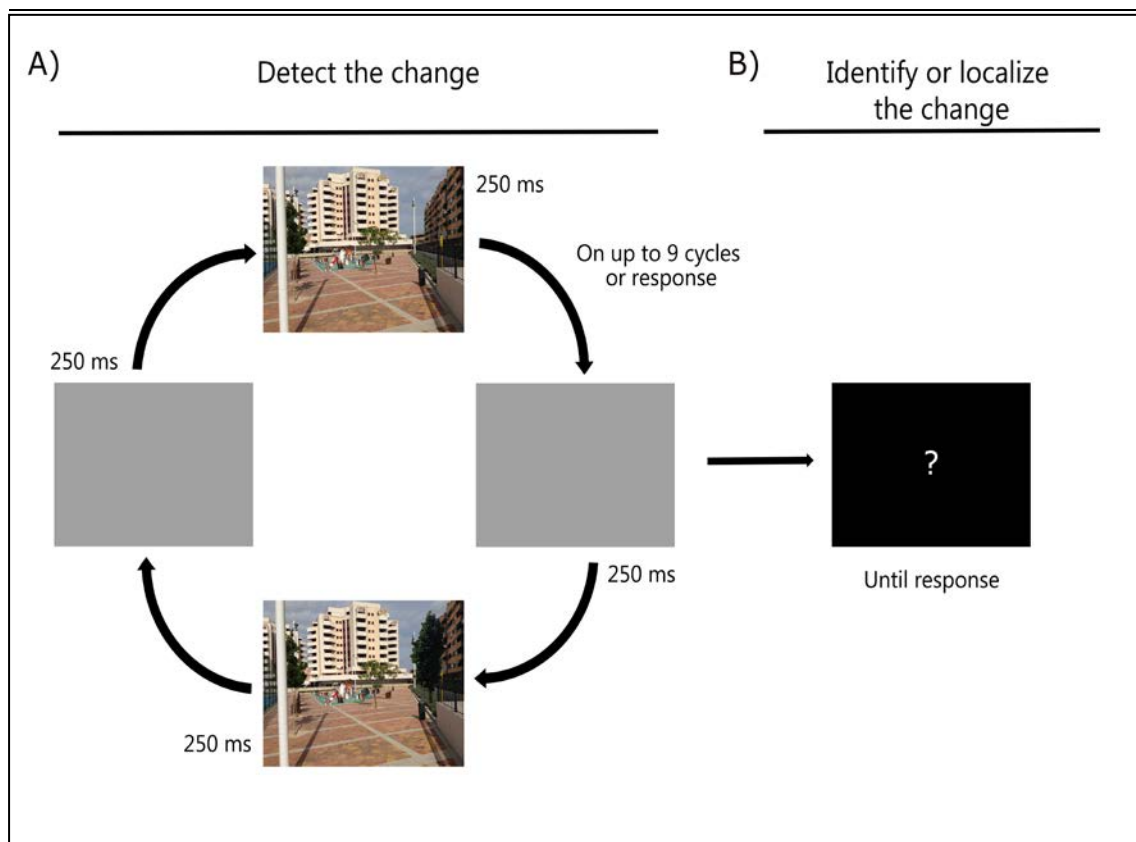


Figure 1. Representation of the trial structure. A) Detection response. B) Identification response.

participant, each target object was only presented once on either a congruent or and incongruent object-background combination. Object-background congruency, as well as the assignment of each target to either the pre or the post-stimulation block, was counterbalanced between participants so that across the entire sample each object was seen on every possible combination of congruency and pre-post stimulation phase.

Participants were required to press the space bar as soon as they noticed a change from one version of the image to the other, even if they were unable to identify the object. Importantly, unbeknownst to the participants, on 10% of the trials the two images were identical, no object was added (catch trials). These trials were included to allow for task performance assessment. This precaution was taken since it has been shown that being aware of the presence of catch trials biases participants' responses (Ortiz-Tudela et al., 2016). After making a response, the alternation stopped, and the image was replaced by a black screen that cued participants to verbally identify the object with one or two words (e.g., “a tiger”) or to indicate its approximate location on the screen (e.g., “top left”) if identification was not possible (see Figure 1B). The experimenter registered participants' responses and these were offline coded later on. Emphasis was made on speed for the change detection task.

TMS protocol

Scalp coordinates for the stimulation sites were located by using the native space of each participant's T1-weighted anatomical magnetic resonance scans, acquired for all participants at the Brain, Mind, and Behavior Research Center (CIMCYC) at the University of Granada. We used a 3-T Siemens magnetization prepared rapid gradient echo, flip-angle = 7, Repetition Time = 2530 ms, Echo Time = 2.5 ms, slice thickness = 1 mm, FOV = 256 mm. These scans were fed into the Brainsight neuronavigation system (Brainsight, Rogue Systems, Montreal, Canada) to perform a sectional and 3D reconstruction of participants' brains and scalp. The TMS coil was controlled by a robotic arm (TMS Robot, Axilum Robotics) with the capacity to estimate and track in real time the relative position, orientation, and tilting of the coil with a precision of 5 mm. Two regions of interest (ROIs) were stimulated in two different groups of participants: the right TPJ, Montreal Neurological Institute (MNI) coordinates: $x=53, y=-40, z=30$ (Corbetta et al., 2000) as the experimental region, and vertex, MNI coordinates: $x=0, y=-34, z=78$ (Heinen et al., 2011) as the control region.

Note that the use of the vertex control was not expected to induce any specific effects based on previous reports (Harris, Benito, Ruzzoli, & Miniussi, 2008; Kalla, Muggleton, Cowey, & Walsh, 2009; Muggleton, Cowey, & Walsh, 2008). Note also that due to the reduced number of available stimuli for this type of ecological materials and in order to avoid unknown effects of extended practice on participants' strategies a between-participants approach was adopted.

Repetitive TMS (rTMS) was delivered by means of a biphasic repetitive stimulator (Super Rapid 2, Magstim, Withland UK) and a 70 mm TMS figure-of-eight coil (Magstim, Withland UK) positioned at 45° respect to the scalp (Lazzaro et al., 1998). rTMS patterns consisted of 1200 pulses applied at 1 Hz with an inter-pulse interval of 1s, for a total of 20'. Previous studies have suggested that this protocol transiently reduces cortical excitability in motor regions outlasting for approximately 50% of the stimulation duration (Boroojerdi, Prager, Muellbacher, & Cohen, 2000; Chen et al., 1997; Hilgetag, Théoret, & Pascual-Leone, 2001; Maeda, Keenan, Tormos, Topka, & Pascual-Leone, 2000; Valero-Cabré, Payne, & Pascual-Leone, 2007). The time window of reduced excitability in our study was then estimated in about 10' – which should cover most of the duration of the post-stimulation block.

We individualized TMS intensity for each participant by stimulating at an intensity of 100% of their resting motor threshold (rMT)⁶. Electromyography (EMG) and motor evoked potentials (MEPs) were recorded from the first dorsal interosseous (FDI) of the left hand by using snap surface electrodes (Natus Neurology). The rMT was defined as the minimal intensity of stimulation applied over the primary motor cortex necessary to induce a 50 μ V response on 5 out of 10 times (Rossini et al., 2015). The average stimulation intensity for the whole sample was 62% (SD: 6.9) of the stimulator maximum output (MSO). Thresholds were similar for both the right TPJ and vertex groups (right TPJ: 60%MSO, SD=10.1; vertex: 62% MSO, SD=4.0).

Session structure design

Each participant completed a pre-stimulation block of 60 change detection trials (approximate duration: 10'), then a stimulation period of 20', and lastly a post-

⁶ Higher intensities induced facial sensations, involuntary blinks, or jaw movements.

stimulation block identical to the pre-stimulation block (see also Figure 2 and 3 for a graphical depiction of the session structure). At the end of the session, participants completed a questionnaire regarding the strategies they used to approach the change detection task. In between periods, experimenters performed the set-up of all the instruments involved, which took approximately 4-5' on each in-between period, making the total duration of the session to add up to 60 minutes.

Results

For the analysis of mean reaction time (RT), trials in which the target change was missed (8%) and those with correct responses but with RT 4 SD above each participant's mean were excluded (23 observations; .67% of trials). Both a Null Hypothesis Significance Testing and a Bayesian approach were taken for all the analyses.

A first analysis was conducted on the data obtained on the pre-stimulation block to assure that the paradigm produced the expected results and to test for possible between-groups differences before stimulation. The analysis for Detection accuracy (proportion of misses), mean RT, and Identification accuracy (% of identification errors) revealed a significant main effect of congruity, $F(1,22)= 34.83$, $p<.001$, $\eta_p^2=.62$, $BF_{10}=14,150$, $F(1, 22)=39.49$, $p<.001$, $\eta_p^2=.64$, $BF_{10}=10,974$, and $F(1,22)= 36.20$, $p<.001$, $\eta_p^2=.62$, $BF_{10}=15,480$, respectively. Thus, as expected based on previous findings (Hollingworth & Henderson, 2000; LaPointe et al., 2013; Ortiz-Tudela et al., 2016), longer RT and more misses were observed for congruent than for incongruent trials (see Table 1). The impaired detection for congruent as compared to incongruent trials was even clearer in the combination of these two variables in a *detection efficiency* index (Mean RT/Detection accuracy), $F(1,22)= 49.71$, $p<.001$, $\eta_p^2=.69$, $BF_{10}=83,064$. In contrast, fewer identification errors were made on congruent than on incongruent trials, showing discrimination inefficiency for the former. Note that the two groups were equivalent, as no effect of group or interaction between group and congruency were observed with any of the dependent variables (all $F_s < 1$ and $BF_{10} < .4$).

Since the set-up of the robot and the stimulator took longer than expected (see Figure 2 for an approximate representation of the timing of the procedure), we analyzed the temporal dynamics of TMS in both groups. An analysis was performed to compare groups' performance on the first half of trials after stimulation and the second half of

trials after stimulation, in order to evaluate whether the right TPJ stimulation modulated the observed congruency effect after the stimulation, and whether the modulation occurred across the whole post stimulation block.

In the first half after the stimulation, the analyses of both mean RT and detection accuracy revealed a reduction in the congruency effect after the right TPJ stimulation (see Table 1), although in neither case the group x congruency interaction was significant, $F(1, 22)=1.76$, $p=.198$, $\eta_p^2=.04$, $BF_{10}=.7$, and $F(1, 22)=1.46$, $p=.240$, $\eta_p^2=.04$, $BF_{10}=.8$. Nevertheless, combining these two measures in the *detection efficiency* index showed that the congruency effect was marginally reduced in the right TPJ stimulation group as compared to the vertex group, $F(1, 22)=3.66$, $p=.069$, $\eta_p^2=.14$, $BF_{10}=2$ (see Figure 2). Unexpectedly but interestingly, the results also showed a significant interaction between group and congruency in identification errors, $F(1, 22)=6.33$, $p=.020$, $\eta_p^2=.15$, $BF_{10}=3.29$ in the first half after the stimulation period (Figure 3). The vertex stimulation group showed a significant effect of congruency, $F(1, 22)=19.71$, $p<.001$, $\eta_p^2=.66$, $BF_{10}=117.7$, with more errors for incongruent than for congruent trials. In sharp contrast, the congruency effect was completely absent in the right TPJ stimulation group ($F<1$, $BF_{10}=.33$). To further explore this unexpected result, a repeated measures ANOVA was performed for each group with Phase (pre-stimulation vs. first half post-stimulation) and Congruency (congruent vs incongruent) as within-subjects factors. The analysis of the vertex group showed the congruency effect was not significantly different before (15%) and after stimulation (17%, $F<1$, $BF_{10}=.40$). Conversely, in the right TPJ stimulation group, the effect was significantly reduced after stimulation (3%) as compared with the pre-stimulation block (13%), $F(1, 11)=9.37$, $p=.011$, $\eta_p^2=.46$, $BF_{10}=73$ (see Figure 2). Interestingly, post-hoc Tuckey comparisons revealed that the reduction in the congruency effect was due to better identification of incongruent objects in the post-stimulation block when compared with pre-stimulation one ($p=.036$). In other words, identification for context-incongruent objects was improved after rTMS over the right TPJ but not over the vertex.

Table 1. Mean RT and percentage of accurate detection responses (in parenthesis) for object detection, and percentage of accurate responses for object identification, for each experimental condition on each phase of the experiment (pre and post stimulation and halves in the post-stimulation block).

ROI	Object Detection				Object Identification							
	Pre		Post		Pre		Post					
	1st half		2nd half		1st half		2nd half					
C	|	C	|	C	|	C	|	C				
TPJ	2067 (0.87)	1699 (0.96)	1858 (0.88)	1612 (0.94)	1958 (0.91)	1492 (0.93)	0.80	0.67	0.82	0.79	0.85	0.79
Vertex	2199 (0.88)	1828 (0.96)	2349 (0.88)	1859 (0.98)	1912 (0.91)	1614 (0.97)	0.85	0.70	0.88	0.71	0.84	0.77

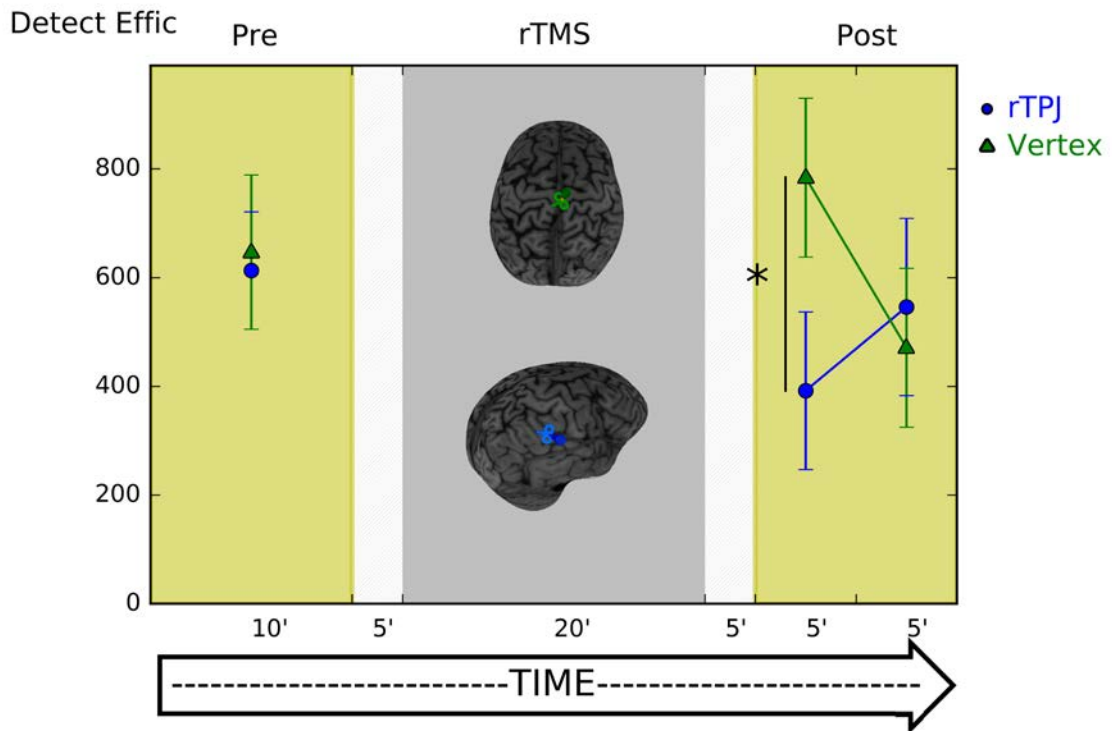


Figure 2. Congruity effect (congruent – incongruent) on efficiency index for the two stimulation conditions (right TPJ, in blue, and vertex, in green). The relevant phases for task analysis are, from left to right, before stimulation (10'), first block after stimulation (5'), and second block after stimulation (5'), with an approximate 4-5' preparation delay between the end of the stimulation and the beginning of the post-stimulation phases. A 3D representation of the two areas of stimulation is included.

In the second half after the stimulation, the analysis showed again a main effect of congruency in mean RT, $F(1,22)= 20.01$, $p<.001$, $\eta_p^2=.46$, $BF_{10}=325$, *detection efficiency*, $F(1,22)= 21.61$, $p<.001$, $\eta_p^2=.49$, $BF_{10}=643$, and Identification errors ($F(1,22)= 4.42$, $p=.047$, $\eta_p^2=.17$, $BF_{10}=2$). The effect was absent in detection accuracy, $F(1,22) = 2.37$, $p=.13$, $\eta_p^2=.10$, $BF_{10}=1$. Finally, the group factor did not modulate the effect of any other dependent variables (all $F_s < 1$ and $BF < .8$).

To sum up, the right TPJ stimulation seemed to eliminate or reduce the effect of congruency, although the effect was only significant with identification errors, marginally significant with *detection efficiency*, and only lasted for approximately 10' reaching about half of the trials after stimulation. Caution is needed when drawing strong conclusions, however, since we acknowledge that the split-half analysis was performed based on procedural reasons and not on statistical ones. Exhaustive replication of these data is essential to consolidate the findings reported here.

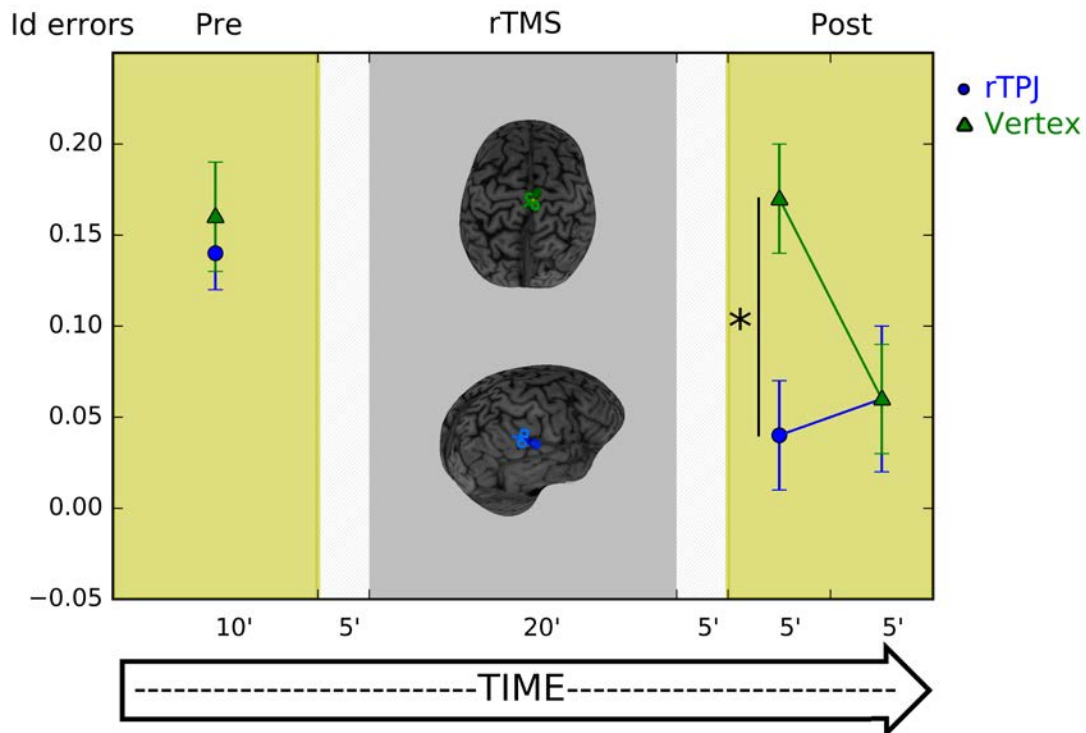


Figure 3. Congruity effect on identification errors (incongruent – congruent) for the two stimulation conditions (right TPJ, in blue, and vertex, in green). The relevant phases for task analysis are, from left to right, before stimulation (10'), first block after stimulation (5'), and second block after stimulation (5'), with an approximate 4-5' preparation delay between the end of the stimulation and the beginning of the post-stimulation phases. A 3D representation of the two areas of stimulation is included.

Discussion

The aim of this study was to explore the interplay between unconscious semantic processing and attentional allocation during scene viewing at the neural level. We did so by applying offline inhibitory rTMS combined with a change detection task with context-congruent and context-incongruent target objects. We compared participants' performance before and after stimulation with an active vertex control group. Right TPJ activity has been related to attentional orienting/re-orienting (Bourgeois, Chica, Valero-Cabré, & Bartolomeo, 2013; Corbetta et al., 2000a) and contextual updating (Doricchi et al., 2010; Geng & Vossel, 2013). We therefore hypothesized that this region would be important for target *detection*.

Our *pre-stimulation* results appropriately replicated the two processes dissociation of object perception (LaPointe et al., 2013; LaPointe & Milliken, 2016; Ortiz-Tudela et al., 2016) ensuring that semantic processing of the scene was

effectively biasing attention allocation towards the most informative region of space – i.e., attention was attracted to semantically incongruent objects. These results demonstrate that some form of semantic processing must take place before conscious access, at least at the category level. Indeed, since we controlled for low-level differences in saliency (L. Zhang et al., 2008b) between congruent and incongruent trials, the most plausible cause for the asymmetrical behavioral patterns in detection and identification tasks is the semantic fitness of the object with its surrounding context. However, in order to notice a specific object-context mismatch it is enough to access its belonging category and contrasting it to the gist of the surrounding scene. In other words, it suffices to know that an item is an animal-like object to notice that it does not belong in a city-like environment.

Our *post-stimulation results* show an interaction between the region of stimulation and the target-context combination for both object detection and—unexpectedly— object identification. This interaction will be described and discussed in the following sections.

Right TPJ's involvement in object detection/identification

Activity in the right TPJ has been correlated (Corbetta & Shulman, 2002; Vossel et al., 2014) and causally related (Chica, Bartolomeo, & Valero-Cabré, 2011) to attentional performance in a wide range of tasks in healthy populations. Evidence from clinical patients also suggests that its proper functioning is critical for an appropriate attentional allocation. For instance, studies in neglect patients (Bartolomeo & Chokron, 2002; Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Posner, Walker, Friedrich, & Rafal, 1984) have supported the role of the right TPJ in spatial attention by showing an impaired ability to adequately shift attention toward regions of a scene located contralaterally to the brain lesion (Bartolomeo, Schotten, & Chica, 2012).

Interestingly, it has been reported that when looking at pairs of objects, neglect patients tend to miss the object placed contralaterally to the lesion, which is known as *extinction*. This deficit is especially pronounced when the stimulus presented in the ipsilateral field shares the same meaning and elicits the same action as the one presented on the contralateral field (Baylis et al., 1993; Bender & Furlow, 1945; Rafal, Danziger, Grossi, Machado, & Ward, 2002). In other words, extinction refers to a *cost*

in detecting a particular item especially when it shares some specific features with a competing one; this cost can be overridden when the two objects' features mismatch. Although evidence for this effect is sparse, it suggests that a representation of the two objects and their attached responses can be established unconsciously and is capable of biasing attention allocation, modulating conscious access.

Our study deepens in this idea by showing that temporally inhibiting right TPJ's activity with rTMS hinders efficient incongruent-object detection. Indeed, when contrasting rTMS over the right TPJ versus the vertex, the former critically reduces the congruity effect on detection efficiency. Although caution is needed when drawing conclusions from this interaction since we did not obtain strong statistical support – most likely due to not having enough statistical power – the fact that the uncovered pattern follows our a priori predictions and is in line with previous literature supporting the involvement of right TPJ in object detection (Corbetta et al., 2000a; Kincade et al., 2005) makes it worth considering. Besides, this result also extends previous findings since it is, to our knowledge, the first demonstration of the right TPJ's involvement in attentional (re-)orienting associated with a semantic incongruity. It is also worth noting, however, that on a different field of research, the right TPJ's activity has been related to humor processing (Bekinschtein, Davis, Rodd, & Owen, 2011; Samson, Hempelmann, Huber, & Zysset, 2009), especially when a semantic incongruity resolution is involved in the joke (Chan & Lavalley, 2015).

More interestingly, our results also show that rTMS over the right TPJ causes a reduction in the congruity effect for *identification scores*. This unexpected finding calls for a reanalysis of the assumed role of the right TPJ in object processing (Doricchi et al., 2010). Consistently, Doricchi et al.'s proposal challenges the relationship between right TPJ's activity and object detection (see also Geng & Vossel, 2013, and Macaluso & Doricchi, 2013, for updated versions of this proposal). The authors argue that the set of – sometimes contradictory – evidence on right TPJ's activity can be better accommodated by an account that signals contextual updating as the main function of this region. They argue that post-perceptual processes and readjustments of top-down expectations are much better candidates since (1) the right TPJ responds to target appearance later than other brain regions such as Frontal Eye Fields (Meister et al., 2006; Mohler, Goldberg, & Wurtz, 1973) and (2) the left TPJ also responds to target

object onsets but does so for those that match expectations and those that do not, whereas right TPJ only responds for expectation-mismatching ones (Doricchi et al., 2010). This proposal is congruent with the idea that the right TPJ may encode expectations regarding the relationship between a sensory stimulus and the context-appropriate action (Downar et al., 2001; Geng & Mangun, 2011).

The results reported here can complement this new framework by assuming that context (or expectation)-mismatching objects might require a re-evaluation of the initial gist of the scene, recruiting the right TPJ. This re-evaluation would, in turn, act as circuit breaker for the identification process, stopping it from developing any longer and leading to a poor identification. Complimentarily, this abrupt stopping of the identification process would allow a fast response of the detection one. Therefore, we argue – while speculative – that in the experiment reported here rTMS over the right TPJ would prevent the abortion of the identification process which would improve identification scores for context-mismatching objects at a cost on their detection (Doricchi et al., 2010; Geng & Vossel, 2013; Macaluso & Doricchi, 2013). Note in Table 1 that the lack of congruency effect after rTMS over right TPJ is not due to any hindering effect on the congruent condition after stimulation (.80 before vs. .82 after stimulation), but to a recovery in the incongruent condition (.67 before vs. .79 after stimulation). Thus by stimulating the right TPJ, rather than hindering identification performance on congruent trials what seems to be happening is that identification of incongruent trials is improved by preventing the abandonment of the identification process. Future research, perhaps with a comparison between rTMS over both right and left TPJ, would help clarifying the specific role of right TPJ and disentangling the interaction between pure object detection and semantic incongruity processing. In addition, an exhaustive exploration of the temporal involvement of the right TPJ in the present task would provide very interesting information. Indeed, two different types of TPJ's activity have been shown to underlie contextual updating. One of them is related to preparatory orienting of attention (Doricchi et al., 2010; Shulman, Astafiev, McAvoy, D'Avossa, & Corbetta, 2007, for corresponding event-related potential evidence see Lasaponara et al., 2017 and Lasaponara, Chica, Lecce, Lupianez, & Doricchi, 2011) and the other one reflects a specific activation for context-mismatching targets (Geng & Mangun, 2011). In the present study, it is impossible to distinguish the separate contribution of each of them and the consequences of disrupting one or the

other since the repetitive off-line protocol likely suppresses both of them. An online stimulus-locked study would offer valuable information into which one of the two types of activity is crucial for object detection and object identification in ecological set ups.

In the next section, we further discuss the implication of the present set of results at the cognitive level for the two processes involved (i.e., object detection and object identification) and offer an alternative explanation for the unexpected identification pattern.

Two processes fully dissociated?

The classical temporal dynamics of object detection and object identification reports tells us that the former necessarily occurs *before* the latter (Holender, 1986). However, whether they constitute two independent processes or two sides of the same general object-processing coin is still to solve (LaPointe & Milliken, 2016; Ortiz-Tudela et al., 2016; Stein & Peelen, 2015a). The rTMS approach used here attempted at affecting one of them without impairing the other. As noted before, while the right TPJ's involvement in object detection has been previously reported (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000b; Natale, Marzi, Girelli, Pavone, & Pollmann, 2006; Shulman et al., 2010), its relation with object identification is not so clear (but see Marois, Leung, & Gore, 2000; Geng & Vossel, 2013). Here we show that rTMS over the right TPJ impacts both object detection and object identification, as the congruity-mediated dissociation was equally modulated by the disruption of the right TPJ's activity. Does this result mean that detection and identification processes are not fully dissociable? In our opinion, it does not. What it does is to soften the distinction between the two and to point at the fact that, even if independent, the two processes need to closely interact with each other.

In our framework this result can be interpreted as two independent but interactive processes influencing each other by means of shared operations (and neural substrates) such as contextual elaboration, object segregation, or schema completion. While regions more specialized on object detection and object identification could be located somewhere else in the brain (Bar et al., 2001; Malach et al., 1995), the right TPJ would be a common hub for these two processes – see section above. Thus, we need to consider more complex models of scene processing than just two independent

sequential processes (Marois et al., 2000). Probably both object detection and object identification engage into interactive dynamics in the sense *predictive coding* models propose: feedforward connections modulate object identification from object detection and conversely, feedback relations bias object detection from the accumulative knowledge acquired through recursive partial-identification (Rao & Ballard, 1999; Summerfield et al., 2006). Several of these iterations would be necessary for information to (resonate and) access consciousness. However, as it has been shown in the present set of results, pre-conscious recursive scene processing would be able to appropriately guide attention towards certain regions of a given context.

Finally, it is worth noting that analyses of the post-stimulation data on the right TPJTMS group revealed that identification levels for context-incongruent objects were brought up to context-congruent levels. This result also calls for a re-evaluation of the explanation given to the congruity effect on identification (LaPointe et al., 2013; Ortiz-Tudela et al., 2016). It has been previously argued that the differential performance on identification of congruent and incongruent objects could be explained in terms of semantic priming from the gist of the background scene to the identity of the object. This priming influence would be beneficial only for context-congruent objects thus rendering the previously observed pattern both in online reports and offline delayed memory test (LaPointe et al., 2013; Ortiz-Tudela et al., 2016). However, this account would have problems explaining why inhibiting activity on the right TPJ would boost incongruent object identification. Here we speculate in two different alternatives that should be tested in future studies: (1) In standard situations, the identification process is gradually performed by building up the meaning of the available targets. When an incongruity is found, this process is aborted in favor of a rapid and unspecific conscious detection. Inhibiting activity in the right TPJ would prevent this abortion thus allowing the identification process for incongruent targets to reach that of congruent targets based solely on object information; (2) The inability to properly use contextual cues to facilitate identification would come from the setting up of a contextual schema that would not ease (at least not only) the identification of new schema-congruent objects but which would also inhibit or impair – through implausibility discard or erroneous inferences – schema-incongruent objects (see Van Kesteren, Ruiters, Fernández, & Henson, 2012, for a similar reasoning on memory formation for schema-incongruent objects). Therefore, preventing this schema-formation would allow incongruent objects

to be properly identified. Future research is needed to fully understand this pattern of results.

Conclusions and future directions

Whether attention can be drawn unconsciously to specific objects that semantically mismatch a particular scene is a very interesting and still highly-debated topic. In the present paper we offer evidence from an ecologic paradigm of semantic processing taking place prior to conscious access that effectively biases attention. In addition, our results further extend previous research pointing at the relevant causal role that the right TPJ has on attentional orienting driven by semantic incongruity showing that one can successfully reduce attentional effects by inhibiting activity in that area. Future research is needed to further extend these results by exploring the temporal dynamics of the right TPJ's involvement in object processing. Does TPJ act right after the detection of the incongruity takes place? Does it have any partial role in the processing of the incongruity itself? How does it interact with object identification? All these questions will provide important information about the interplay between attention and pre-conscious processing.

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CHAPTER V: DISCUSSION

Processing and responding to an environment as complex and rich as our world is a challenging endeavor with which our cognitive system deals efficiently. The predictive coding perspective offers an appealing account for such a fact. Under this framework it is assumed that our cognitive system's default mode of functioning is to anticipate upcoming inputs based on previous knowledge about the regularities inherent to our world. In addition, it is also assumed that unpredicted events have a prominent role as they represent a failure of the system's main function but, at the same time, they signal the presence of new information that, if captured, can improve future predictions. This dissertation has aimed at testing some of this framework's main assumptions regarding both immediate and delayed consequences of violated predictions.

In this final section we will more deeply discuss the most relevant findings of the present work.

On the search for a pure prediction error

Most of the models assuming prediction as our system's main function assign a central role to prediction errors (Henson and Gagnepain, 2010). Indeed, events that are ill-predicted have been shown to correlate with physiological (Braem et al., 2015), electrophysiological (Wacongnea, et al., 2011; Yabe et al., 1997; Todorovic et al., 2011; Parmentier, 2011) and neural activity (d'Acremont et al., 2009; O'Doherty et al., 2004; McClure et al., 2003; Preuschoff et al., 2008) measures. They are often assumed to represent some form of signal that our system can utilize to increase encoding of potentially relevant events with the ultimate goal of improving future predictions. This prediction error-triggered learning, which origins can be traced back to Rescorla and Wagner's early 70's proposal, is at the basis of many cognitive, neural and computational models. From the initial proposals to state of the art complex models, the core assumption remains: prediction error leads to increased encoding (Henson and Gagnepain, 2010; Verguts & Notebaert, 2008; Rescorla & Wagner, 1972; Van Kesteren et al., 2012; for classical experimental back up of these predictions see Bowles & Glanzer, 1983; Kinsbourne & George, 1974; E. Tulving, Markowitsch, Craik, Habib, & Houle, 1996; E Tulving & Kroll, 1995; and for more recent ones see Krebs et al., 2015; Rosner et al., 2016).

However, regardless of how appealing and easy to understand these models'

assumptions can be, there is still a gap between modeling and experimental testing. Most of the experiments designed under this framework necessarily include some confounds that weaken the strength of the conclusions drawn regarding prediction error. Surrounding factors such as cognitive effort, depth of processing or motivation are often intermingled with prediction error itself. Based on the existing literature, it is therefore difficult to make strong claims about the effects of a domain general mismatch between expectations and actual inputs.

In the first experimental series we aimed at isolating the effects of pure prediction error from other confounding factors. To that end, we used a basic Posner cueing paradigm to generate and to either fulfill or break predictions about the location of upcoming stimuli; later on, we tested memory for our stimuli using a recognition memory test. Our results revealed that when prediction error was induced by means of a spatial expectancy in isolation from other factors, no memory advantage was observed. This conclusion drawn from the absence of an effect was backed up by extensive replication of the phenomenon (across seven experiments) and by Bayesian statistics.

In light of the results reported in Chapter II, we argue that prediction error in isolation, in spite of generating the usual costs in immediate processing of the stimulus, is not able to generate a boost in encoding. The presence of confounding factors in previous studies might have acted as an intermediate variable linking expectation mismatch to enhanced encoding. For instance, it is possible that certain paradigms promote a stronger and deeper elaboration of the information presented on expectation mismatching trials (Krebs et al., 2014; Rosner et al, 2015); it is also possible that increased attention to distinctive stimuli (von Restorff, 1933) can be responsible for an encoding enhancement, which will not take place for expectation matching stimuli. Lastly, other strange variables such as the re-evaluation of the causes for the mismatches or the experimenters' aims (Brewer & Treyens, 1981) can boost post-perceptual elaboration in some paradigms. In conclusion, an operative definition that conveys all the mandatory requirements for a mismatching event to trigger learning mechanisms is needed.

Prediction in the real world

Whereas aseptic inside-the-lab situations often offer great experimental control about many variables, it is also important to attempt at recreating more life-like situations. In Chapter 1 we showed that, in very controlled situations immediate consequences of simple and aseptic prediction error, on the basis of spatial expectancies, are easily obtained but that long-term memory consequences can be elusive. However, in outside-the-lab situations, the expectations we generate are usually based on contextual information. Besides the structural low-level factors that can anticipate certain types of stimuli, most of the information we use to predict upcoming stimuli is semantic in nature. Therefore, in the following experimental series we decided to test the role of prediction errors arising from semantic expectation mismatches during processing of objects embedded within real world scenes, from their immediate consequences on object perception to their delayed ones on later recognition. How do predictions modulate information processing in ecological scenarios? Can we measure immediate and delayed consequences of predictions and prediction errors when these are based on prior knowledge?

While accurately recreating real-world scenarios inside the lab can be difficult sometimes, intermediate attempts, such as using ecological stimuli, can be taken. In the second, third and fourth experimental series we used a flickering change detection task (Rensink et al., 1997) to mimic real-life scenarios in which one can be faced with expected and unexpected objects. Previous research on scene processing using semantic information as an independent variable has shown that objects that are unexpected on a given context quickly attract attention and thus, their detection is facilitated (Hollingworth and Henderson, 2000; Stirr and Underwood, 2007) but, at the same time, they lack a coherent schema in which they can be inserted and thus, their identification is impoverished (LaPointe et al., 2013; LaPointe and Milliken, 2016). Furthermore, and importantly, according to prediction error-triggered learning models unexpected objects ought to be also better remembered than expectation matching ones. However, our results point otherwise.

In the next section, we review previous research on both immediate and delayed consequences of predictions established based on previous knowledge of real-world associations and incorporate our results onto them.

Object detection

Realizing that something has appeared where nothing was before is arguably the first gate into conscious processing. This unspecific realization of the presence of a *novel* stimulus is what it is often referred to as the detection process. For over a century already, scientists have debated over whether that process can be modulated by internal states such as attention. As early as 1908, the law of prior entry was enunciated by Titchener (1908, p.251) as “*the object of attention comes to consciousness more quickly than the objects which we are not attending to*”, and in spite of the antiquity of the quote, little consensus was achieved before the early 2000’s (Mollon & Perkins, 1996; Scharlau, 2007; for a review see Shore, Spence, & Klein, 2001). Today, evidence on the matter is still being collected.

One of the key variables that have been used to address the issue of prior entry is perceptual saliency (Koch and Ullman, 1985; Itti and Koch, 2000; Posner and Cohen, 1984). This term refers to the conspicuity of a given item with respect to its surroundings irrespective of specific features (Koch and Ullman, 1985). Evidence in support of the idea of attentional allocation being influenced by saliency comes from behavioral studies (Awh, Belopolsky, & Theeuwes, 2012; Shore et al., 2001; Theeuwes, 2010, 2013), animal research (Yoshida et al., 2012) and neuroimaging data (Betz, Wilming, Bogler, Haynes, & Konig, 2013; Bogler et al., 2011; Li, 2002; Nardo, Santangelo, & Macaluso, 2011; X. Zhang, Zhaoping, Zhou, & Fang, 2012). For instance, Bogler, Bode and Haynes (2011) showed that saliency related activity can be decoded from specific regions of the posterior parietal cortex (PPC; see also Nardo et al., 2011, for converging evidence) a region which activity has traditionally been related to a wide range of attentional tasks (Corbetta & Shulman, 2002; Vossel et al., 2014; Chica et al., 2011).

However, attention allocation is not guided merely by low-level perceptual factors. Top-down mechanisms have also been shown to guide attention independently and even beyond saliency (Einhäuser, Rutishauser, & Koch, 2008; Henderson, Brockmole, Castelano, & Mack, 2007; Humphrey & Underwood, 2009). Conscious spatial expectancy based on external cues also directs attention toward relevant regions of the space accordingly. For instance, predictive central cues are capable of biasing people’s visual processing of different regions of space in a controlled, volitional

manner. This so called endogenous orienting has been shown to be qualitatively different than a more automatic attentional orienting based on peripheral non-predictive cues with abrupt onsets (i.e, exogenous orienting; Chica & Lupiáñez, 2009; Chica, Lupiáñez, & Bartolomeo, 2006).

Besides endogenous attentional orienting, top-down influences on detection have also been widely studied by using semantic information about relationships between objects. By manipulating the consistency between a given object and the background in which it is embedded it is possible to generate semantically coherent (or incoherent) scenarios. Several reports coming from behavioral (Becker, Pashler, & Anstis, 2000; Coco, Malcolm, & Keller, 2013; Gordon, 2004; Henderson & Hayes, 2017; Henderson et al., 1999; Hollingworth & Henderson, 2000; Mudrik et al., 2011; Spotorno, Tatler, & Faure, 2013; Stirk & Underwood, 2007; Torralba et al., 2006; Underwood & Foulsham, 2006; Underwood, Templeman, Lamming, & Foulsham, 2008; Vo & Henderson, 2009) and neuroimaging studies (Rémy, Vayssière, Pins, Boucart, & Fabre-Thorpe, 2014; Santangelo et al., 2015) have shown that semantic manipulations determine priority selection.

For instance, Henderson and Hayes have recently shown that decomposing a given scene into so called *semantic maps* is a much better predictor of people's attentional guidance during the visual exploration of a scene than low-level saliency (Henderson and Hayes, 2017). Even stronger evidence can be found from brain stimulation studies in which stimulation is applied over regions higher in the hierarchy than the visual cortices such as the parietal cortex (Beck, Muggleton, Walsh, & Lavie, 2006; Chica et al., 2011; Reeder, Perini, & Peelen, 2015). Take for instance Reeder, Perini and Peelen study (2015). The authors applied TMS over the posterior temporal cortex while subjects were cued to detect specific objects on natural scenes. Their results showed that TMS over the posterior temporal cortex impaired participants' performance which points to a direct relationship between previous semantic knowledge (Peelen and Kastner, 2011) and object detection (see Beck et al., 2006 for related findings).

The results of the second experimental series replicate previous reports of change detection being facilitated by contextual incongruity (Hollingworth and Henderson, 2000; LaPointe et al., 2013; LaPointe and Milliken, 2016). On the third experimental

series we further extended these findings by showing that object competition (Baylis & Driver, 1993; Duncan, 1984; Egly, Driver, & Rafal, 1994; Potter & Fox, 2009) seems to be the factor impacting the detection process. By using cluttered and sparse natural scenes we were able to demonstrate that some contextual effects on detection depend on the presence (or absence) of competing objects (see Gronau & Shachar, 2015, for a discussion on the impact of multiple competing objects on perceptual processes). Finally, the results reported in the fourth experimental series on the effects of rTMS over right TPJ strengthen the idea that parietal regions have an important role on the detection process (Corbetta and Shulman, 2002; Vossel et al., 2014; Santangelo et al., 2015) by showing that suppressing activity in that region can modulate contextual influences on detection.

Together, the findings of the second, third and fourth experimental series point to the relevance of top-down mechanisms in early stages of processing (i.e., detection) which were traditionally thought to be semantics-free. We have shown that not only a semantic schema can ease the detection of certain objects, but also that it does so by prioritizing those objects over others when the amount of likely candidates exceeds our attentional capacities.

Object identification

Accessing an object's identity requires to analyze it beyond its basic, low-level features. When viewing complex visual scenes, object identification is facilitated on the basis of contextual information (Biederman, 1972). Pre-existing knowledge on object-to-object or context-to-objects relationships can boost object identification by dynamically updating the expectations of upcoming items not yet identified (Eger et al., 2007; Esterman & Yantis, 2010; Gorlin et al., 2012; Gronau & Shachar, 2015; Summerfield et al., 2006).

The results reported on the second and third experimental series of the present work are consistent with classic (Biederman, 1972) and recent (LaPointe et al., 2013) research by robustly replicating contextual semantic facilitation for object identification. Furthermore, they also strengthen previous reports of the dissociation between detection and identification (LaPointe et al., 2013) by showing that basic mechanisms such as object competition can have an influence over the former but not

the latter. More concretely, on Experiment 1A and 1B of the third experimental series we used two different sets of stimuli in which we manipulated the presence/absence of non-target distracter objects. The detection results of both experiments showed that the congruity detection cost is lost when no competing distracter objects are presented indicating that object competition can effectively bias the detection process. Conversely, the identification results proved that, even under these low-competition conditions, the identification benefit for context-congruent objects is preserved which further bolsters the dissociation between the two processes. Finally, the results of the fourth experimental series showed that rTMS over right TPJ affected both object detection and identification, thus suggesting that both processes shared some of its neural substrates, even though they can be behaviorally dissociated (Geng and Vossel, 2014; Doricchi, 2010).

The main implication of the results reported on these experimental series for the identification process is that they depict a scenario where detection and identification represent two separate but dynamically interacting races that make use of previous knowledge to either speed up or slow down their pace. Although in most real life situations both processes are very likely to be indistinguishable, inside the lab it is possible to selectively affect one of them (second and third experimental series) and to affect both by means of disrupting a contextual schema (fourth experimental series).

Object recognition

Which type of information gets stored into memory without our willingness to do so (i.e., with incidental encoding) has been a topic of research for a long time (Brewer & Treyns, 1981; Chun & Jiang, 1999; Mandler & Parker, 1976; Mandler & Ritchey, 1977; Miller & Gazzaniga, 1998). Although some key effects are thought to index principles of memory formation such as repetition (Ebbinghaus, 1885; Hintzman, 1976) or depth of processing (Craik & Lockhart, 1972), others are still a matter of debate.

Prediction error has been argued to be one of these memory principles by many model developers (Henson and Gagnepain, 2010; VanKesteren et al., 2012; Verguts and Notebaert, 2008) and experimental researchers (Pedale & Santangelo, 2015; Friedman, 1979; Goodman, 1980; Pezdek, et al. 1989; Balota & Neely, 1980; Glanzer & Bowles, 1976; Tulving & Kroll, 1995). However, across all the experiments reported

on the first, second and third experimental series, rather than finding the expected memory improvement following prediction errors, we consistently obtained either no better memory for spatial expectation-mismatching words (first experimental series), or even better remembering for semantic expectation-matching objects (second and third experimental series).

Interestingly, the particular task used in the change detection experiments, allows for a clear dissociation between *difficulty* and expectation mismatches, which was impossible to accomplish in previous studies, where incongruent stimuli (i.e., those mismatching expectancies), were better remembered but also more difficult to process (Krebs et al., 2015; Rosner et al., 2015). Indeed, in the encoding phase of our change detection experiments, context-matching objects are more slowly and less accurately detected than context-mismatching ones. Thus, in our case, mismatching objects, for which we expected better memory, were easier, rather than more difficult to process. Therefore, our results of better remembering for expectation-matching objects (and the previous results of better memory for incongruent items of Krebs et al., 2015; Rosner et al., 2015) can arguably be understood as better remembering for the most disfluent targets (Bjork & Bjork, 1992).

Even though this latter account might be appealing, because it is able to account for the results of the second and (partially) the third experimental series, and it can be consistent with some previous results, caution is needed when considering the broader picture. First, the definition of *difficulty* is often weak if not entirely elliptical. In fact, the term itself does not refer to a process or a mechanism but rather to a measurable effect. This is not a trivial fact since attempting at using such a concept as an independent variable to affect cognitive processes often leads to misinterpretations and circularity such as: ‘How can I know that experimental condition A is more difficult than B?’ ‘Because A renders longer response times and higher proportion of errors than B does’. ‘And why do I measure longer response times and higher proportion of errors in A than in B?’ ‘Because A is more difficult than B.’ Second, an interpretation in terms of difficulty of processing enhancing encoding would have problems accounting for the results reported on the first experimental series (i.e., invalid trials can arguably be considered to be *more difficult* than valid ones) and the lack of an effect on Experiment 1A and 1B of the third experimental series (i.e., congruent and incongruent conditions

were as *difficult* or as *easy* in those experiments as they were in any other experiment reported).

The reasons listed above lead us to argue that our results can be better understood within the schema literature (Anderson & Pichert, 1978; Brewer & Treyens, 1981; Fass & Schumacher, 1981; Palmer, 1975). More specifically, schemata are generally understood as high order constructs that contain information about the structure and the semantic regularities of a particular environment (Gronau and Shachar, 2015). These schemata are also thought to aid object identification as well as object recognition by matching upcoming items with pre-existing knowledge. In the paradigm used on the second and third experimental series, objects are embedded within natural scenes that can act as schemata. Congruent targets, thus, would be easily integrated onto them and thus their remembering would be facilitated either by a more coherent and deep elaboration (Craik and Lockhart, 1972) or by a facilitated guided search during the retrieval process (Schulman, 1974; Craik & Tulving, 1975). This last account is especially interesting since it would easily account for the results of Experiment 1B of the third experimental series in which the exact same encoding situations lead to different memory results when interfering objects were included at retrieval. However, this is a question that remains open for future research.

Summary of findings and integrative proposal

Although the challenging endeavor of following the stream of processing of a given stimulus from its first entrance to the system to its eventual retrieval is far from completed, in the present work we have provided some preliminary evidence on the matter and presented a promising paradigm that can be used in future studies. In this final section we offer a tentative description of the broader picture aiming at integrating our results with previous data and models.

Over the first milliseconds of scene viewing people are able to setting up a scene context (Castelhano & Henderson, 2008; Fei-Fei et al., 2007; Greene & Oliva, 2009; Hochstein & Ahissar, 2002; Potter, 1976), probably with an important involvement of the dorsal frontoparietal network (Bogler et al., 2011; Santangelo et al., 2015) and of certain areas along the ventral frontoparietal network (namely, right TPJ) in charge of updating the previous state of the system (Doricchi, 2010; Geng and Vossel, 2014).

This includes overall layout, color, openness or depth but also higher semantic information such as whether the scene depicts an indoor or outdoor location, whether it is day or night, or even whether it is a natural or an artificial location. Grasping these scene features is enough to be able to ascertain whether a given item belongs in that context or whether it does not, and what is more important, it is enough to start anticipating possible upcoming items. On static images, when the scene contains a small number of objects or when one of them *pops out*, these objects capture attention early on (LaPointe et al., 2013). Conversely, when the number of elements exceeds our attentional capacities, some elements must be prioritized over the others and scene scanning takes place mostly in a goal-driven manner (Coco et al., 2013; Henderson et al., 2007; Henderson & Hayes, 2017; Stirk & Underwood, 2007).

This top-down guiding of attention matches overt and covert attentional allocation to the specific requirements of the task in hand. For instance, when looking for people on a city street, we will primarily select sidewalks, benches and zebra crossings; little initial attention will be paid to building's walls or to items in the sky (Peelen & Kastner, 2014). However, under free viewing conditions, attention will be guided to the more meaningful areas of the scene (i.e., along saliency and meaning maps, Henderson & Hayes, 2017) and captured by any unpredicted element (either at a perceptually salient change or a semantically-mismatching object) that generates a prediction error. Inputs received from lower levels in the visual hierarchy will be contrasted with anticipations from higher levels and the differential outcome, i.e., prediction error, will attract attention (recruiting right IPS; Santangelo et al., 2015), update the contextual schema once again (with the involvement of right TPJ; Geng and Vossel, 2014; Doricchi, 2010) and generate new predictions (left MFG, Santangelo et al., 2015) that will be contrasted again. Several of these iterations might be performed until, finally, the prediction error is minimized and the item's identity is consciously available (Henson and Gagnepain, 2010).

The change detection paradigm allows for a scene-scanning mode that is similar to free viewing in the sense that no a priori perceptual or semantic information about the target is available to the viewer but, at the same time, it allows for the recording of different open behavioral responses. This last feature renders possible to obtain a behavioral dissociation between target detection and its identification. Under these

unique paradigm features it is possible to measure bias-free attention allocation toward unpredicted elements by showing that, when asked to detect a change, people perform better (i.e., faster and more accurately) with unpredicted items than with predicted ones (Hollingworth & Henderson, 2000; Stirk & Underwood, 2007). Including an identification question within this paradigm will render the expected result of better identification for context-matching objects (Biederman, 1972; LaPointe et al., 2013).

Following the model described in the introduction of the present dissertation, whereas for context-matching objects a small prediction error (or none at all) is generated, as their representations can freely resonate with pre-existing schemata (most likely on mPFC; VanKesteren et al., 2012), for context-mismatching ones, several iterations between the levels are needed to fully identify the object (Henson and Gagnepain, 2010). As the detection task can be resolved when the first prediction error signal is generated, identification for context-mismatching objects will still be unfinished when a response is emitted and thus, identification errors will be more frequent in this condition. Complimentarily, this early response based on the first prediction errors will consequently render faster detection responses for context-mismatching objects than for context-matching ones which would, by definition, not generate so prominent (and early) prediction errors (Henson and Gagnepain, 2010).

While detection and identification are taking place, information is also being stored in memory for later use. Following the SLIMM model (vanKesteren et al., 2012), the default mode of our system would be to generate episodic instances of the information presented, with a primary involvement of the medial temporal lobe (MTL). This generation will be aborted via inhibitory connections between mPFC and MTL when the representations of schema-matching objects resonate with previous knowledge; pre-existing connections between the new item and previous ones would, in turn, be strengthened by this resonance (and hence, strengthen memory for schema-matching objects can be measured). The mPFC will not experience heightened activity when a schema-mismatching object is presented since its representation cannot resonate with the active-schema and thus, the MTL will be allowed to freely generate an episodic instance of the event (and hence, strengthen memory for schema-mismatching objects could be measured).

These complex interactions between medial and frontal structures, as described in

VanKesteren et al., can explain memory formation for context-matching and context-mismatching objects. However, situations which render differences between remembering performance for both types of objects, such as the one reported in the second and third experimental series, would need of yet another component. The SLIMM model is able to beautifully capture memory formation under task-free exploration of the world. When selection of specific items is performed due to task demands, the lateral Prefrontal Cortex (IPFC) would be involved in an attempt to integrate the item into existing schemas (Brod, Lindenberger, Werkle-Bergner, & Shing, 2015; Murray & Ranganath, 2007); activation of the IPFC following item selection would thus take place regardless of the congruity between the item and the context. Connections from IPFC to MTL would inhibit activity in the MTL in a similar way to that described for mPFC to MTL connections (VanKesteren et al., 2012) and thus episodic encoding of novel items would be prevented. Whereas under item selection conditions episodic encoding would be suppressed, and thus, memory for schema-mismatching items would be poor, the strengthening of pre-existing connections via Hebbian following schema resonance would still take place (VanKesteren et al., 2012) and thus, memory for congruent items would be improved.

A similar proposal has been put forward recently (Brod, Werkle-Bergner, & Shing, 2013) under which IPFC activity would be recruited for increased semantic elaboration and intentional encoding of schema-mismatching items. However, here we proposed that this enhanced IPFC activity would follow unspecific item selection to promote active online processing of goal-relevant items (Murray & Ranganath, 2007). This update version of the SLIMM model can account for the congruity-memory advantage observed in our change detection tasks.

Although the present proposal is highly speculative and will need strong experimental support (note, for instance, that evidence of connections between IPFC and MTL comes from the old studies in rhesus monkeys; Barbas & Blatt, 1995; Goldman-Rakic, Selemon, & Schwartz, 1984), we believe that it represents an integrative framework from which it is possible to derive specific predictions for a wide range of different techniques for future testing. Future research exploring different variables that could potentially impact schema integration such as retrieval cues, item distinctiveness, or ageing effects (Brod, Lindenberger, & Shing, 2017) could offer great

insight into the relationships between semantic information and memory formation. Furthermore, independently exploring the episodic and semantic components of remembering, perhaps by comparing memory performance on free recall versus recognition tasks could also be key to obtain the hypothesized memory enhancements following expectation mismatches (although for unoptimistic evidence see Meier, Rey-Mermet, Rothen, & Graf, 2013; Rosner, Davis, & Milliken, 2015).

Finally, an interesting and logical follow-up of the issues described in the present dissertation that remains open for future studies is the appliance of brain stimulation over different parietal and frontal regions in an attempt at exploring their causal involvement in memory formation.

ABSTRACT

Among the wide variety of stimuli that we process everyday just a small portion enters our conscious mind, and even a smaller fraction is efficiently encoded into memory and can be later remembered. How does our system select which information will be made available to consciousness? What are the characteristics of a given event that would render it relevant enough to be encoded into memory? This doctoral dissertation aims at offering insight into these and other related questions by framing the broader topic within a predictive coding approach. Assuming that cognition works by default by anticipating the most likely input and setting up the system to respond adaptively to this predicted input, this work will present different ways to address the overall question of how introducing conflict or breaking up expectations modulate different stages of cognition.

These hypotheses were tested in four experimental series, presented in two chapters, thus grouping the experimental series into two major categories, based on a methodological distinction: in the first chapter we used external cues to generate spatial predictions; in the second chapter we used ecological visual materials to generate predictions based on previous semantic knowledge.

The first chapter aims to ascertain whether there is a core learning mechanism triggered by mere expectation mismatch. Several neural and computational models predict that breaking an expectation should trigger a learning signal that enhances encoding of the episode as a way to improve future predictions of this previously unexpected event (Henson & Gagnepain, 2010; Verguts & Notebaert, 2009). This expectation mismatch, or prediction error, as it is known within the predictive coding framework, is thought to be domain general and therefore to result from any expectation violation. Whereas it is possible to find studies that show these memory improvements after different unfulfilled expectations, they often include a number of confounding factors (Krebs et al., 2015; Rosner, D'Angelo, et al., 2015; Rosner, Davis, et al., 2015). In this experimental series we aimed at solving this confound by using the most basic and aseptic paradigm capable of inducing an expectation: a Posner cueing paradigm. Across seven experiments we thoroughly manipulated many commonly studied variables to show that mere expectation mismatch is not able to enhance memory as attested by a surprise recognition test. This finding is important to shape current models of prediction error-induced learning, since it implies that either a more

cautious definition of prediction error needs to be established, or a reevaluation of the major assumptions of these models is required.

The second chapter makes use of ecological scenes to explore expectation mismatches at a semantic level. Scene processing is known to proceed gradually from the gist of the scene, that is grasped very early (Castelhano & Henderson, 2008; Oliva & Torralba, 2006; Sampanes et al., 2008), to the identification of individual objects, that may take considerably more time. Under this framework, we assumed that individual object processing can also be understood in terms of anticipations of the most likely candidates based on the available semantic information (Rao & Ballard, 1999; Summerfield et al., 2006). Therefore, the experiments integrated in this chapter include objects that are semantically incongruent with their surrounding background, to induce a form of semantic prediction error. We used a change detection task in which we manipulated the semantic congruity between the target objects and the background scenes in which they were embedded. In the three experimental series included within this second chapter we used this general method to explore how semantic mismatches impact cognitive processing at different stages ranging from pure detection, through identification, and to eventual remembering.

The first experimental series of this second chapter presents a counterintuitive effect of semantic mismatch on remembering. As stated above, current models on conflict-induced learning predict that better memory should be obtained for context-incongruent objects (Henson & Gagnepain, 2010; Verguts & Notebaert, 2009). However, our results show that the opposite is true. Those targets that are semantically congruent with their surrounding scene were remembered better than those that did not. This unexpected result is in line with the findings obtained in the first chapter and thus supports the need for reevaluating the idea that expectation mismatches are always associated to an increase in memory or learning. Moreover, the results indicate that, at least under certain conditions, structured and coherent items could be better encoded into memory than are either unexpected or incongruent ones.

The second experimental series of this chapter further explores this puzzling result by analyzing three behavioral indexes that serve as proxies for three stages in the stream of processing of visual information. Namely, it has been found that the same factor of semantic congruity produces opposite effects at different processing stages,

giving place to a detection cost, an identification benefit and a recognition benefit. In this study, we attempt to characterize the mechanisms underlying each of these three indexes, as well as the eye-movements' patterns associated with them. Our results of participants performance showed that i) the detection cost, but not the identification benefit nor the recognition benefit, is contingent on the presence of object competition and that shorter and earlier fixations on incongruent targets are responsible for the detection cost, ii) that the identification benefit is not associated to the most common measures of eye movement and iii) although better memory in general is observed for better identified objects, the recognition benefit is not dependent on the level of object identification. To sum up, the results from the third experimental series further support that semantic characteristics of the stimuli affect processing from the earliest stages of conscious processing to eventual remembering.

Finally, the last experimental series of the second chapter, aimed at analyzing these semantic influences on object processing at a neural level. We used Transcranial Magnetic Stimulation (TMS) to suppress activity in a brain region that has been related with attentional reorienting, namely, the right temporo-parietal junction (TPJ), and assessed whether this manipulation would affect the detection cost or the identification benefit. Although activity in the entire right parietal lobe has been traditionally implicated on attentional tasks (Geng & Mangun, 2011; Serences et al., 2005), the right TPJ is specifically thought to be responsible for attentional re-orienting in space (Bourgeois et al., 2013; Corbetta et al., 2000b). We hypothesized that, given that the detection cost, but not the identification benefit, seems to arise as a consequence of efficient attentional attraction toward the target region, suppressing activity in right TPJ would reduce, or even eliminate, the detection cost, while leaving unaffected the identification benefit. Our results show that repetitive TMS over right TPJ effectively reduced the detection cost compared to the stimulation of a control region (vertex). Importantly however, the identification was also reduced by right TPJ stimulation. This double and partially unexpected finding implies that, although a clear dissociation between detection and identification processes can be behaviorally established, both processes most likely interact with each other by means of some shared underlying neural substrate. Moreover, the attentional role traditionally assigned to right TPJ might need reevaluation. Indeed, this result is in line with other recent research attributing to this region the role of contextual updating rather than that of re-orienting attention

(Doricchi et al., 2010; Geng & Vossel, 2013). In our data set, impairing of efficient contextual updating could account for the reduction of both the detection cost and the identification benefit.

In sum, the present thesis reveals the need for rethinking those models that characterize learning as generally bolstered by any kind of conflict or prediction error. It also presents an interesting and promising perspective on the study of semantic influences at different levels across the stream of processing, from very early stages of object detection, to identification and memory. Finally, the present work supports a new conceptualization of the role of right TPJ on attentional processes (Doricchi et al., 2010; Geng & Vossel, 2013) and opens new questions regarding the brain areas implicated in congruity-mediated recognition processes.

RESUMEN

De entre la amplia variedad de estímulos que procesamos cada día, solo una pequeña porción entra nuestra mente consciente, y una parte aún más pequeña se codifica adecuadamente para poder ser recordada más adelante. ¿Cómo selecciona nuestro sistema qué información debe ser consciente? ¿Cuáles son las características de un determinado evento que lo hacen suficientemente relevante como para que se codifique en memoria? Esta tesis doctoral intenta ofrecer información sobre estas y otras cuestiones relacionadas a través de la conceptualización del tema dentro del marco del *predictive coding*. Asumiendo que nuestra cognición funciona por defecto anticipando los estímulos más probables a encontrar y ajustando nuestro sistema para responder adaptativamente, este trabajo presentará diferentes maneras de abordar la pregunta general de cómo la introducción de conflictos o la ruptura en las expectativas pueden modular diferentes etapas de la cognición.

Estas hipótesis fueron comprobadas en cuatro series experimentales presentadas en dos capítulos distintos que las agrupan a su vez en dos categorías en función de una distinción metodológica: en el primero de los capítulos utilizamos estímulos externos para generar expectativas espaciales; en el segundo capítulo usamos materiales visual ecológicos para el estudio tanto las consecuencias inmediatas como las demoradas de las predicciones basadas en el conocimiento previo del mundo.

Los experimentos recogidos en el primer capítulo experimental intentan dirimir si existe un mecanismo de aprendizaje fundamental disparado por una mera ruptura en las expectativas. Numerosos modelos neurales y computacionales predicen que la ruptura de una expectativa debería disparar una señal de aprendizaje que aumentaría la codificación del episodio consiguiendo así una mejora de las futuras predicciones de ese evento (Henson & Gagnepain, 2010; Verguts & Notebaert, 2009). Esta falta de encaje con nuestras expectativas, o error de predicción, como se conoce en la literatura de *predictive coding*, ha sido propuesta como una señal inespecífica y general y que, por lo tanto, debería aparecer tras cualquier tipo de ruptura en nuestras expectativas. Sin embargo, mientras que es posible encontrar estudios que muestran ciertas mejoras en memoria después de diferentes expectativas no cumplidas, muchos de ellos incluyen un gran número de confundidos (Krebs et al., 2013; Rosner et al., 2013; Rosner et al., 2015). En esta serie experimental tratamos de resolver estos confundidos usando el paradigma más básico y aséptico capaz de inducir una expectativa: un paradigma de

cueing. A través de siete experimentos cuidadosamente manipulamos muchas variables estudiadas comúnmente para demostrar que la simple ruptura en las expectativas no es capaz de mejorar la memoria, al menos cuando esta es medida con un test de reconocimiento. Este descubrimiento es importante para dar forma a los modelos actuales de aprendizaje inducido por el error de predicción, ya que implican que o bien una definición más cautelosa del error de predicción es necesaria o bien una reevaluación de tales modelos es requerida.

El segundo capítulo experimental hace uso de escenas ecológicas para explorar las predicciones a nivel semántico. Se sabe que el procesamiento de escenas se produce gradualmente desde la esencia de la escena, que se capta muy tempranamente (Castelhano & Henderson, 2008; Oliva & Torralba, 2006; Sampanes et al., 2008), a la identificación de objetos individuales, que puede tardar considerablemente más tiempo. Bajo este enfoque, asumimos que el procesamiento individual de objetos puede también ser entendido en términos de anticipaciones de posibles candidatos basados en la información semántica disponible (Rao & Ballard, 1999; Summerfield et al., 2006). Por lo tanto, los experimentos integrados en este capítulo incluyen objetos que son semánticamente incongruentes con su contexto para inducir una forma de error de predicción. Usamos una tarea de detección de cambio en la cual manipulamos la congruencia semántica entre los objetos a detectar y el contexto en el que se presentaban. En las tres series experimentales incluidas en este segundo capítulo usamos este método general para explorar el impacto que incongruencia semántica puede tener a lo largo de diferentes etapas del procesamiento desde la percepción temprana hasta el posterior recuerdo.

La primera serie experimental de este segundo capítulo presenta un resultado contraintuitivo en cuanto al recuerdo de eventos incongruentes semánticamente. Mientras que los modelos mencionados arriba predicen que los objetos incongruentes deberían ser recordados mejor que los congruentes, los resultados obtenidos en esta serie apuntan al caso opuesto. Aquellos objetos que se presentaron en condiciones de congruencia semántica fueron recordados mejor que aquellos que se presentaban en un contexto incongruente.

La segunda serie experimental explora aún más este resultado analizando tres índices comportamentales que pueden ser utilizados como aproximaciones a tres etapas

del procesamiento visual; a saber, la detección, la identificación y el reconocimiento de objetos. En este estudio intentamos caracterizar algunos de los mecanismos que subyacen a estos índices así como los patrones de movimientos oculares asociados con ellos. Nuestros resultados demostraron que i) el coste por detección, pero no la ventaja en identificación para objetos congruentes solo aparece en situaciones de alta competición estimular ii) que el beneficio en identificación es independiente del patrón de movimientos oculares durante la fase de estudio y iii) que aunque el nivel de identificación en la fase de estudio sí puede modular la calidad del recuerdo, este no puede explicar las diferencias entre objetos congruentes e incongruentes.

Por último, la tercera serie experimental del segundo capítulo intentaba analizar las influencias semánticas sobre el procesamiento de objetos a nivel neural. Usamos estimulación magnética transcraneal (TMS) para suprimir la actividad en una región cerebral tradicionalmente asociada con la reorientación atencional, la unión temporoparietal derecha (rTPJ). Nuestras hipótesis predecían que la estimulación sobre esa área concreta reduciría el coste por detección de los objetos congruentes pero no afectaría a la ventaja en identificación. Los resultados revelaron que aunque sí que se logró una afectación del coste por detección también se observó una reducción del efecto de mejor identificación de los objetos congruentes. Este resultado refleja que el rol tradicionalmente asignado a rTPJ debe ser reevaluado (Corbetta et al., 2000) y que una nueva perspectiva en la línea de la actualización contextual sea probablemente más adecuada (Doricchi et al., 2011; Geng & Vossel, 2013).

En resumen, la presente tesis revela la necesidad de repensar los modelos basados en un aprendizaje disparado por conflictos inespecíficos o por errores de predicción. Además, presenta una perspectiva interesante y prometedora en el estudio de las influencias semánticas sobre diferentes etapas a través del flujo de procesamiento, desde estadios muy tempranos hasta la memoria. Por último, el presente trabajo apoya la idea de una re-conceptualización del papel de rTPJ en procesos atencionales y abre nuevas preguntas en torno a las áreas cerebrales implicadas en los procesos de reconocimiento mediados por la congruencia.

REFERENCES

- Alameda, J. R., & Cuetos, F. (1995). *Diccionario de frecuencias de las unidades lingüísticas del castellano*. Univ. de Oviedo, Servicio de Publ.
- Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin & Review*, 7(3), 522–530. <https://doi.org/10.3758/BF03214366>
- Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20(5), 1063–1087. <https://doi.org/10.1037/0278-7393.20.5.1063>
- Anderson, R. C., & Pichert, J. W. (1978). Recall of previously unrecallable information following a shift in perspective. *Journal of Verbal Learning and Verbal Behavior*, 17(1), 1–12. [https://doi.org/10.1016/S0022-5371\(78\)90485-1](https://doi.org/10.1016/S0022-5371(78)90485-1)
- Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: a failed theoretical dichotomy. *Trends in Cognitive Sciences*, 16(8), 437–443. <https://doi.org/10.1016/J.TICS.2012.06.010>
- Bajo, M. T., Burton, A., Burton, E., & Canas, J.-J. (1994). Word recognition across orthographies: Another look at the interaction between context and degradation. *European Journal of Cognitive Psychology*, 6(2), 171–193. <https://doi.org/10.1080/09541449408520142>
- Bar, M. (2003). A Cortical Mechanism for Triggering Top-Down Facilitation in Visual Object Recognition. *Journal of Cognitive Neuroscience*, 15(4), 600–609. <https://doi.org/10.1162/089892903321662976>
- Bar, M., Tootell, R. B. ., Schacter, D. L., Greve, D. N., Fischl, B., Mendola, J. D., ... Dale, A. M. (2001). Cortical Mechanisms Specific to Explicit Visual Object Recognition. *Neuron*, 29(2), 529–535. [https://doi.org/10.1016/S0896-6273\(01\)00224-0](https://doi.org/10.1016/S0896-6273(01)00224-0)
- Barbas, H., & Blatt, G. J. (1995). Topographically specific hippocampal projections target functionally distinct prefrontal areas in the rhesus monkey. *Hippocampus*, 5(6), 511–533. <https://doi.org/10.1002/hipo.450050604>
- Bartolomeo, P., & Chokron, S. (2002). Orienting of attention in left unilateral neglect. *Neuroscience and Biobehavioral Reviews*, 26(2), 217–234. [https://doi.org/10.1016/S0149-7634\(01\)00065-3](https://doi.org/10.1016/S0149-7634(01)00065-3)
- Bartolomeo, P., Schotten, M. T. de, & Chica, A. B. (2012). Brain networks of visuospatial attention and their disruption in visual neglect. *Frontiers in Human Neuroscience*, 6(May), 110. <https://doi.org/10.3389/fnhum.2012.00110>
- Baylis, G. C., & Driver, J. (1993). Visual attention and objects: Evidence for hierarchical coding of location. *Journal of Experimental Psychology: Human Perception and Performance*, 19(3), 451–470. <https://doi.org/10.1037/0096-1523.19.3.451>
- Baylis, G. C., Driver, J., & Rafal, R. D. (1993). Visual Extinction and Stimulus Repetition. *Journal of Cognitive Neuroscience*, 5(4), 453–466. <https://doi.org/10.1162/jocn.1993.5.4.453>
- Beck, D. M., Muggleton, N., Walsh, V., & Lavie, N. (2006). Right parietal cortex plays a critical role in change blindness. *Cerebral Cortex*, 16(5), 712–717. <https://doi.org/10.1093/cercor/bhj017>
- Becker, M. W., Pashler, H., & Anstis, S. M. (2000). The role of iconic memory in change-detection tasks. *Perception*, 29(3), 273–286. <https://doi.org/10.1068/p3035>
- Bekinschtein, T. A., Davis, M. H., Rodd, J. M., & Owen, A. M. (2011). Why Clowns Taste Funny: The Relationship between Humor and Semantic Ambiguity. *Journal of Neuroscience*, 31(26). Retrieved from <http://www.jneurosci.org/content/31/26/9665.short>
- Bender, M. B., & Furlow, L. T. (1945). Phenomenon of visual extinction in homonymous fields and psychologic principles involved. *Archives of Neurology And Psychiatry*, 53(1), 29. <https://doi.org/10.1001/archneurpsyc.1945.02300010039002>
- Betz, T., Wilming, N., Bogler, C., Haynes, J.-D., & König, P. (2013). Dissociation between saliency signals and activity in early visual cortex. *Journal of Vision*, 13(14), 6–6. <https://doi.org/10.1167/13.14.6>
- Biederman, I. (1972). Perceiving Real-World Scenes. *Science*. <https://doi.org/10.1126/science.177.4043.77>

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- Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In *Healy, Alice F [Ed]; Kosslyn, Stephen Michael [Ed]; Shiffrin, Richard M [Ed]* (pp. 35–67).
- Bogler, C., Bode, S., & Haynes, J.-D. (2011). Decoding Successive Computational Stages of Saliency Processing. *Current Biology, 21*(19), 1667–1671. <https://doi.org/10.1016/j.cub.2011.08.039>
- Boroojerdi, B., Prager, A., Muellbacher, W., & Cohen, L. G. (2000). Reduction of human visual cortex excitability using 1-Hz transcranial magnetic stimulation. *Neurology, 54*(7), 1529–31. <https://doi.org/10.1212/WNL.54.7.1529>
- Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*(3), 624–652.
- Bourgeois, A., Chica, A. B., Valero-Cabré, A., & Bartolomeo, P. (2013). Cortical control of inhibition of return: Causal evidence for task-dependent modulations by dorsal and ventral parietal regions. *Cortex, 49*(8), 2229–2238. <https://doi.org/10.1016/j.cortex.2012.10.017>
- Bowles, N. L., & Glanzer, M. (1983). An analysis of interference in recognition memory. *Memory & Cognition, 11*(3), 307–315. <https://doi.org/10.3758/BF03196977>
- Braem, S., Coenen, E., Bombeke, K., van Bochove, M. E., & Notebaert, W. (2015). Open your eyes for prediction errors. *Cognitive, Affective & Behavioral Neuroscience, 15*(2), 374–80. <https://doi.org/10.3758/s13415-014-0333-4>
- Braver, T. S., Reynolds, J. R., & Donaldson, D. I. (2003). Neural Mechanisms of Transient and Sustained Cognitive Control during Task Switching. *Neuron, 39*(4), 713–726. [https://doi.org/10.1016/S0896-6273\(03\)00466-5](https://doi.org/10.1016/S0896-6273(03)00466-5)
- Brewer, W. F., & Treyens, J. C. (1981). Role of schemata in memory for places. *Cognitive Psychology, 13*(2), 207–230. [https://doi.org/10.1016/0010-0285\(81\)90008-6](https://doi.org/10.1016/0010-0285(81)90008-6)
- Brod, G., Lindenberger, U., & Shing, Y. L. (2017). Neural activation patterns during retrieval of schema-related memories: differences and commonalities between children and adults. *Developmental Science, 20*(6), e12475. <https://doi.org/10.1111/desc.12475>
- Brod, G., Lindenberger, U., Werkle-Bergner, M., & Shing, Y. L. (2015). Differences in the neural signature of remembering schema-congruent and schema-incongruent events. *NeuroImage, 117*, 358–366. <https://doi.org/10.1016/J.NEUROIMAGE.2015.05.086>
- Brod, G., Werkle-Bergner, M., & Shing, Y. L. (2013). The Influence of Prior Knowledge on Memory: A Developmental Cognitive Neuroscience Perspective. *Frontiers in Behavioral Neuroscience, 7*(October), 1–13. <https://doi.org/10.3389/fnbeh.2013.00139>
- Castelhano, M. S., & Heaven, C. (2010). The relative contribution of scene context and target features to visual search in scenes. *Attention, Perception & Psychophysics, 72*(5), 1283–1297. <https://doi.org/10.3758/APP.72.5.1283>
- Castelhano, M. S., & Henderson, J. M. (2008). The influence of color on the perception of scene gist. *Journal of Experimental Psychology: Human Perception and Performance, 34*(3), 660–675. <https://doi.org/10.1037/0096-1523.34.3.660>
- Chan, Y.-C., & Lavalley, J. P. (2015). Temporo-parietal and fronto-parietal lobe contributions to theory of mind and executive control: an fMRI study of verbal jokes. *Frontiers in Psychology, 6*, 1285. <https://doi.org/10.3389/fpsyg.2015.01285>
- Chen, R., Classen, J., Gerloff, C., Celnik, P., Wassermann, E. M., Hallett, M., & Cohen, L. G. (1997). Depression of motor cortex excitability by low-frequency transcranial magnetic stimulation. *Neurology, 48*(5), 1398–403. <https://doi.org/10.1212/WNL.48.5.1398>
- Chica, A. B., Bartolomeo, P., & Valero-Cabré, A. (2011). Dorsal and Ventral Parietal Contributions to Spatial Orienting in the Human Brain. *Journal of Neuroscience, 31*(22). Retrieved from <http://www.jneurosci.org/content/31/22/8143.short>
- Chica, A. B., & Lupiáñez, J. (2009). Effects of endogenous and exogenous attention on visual processing: An Inhibition of Return study. *Brain Research, 1278*, 75–85. <https://doi.org/10.1016/J.BRAINRES.2009.04.011>
- Chica, A. B., Lupiáñez, J., & Bartolomeo, P. (2006). Dissociating inhibition of return from endogenous orienting of spatial attention: Evidence from detection and discrimination tasks. *Cognitive*

-
- Neuropsychology*, 23(7), 1015–1034. <https://doi.org/10.1080/02643290600588277>
- Chica, A. B., Martín-Arévalo, E., Botta, F., & Lupiáñez, J. (2014). The Spatial Orienting paradigm: How to design and interpret spatial attention experiments. *Neuroscience and Biobehavioral Reviews*, 40, 35–51. <https://doi.org/10.1016/j.neubiorev.2014.01.002>
- Chiu, Y.-C., & Egner, T. (2014). Inhibition-Induced Forgetting: When More Control Leads to Less Memory. *Psychological Science*. <https://doi.org/10.1177/0956797614553945>
- Chopin, A., & Mamassian, P. (2012). Predictive Properties of Visual Adaptation. *Current Biology*, 22(7), 622–626. <https://doi.org/10.1016/J.CUB.2012.02.021>
- Chun, M. M., & Jiang, Y. (1999). Top-Down Attentional Guidance Based on Implicit Learning of Visual Covariation. *Psychological Science*, 10(4), 360–365. <https://doi.org/10.1111/1467-9280.00168>
- Clare, J., & Lewandowsky, S. (2004). Verbalizing Facial Memory: Criterion Effects in Verbal Overshadowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30(4), 739–755. <https://doi.org/10.1037/0278-7393.30.4.739>
- Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *The Behavioral and Brain Sciences*, 36(3), 181–204. <https://doi.org/10.1017/S0140525X12000477>
- Coco, M. I., Malcolm, G. L., & Keller, F. (2013). The interplay of bottom-up and top-down mechanisms in visual guidance during object naming. *Quarterly Journal of Experimental Psychology (2006)*, 0(January 2015), 1–25. <https://doi.org/10.1080/17470218.2013.844843>
- Constantinidis, C., & Steinmetz, M. A. (2005). Posterior Parietal Cortex Automatically Encodes the Location of Salient Stimuli. *Journal of Neuroscience*, 25(1), 233–238. <https://doi.org/10.1523/JNEUROSCI.3379-04.2005>
- Corbetta, M., Kincade, J. M., Ollinger, J. M., McAvoy, M. P., & Shulman, G. L. (2000a). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neuroscience*, 3(3), 292–298. Retrieved from <http://go.galegroup.com/ps/anonymous?p=AONE&sw=w&issn=10976256&v=2.1&it=r&id=GAL E%7CA185568876&sid=googleScholar&linkaccess=fulltext&authCount=1&isAnonymousEntry=true>
- Corbetta, M., Kincade, J. M., Ollinger, J. M., McAvoy, M. P., & Shulman, G. L. (2000b). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neuroscience*, 3(3), 292–7. <https://doi.org/10.1038/73009>
- Corbetta, M., Kincade, M. J., Lewis, C., Snyder, A. Z., & Sapir, A. (2005). Neural basis and recovery of spatial attention deficits in spatial neglect. *Nature Neuroscience*, 8(11), 1603–1610. <https://doi.org/10.1038/nn1574>
- 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. <https://doi.org/10.1016/j.neuron.2008.04.017>
- Corbetta, M., & Shulman, G. L. (2002). CONTROL OF GOAL-DIRECTED AND STIMULUS-DRIVEN ATTENTION IN THE BRAIN. *Nature Reviews Neuroscience*, 3(3), 215–229. <https://doi.org/10.1038/nnr755>
- Correa, A. (2010). Enhancing behavioural performance by visual temporal orienting. Retrieved from <https://philpapers.org/rec/COREBP>
- Coull, J. T., & Nobre, A. C. (1998). Where and when to pay attention: the neural systems for directing attention to spatial locations and to time intervals as revealed by both PET and fMRI. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, 18(18), 7426–35. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9736662>
- Cousineau, D., & O'Brien, F. (2014). Error bars in within-subject designs: a comment on Baguley (2012). *Behavior Research Methods*, 46(4), 1149–51. <https://doi.org/10.3758/s13428-013-0441-z>
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11(6), 671–684. [https://doi.org/10.1016/S0022-5371\(72\)80001-X](https://doi.org/10.1016/S0022-5371(72)80001-X)
- Critchley, H. D., Tang, J., Glaser, D., Butterworth, B., & Dolan, R. J. (2005). Anterior cingulate activity

-
- during error and autonomic response. *NeuroImage*, 27(4), 885–895. <https://doi.org/10.1016/j.neuroimage.2005.05.047>
- Crump, M. J. C., Gong, Z., & Milliken, B. (2006). The context-specific proportion congruent Stroop effect: Location as a contextual cue. *Psychonomic Bulletin & Review*, 13(2), 316–321. <https://doi.org/10.3758/BF03193850>
- d’Acremont, M., Lu, Z.-L., Li, X., Van der Linden, M., & Bechara, A. (2009). Neural correlates of risk prediction error during reinforcement learning in humans. *NeuroImage*, 47(4), 1929–1939. <https://doi.org/10.1016/j.neuroimage.2009.04.096>
- Davenport, J. L., & Potter, M. C. (2004). Scene Consistency in Object and Background Perception. *Psychological Science*, 15(8), 559–564. <https://doi.org/10.1111/j.0956-7976.2004.00719.x>
- de Winstanley, P. A., & Bjork, E. L. (1997). Processing instructions and the generation effect: a test of the multifactor transfer-appropriate processing theory. *Memory (Hove, England)*, 5(3), 401–21. <https://doi.org/10.1080/741941392>
- de Winstanley, P. A., & Bjork, E. L. (2004). Processing strategies and the generation effect: Implications for making a better reader. *Memory & Cognition*, 32(6), 945–955. <https://doi.org/10.3758/BF03196872>
- Desimone, R., & Duncan, J. (1995). Neural Mechanisms of Selective Visual Attention. *Annual Review of Neuroscience*, 18(1), 193–222. <https://doi.org/10.1146/annurev.ne.18.030195.001205>
- Dienes, Z. (2011). Bayesian Versus Orthodox Statistics: Which Side Are You On? *Perspectives on Psychological Science*, 6(3), 274–290. <https://doi.org/10.1177/1745691611406920>
- Doricchi, F., Macci, E., Silvetti, M., & Macaluso, E. (2010). Neural Correlates of the Spatial and Expectancy Components of Endogenous and Stimulus-Driven Orienting of Attention in the Posner Task. *Cerebral Cortex*, 20(7), 1574–1585. <https://doi.org/10.1093/cercor/bhp215>
- Downar, J., Crawley, a P., Mikulis, D. J., & Davis, K. D. (2000). A multimodal cortical network for the detection of changes in the sensory environment. *Nature Neuroscience*, 3(3), 277–283. <https://doi.org/10.1038/72991>
- Downar, J., Crawley, a P., Mikulis, D. J., & Davis, K. D. (2001). The effect of task relevance on the cortical response to changes in visual and auditory stimuli: an event-related fMRI study. *NeuroImage*, 14(6), 1256–1267. <https://doi.org/10.1006/nimg.2001.0946>
- Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, 113(4), 501–517. <https://doi.org/10.1037/0096-3445.113.4.501>
- Duthoo, W., Abrahamse, E. L., Braem, S., Boehler, C. N., & Notebaert, W. (2014). The heterogeneous world of congruency sequence effects: an update. *Frontiers in Psychology*, 5, 1001. <https://doi.org/10.3389/fpsyg.2014.01001>
- Ebbinghaus, H. (1885). Ueber das Gedächtnis. Retrieved from <https://philpapers.org/rec/EBBUDG>
- Eger, E., Henson, R., Driver, J., & Dolan, R. (2007). Mechanisms of Top-Down Facilitation in Perception of Visual Objects Studied by fMRI. *Cerebral Cortex*, 17(9), 2123–2133. <https://doi.org/10.1093/cercor/bhl119>
- Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental Psychology: General*, 123(2), 161–177. <https://doi.org/10.1037/0096-3445.123.2.161>
- Egner, T. (2007). Congruency sequence effects and cognitive control. *Cognitive, Affective, & Behavioral Neuroscience*, 7(4), 380–390. <https://doi.org/10.3758/CABN.7.4.380>
- Egner, T., Ely, S., & Grinband, J. (2010). Going, going, gone: characterizing the time-course of congruency sequence effects. *Frontiers in Psychology*, 1(September), 154. <https://doi.org/10.3389/fpsyg.2010.00154>
- Einhäuser, W., Rutishauser, U., & Koch, C. (2008). Task-demands can immediately reverse the effects of sensory-driven saliency in complex visual stimuli. *Journal of Vision*, 8(2), 2. <https://doi.org/10.1167/8.2.2>
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in

-
- a nonsearch task. *Perception & Psychophysics*, 16(1), 143–149. <https://doi.org/10.3758/BF03203267>
- Esterman, M., & Yantis, S. (2010). Perceptual Expectation Evokes Category-Selective Cortical Activity. *Cerebral Cortex*, 20(5), 1245–1253. <https://doi.org/10.1093/cercor/bhp188>
- Fass, W., & Schumacher, G. M. (1981). Schema theory and prose retention: Boundary conditions for encoding and retrieval effects. *Discourse Processes*, 4(1), 17–26. <https://doi.org/10.1080/01638538109544504>
- Fei-Fei, L., Iyer, A., Koch, C., & Perona, P. (2007). What do we perceive in a glance of a real-world scene? *Journal of Vision*, 7(1), 10. <https://doi.org/10.1167/7.1.10>
- Fisher, A., Anderson, G. B., Peng, R., & Leek, J. (2014). A randomized trial in a massive online open course shows people don't know what a statistically significant relationship looks like, but they can learn. *PeerJ*, 2, e589.
- Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings.
- Friedman, A. (1979). Framing pictures: The role of knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General*, 108(3), 316–355. <https://doi.org/10.1037/0096-3445.108.3.316>
- Friston, K. (2003). Learning and inference in the brain. *Neural Networks*, 16(9), 1325–1352. <https://doi.org/10.1016/J.NEUNET.2003.06.005>
- Funes, M. J., Lupiáñez, J., & Milliken, B. (2007). Separate mechanisms recruited by exogenous and endogenous spatial cues: evidence from a spatial Stroop paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, 33(2), 348–362. <https://doi.org/10.1037/0096-1523.33.2.348>
- Geng, J. J., & Mangun, G. R. (2011). Right temporoparietal junction activation by a salient contextual cue facilitates target discrimination. *NeuroImage*, 54(1), 594–601. <https://doi.org/10.1016/j.neuroimage.2010.08.025>
- Geng, J. J., & Vossel, S. (2013). Re-evaluating the role of TPJ in attentional control: Contextual updating? *Neuroscience & Biobehavioral Reviews*, 37(10), 2608–2620. <https://doi.org/10.1016/j.neubiorev.2013.08.010>
- Goldman-Rakic, P. S., Selemon, L. D., & Schwartz, M. L. (1984). Dual pathways connecting the dorsolateral prefrontal cortex with the hippocampal formation and parahippocampal cortex in the rhesus monkey. *Neuroscience*, 12(3), 719–743. [https://doi.org/10.1016/0306-4522\(84\)90166-0](https://doi.org/10.1016/0306-4522(84)90166-0)
- Goodman, G. S. (1980). Picture memory: How the action schema affects retention. *Cognitive Psychology*, 12(4), 473–495. [https://doi.org/10.1016/0010-0285\(80\)90017-1](https://doi.org/10.1016/0010-0285(80)90017-1)
- Gordon, R. D. (2004). Attentional allocation during the perception of scenes. *Journal of Experimental Psychology: Human Perception & Performance*, 30(4), 760–77. <https://doi.org/10.1037/0096-1523.30.4.760>
- Gorlin, S., Meng, M., Sharma, J., Sugihara, H., Sur, M., & Sinha, P. (2012). Imaging prior information in the brain. *Proceedings of the National Academy of Sciences of the United States of America*, 109(20), 7935–40. <https://doi.org/10.1073/pnas.1111224109>
- Gratton, G., Coles, M. G. H., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General*, 121, 480–506.
- Gray, K. L. H., Adams, W. J., Hedger, N., Newton, K. E., & Garner, M. (2013). Faces and awareness: low-level, not emotional factors determine perceptual dominance. *Emotion*, 13(3), 537–44. <https://doi.org/10.1037/a0031403>
- Greene, M. R., Botros, A. P., Beck, D. M., & Fei-Fei, L. (2015). What you see is what you expect: rapid scene understanding benefits from prior experience. *Attention, Perception & Psychophysics*. <https://doi.org/10.3758/s13414-015-0859-8>
- Greene, M. R., & Oliva, A. (2009). Recognition of natural scenes from global properties: Seeing the forest without representing the trees. *Cognitive Psychology*, 58(2), 137–176. <https://doi.org/10.1016/J.COGPSYCH.2008.06.001>

-
- Gronau, N., & Shachar, M. (2015). Contextual consistency facilitates long-term memory of perceptual detail in barely seen images. *Journal of Experimental Psychology: Human Perception and Performance*, 41(4), 1095–1111. <https://doi.org/10.1037/xhp0000071>
- Harris, I. M., Benito, C. T., Ruzzoli, M., & Miniussi, C. (2008). Effects of Right Parietal Transcranial Magnetic Stimulation on Object Identification and Orientation Judgments. *Journal of Cognitive Neuroscience*, 20(5), 916–926. <https://doi.org/10.1162/jocn.2008.20513>
- Hauer, B. J. A., & MacLeod, C. M. (2006). Endogenous versus exogenous attentional cuing effects on memory. *Acta Psychologica*, 122(3), 305–320. <https://doi.org/10.1016/j.actpsy.2005.12.008>
- Heinen, K., Ruff, C. C., Bjoertomt, O., Schenkluhn, B., Bestmann, S., Blankenburg, F., ... Chambers, C. D. (2011). Concurrent TMS-fMRI reveals dynamic interhemispheric influences of the right parietal cortex during exogenously cued visuospatial attention. *European Journal of Neuroscience*, 33(5), 991–1000. <https://doi.org/10.1111/j.1460-9568.2010.07580.x>
- Henderson, J. M., Brockmole, J. R., Castelano, M. S., & Mack, M. (2007). Visual saliency does not account for eye movements during visual search in real-world scenes. In *Eye Movements* (p. 537–III). Elsevier. <https://doi.org/10.1016/B978-008044980-7/50027-6>
- Henderson, J. M., & Hayes, T. R. (2017). Meaning-based guidance of attention in scenes as revealed by meaning maps. *Nature Human Behaviour*. <https://doi.org/10.1038/s41562-017-0208-0>
- Henderson, J. M., & Hollingworth, A. (1999). HIGH-LEVEL SCENE PERCEPTION. *Annual Review of Psychology*, 50(1), 243–271. <https://doi.org/10.1146/annurev.psych.50.1.243>
- Henderson, J. M., Weeks, P. a., & Hollingworth, A. (1999). The effects of semantic consistency on eye movements during complex scene viewing. *Journal of Experimental Psychology: Human Perception and Performance*. <https://doi.org/10.1037/0096-1523.25.1.210>
- Henson, R. N., & Gagnepain, P. (2010). Predictive, interactive multiple memory systems. *Hippocampus*, 20(11), 1315–26. <https://doi.org/10.1002/hipo.20857>
- Hilgetag, C. C., Théoret, H., & Pascual-Leone, A. (2001). Enhanced visual spatial attention ipsilateral to rTMS-induced “virtual lesions” of human parietal cortex. *Nature Neuroscience*, 4(9), 953–957. <https://doi.org/10.1038/nn0901-953>
- Hintzman, D. L. (1976). Repetition and Memory. *Psychology of Learning and Motivation*, 10, 47–91. [https://doi.org/10.1016/S0079-7421\(08\)60464-8](https://doi.org/10.1016/S0079-7421(08)60464-8)
- Hochstein, S., & Ahissar, M. (2002). View from the Top: Hierarchies and Reverse Hierarchies in the Visual System. *Neuron*, 36(5), 791–804. [https://doi.org/10.1016/S0896-6273\(02\)01091-7](https://doi.org/10.1016/S0896-6273(02)01091-7)
- Hock, H. S., Romanski, L., Galie, A., & Williams, C. S. (1978). Real-world schemata and scene recognition in adults and children. *Memory & Cognition*, 6(4), 423–431. <https://doi.org/10.3758/BF03197475>
- Holender, D. (1986). Semantic Activation Without Conscious Identification in Dichotic Listening, Parafoveal Vision, and Visual Masking: A Survey and Appraisal. *Behavioral and Brain Sciences*, 9(1), 1–23. <https://doi.org/10.1017/S0140525X00021269>
- Hollingworth, A., & Henderson, J. M. (2000). Semantic Informativeness Mediates the Detection of Changes in Natural Scenes. *Visual Cognition*, 7(1–3), 213–235. <https://doi.org/10.1080/135062800394775>
- Hollingworth, A., Schrock, G., & Henderson, J. M. (2001). Change detection in the flicker paradigm: The role of fixation position within the scene. *Memory & Cognition*, 29(2), 296–304. <https://doi.org/10.3758/BF03194923>
- Humphrey, K., & Underwood, G. (2009). Domain knowledge moderates the influence of visual saliency in scene recognition. *British Journal of Psychology*, 100(2), 377–398. <https://doi.org/10.1348/000712608X344780>
- Indovina, I., & Macaluso, E. (2007). Dissociation of Stimulus Relevance and Saliency Factors during Shifts of Visuospatial Attention. *Cerebral Cortex*, 17(7), 1701–1711. <https://doi.org/10.1093/cercor/bhl081>
- Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature Reviews Neuroscience*, 2(3), 194–203. <https://doi.org/10.1038/35058500>

- Itti, L., Koch, C., & Niebur, E. (1998). A model of saliency-based visual attention for rapid scene analysis. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 20(11), 1254–1259. <https://doi.org/10.1109/34.730558>
- Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes Factors. *The Journal of Problem Solving*, 7, 2–9. <https://doi.org/10.7771/1932-6246.1167>
- JASPTeam. (2016). JASP (Version 0.7. 5.5)[computer software]. Retrieved from *Jasp-Stats. Org*.
- Kahneman, D., & Beatty, J. (1966). Pupil Diameter and Load on Memory. *Science*, 154(3756). Retrieved from <http://science.sciencemag.org/content/154/3756/1583>
- Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology*, 24(2), 175–219. [https://doi.org/10.1016/0010-0285\(92\)90007-O](https://doi.org/10.1016/0010-0285(92)90007-O)
- Kalla, R., Muggleton, N. G., Cowey, A., & Walsh, V. (2009). Human dorsolateral prefrontal cortex is involved in visual search for conjunctions but not features: A theta TMS study. *Cortex*, 45(9), 1085–1090. <https://doi.org/10.1016/j.cortex.2009.01.005>
- Kaufman, M. A., & Bolles, R. C. (1981). A nonassociative aspect of overshadowing. *Bulletin of the Psychonomic Society*, 18(6), 318–320. <https://doi.org/10.3758/BF03333639>
- Kincade, J. M., Abrams, R. A., Astafiev, S. V., Shulman, G. L., & Corbetta, M. (2005). An event-related functional magnetic resonance imaging study of voluntary and stimulus-driven orienting of attention. *Journal of Neuroscience*. <https://doi.org/10.1523/jneurosci.0236-05.2005>
- Kinsbourne, M., & George, J. (1974). The mechanism of the word-frequency effect on recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 13(1), 63–69. [https://doi.org/10.1016/S0022-5371\(74\)80031-9](https://doi.org/10.1016/S0022-5371(74)80031-9)
- Koch, C., & Ullman, S. (1987). Shifts in Selective Visual Attention: Towards the Underlying Neural Circuitry. In *Matters of Intelligence* (pp. 115–141). https://doi.org/10.1007/978-94-009-3833-5_5
- Krebs, R. M., Boehler, C. N., De Belder, M., & Egner, T. (2015). Neural Conflict-Control Mechanisms Improve Memory for Target Stimuli. *Cerebral Cortex (New York, N.Y. : 1991)*. <https://doi.org/10.1093/cercor/bht283>
- Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior*, 23(1), 39–66. [https://doi.org/10.1016/S0022-5371\(84\)90499-7](https://doi.org/10.1016/S0022-5371(84)90499-7)
- Kurby, C. A., & Zacks, J. M. (2008). Segmentation in the perception and memory of events. *Trends in Cognitive Sciences*, 12(2), 72–79. <https://doi.org/10.1016/J.TICS.2007.11.004>
- Lambert, A., Roser, M., Wells, I., & Heffer, C. (2006). The spatial correspondence hypothesis and orienting in response to central and peripheral spatial cues. *Visual Cognition*, 13(1), 65–88. <https://doi.org/10.1080/13506280500264460>
- Laming, D. R. J. (1968). Information theory of choice-reaction times. Academic Press.
- Lamy, D., & Zoaris, L. (2009). Task-irrelevant stimulus salience affects visual search. *Vision Research*, 49(11), 1472–1480. <https://doi.org/10.1016/J.VISRES.2009.03.007>
- LaPointe, M. R., Lupiáñez, J., & Milliken, B. (2013). Context congruency effects in change detection: Opposing effects on detection and identification. *Visual Cognition*, 21(January 2015), 99–122. <https://doi.org/10.1080/13506285.2013.787133>
- LaPointe, M. R., & Milliken, B. (2016). Semantically incongruent objects attract eye gaze when viewing scenes for change. *Visual Cognition*, 6285(Advance online publication), 1–15. <https://doi.org/10.1080/13506285.2016.1185070>
- Lasaponara, S., Chica, A. B., Lecce, F., Lupianez, J., & Doricchi, F. (2011). ERP evidence for selective drop in attentional costs in uncertain environments: challenging a purely premotor account of covert orienting of attention. *Neuropsychologia*, 49(9), 2648–57. <https://doi.org/10.1016/j.neuropsychologia.2011.05.012>
- Lasaponara, S., D'Onofrio, M., Dragone, A., Pinto, M., Caratelli, L., & Doricchi, F. (2017). Changes in predictive cuing modulate the hemispheric distribution of the P1 inhibitory response to

-
- attentional targets. *Neuropsychologia*, 99(January), 156–164. <https://doi.org/10.1016/j.neuropsychologia.2017.03.010>
- Lazzaro, V. Di, Restuccia, D., Oliviero, A., Profice, P., Ferrara, L., Insola, A., ... Rothwell, J. C. (1998). Magnetic transcranial stimulation at intensities below active motor threshold activates intracortical inhibitory circuits. *Experimental Brain Research*, 119(2), 265–268. <https://doi.org/10.1007/s002210050341>
- Lee, T. S., & Mumford, D. (2003). Hierarchical Bayesian inference in the visual cortex. *Journal of the Optical Society of America A*, 20(7), 1434. <https://doi.org/10.1364/JOSAA.20.001434>
- Li, Z. (2002). A saliency map in primary visual cortex. *Trends in Cognitive Sciences*, 6(1), 9–16. [https://doi.org/10.1016/S1364-6613\(00\)01817-9](https://doi.org/10.1016/S1364-6613(00)01817-9)
- Logan, G. D. (1998). What is learned during automatization? II. Obligatory encoding of spatial location. *Journal of Experimental Psychology: Human Perception and Performance*, 24(6), 1720–1736. <https://doi.org/10.1037/0096-1523.24.6.1720>
- Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, 390(6657), 279–81. <https://doi.org/10.1038/36846>
- Lupiáñez, J., Klein, R. M., & Bartolomeo, P. (2006). Inhibition of return: Twenty years after. *Cognitive Neuropsychology*, 23(7), 1003–1014. <https://doi.org/10.1080/02643290600588095>
- Lupiáñez, J., Martín-Arévalo, E., & Chica, A. B. (2013). Is Inhibition of Return due to attentional disengagement or to a detection cost? The Detection Cost Theory of IOR. *Psicológica*, 34, 221–252. Retrieved from <https://www.uv.es/PSICOLOGICA/articulos2.13/5Lupianyez.pdf>
- Lupyan, G., & Ward, E. J. (2013). Language can boost otherwise unseen objects into visual awareness. *Proceedings of the National Academy of Sciences of the United States of America*, 110(35), 14196–201. <https://doi.org/10.1073/pnas.1303312110>
- Ly, A., Etz, A., Marsman, M., & Wagenmakers, E. J. (2017). Replication Bayes Factors from Evidence Updating. Retrieved from psyarxiv.com/u8m2s.
- Macaluso, E., & Doricchi, F. (2013). Attention and predictions: control of spatial attention beyond the endogenous-exogenous dichotomy. *Frontiers in Human Neuroscience*, 7(October), 75–80. <https://doi.org/10.3389/fnhum.2013.00685>
- Mackintosh, N. J. (1971). An analysis of overshadowing and blocking. *Quarterly Journal of Experimental Psychology*, 23(1), 118–125. <https://doi.org/10.1080/00335557143000121>
- Maeda, F., Keenan, J. P., Tormos, J. M., Topka, H., & Pascual-Leone, A. (2000). Interindividual variability of the modulatory effects of repetitive transcranial magnetic stimulation on cortical excitability. *Experimental Brain Research*, 133(4), 425–430. <https://doi.org/10.1007/s002210000432>
- Malach, R., Reppas, J. B., Benson, R. R., Kwong, K. K., Jiang, H., Kennedy, W. A., ... Tootell, R. B. (1995). Object-related activity revealed by functional magnetic resonance imaging in human occipital cortex. *Proceedings of the National Academy of Sciences*, 92(18), 8135–8139. <https://doi.org/10.1073/pnas.92.18.8135>
- Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory & Cognition*, 22(6), 657–672. <https://doi.org/10.3758/BF03209251>
- Mandler, J. M., & Parker, R. E. (1976). Memory for descriptive and spatial information in complex pictures. *Journal of Experimental Psychology: Human Learning and Memory*, 2(1), 38–48. <https://doi.org/10.1037/0278-7393.2.1.38>
- Mandler, J. M., & Ritchey, G. H. (1977). Long-term memory for pictures. *Journal of Experimental Psychology: Human Learning & Memory*, 3(4), 386–396. <https://doi.org/10.1037/0278-7393.3.4.386>
- Markant, J., & Amso, D. (2014). Leveling the playing field: Attention mitigates the effects of intelligence on memory. *Cognition*, 131(2), 195–204. <https://doi.org/10.1016/j.cognition.2014.01.006>
- Marois, R., Leung, H.-C., & Gore, J. C. (2000). A Stimulus-Driven Approach to Object Identity and Location Processing in the Human Brain. *Neuron*, 25(3), 717–728. [https://doi.org/10.1016/S0896-6273\(00\)81073-9](https://doi.org/10.1016/S0896-6273(00)81073-9)

-
- Martín-Arévalo, E., Lupiáñez, J., Botta, F., & Chica, A. B. (2015). Endogenous attention modulates attentional and motor interference from distractors: evidence from behavioral and electrophysiological results. *Frontiers in Psychology, 6*, 132. <https://doi.org/10.3389/fpsyg.2015.00132>
- McClure, S. M., Berns, G. S., & Montague, P. R. (2003). Temporal Prediction Errors in a Passive Learning Task Activate Human Striatum. *Neuron, 38*(2), 339–346. [https://doi.org/10.1016/S0896-6273\(03\)00154-5](https://doi.org/10.1016/S0896-6273(03)00154-5)
- Meier, B., Rey-Mermet, A., Rothen, N., & Graf, P. (2013). Recognition memory across the lifespan: the impact of word frequency and study-test interval on estimates of familiarity and recollection. *Frontiers in Psychology, 4*, 787. <https://doi.org/10.3389/fpsyg.2013.00787>
- Meissner, C. A., & Brigham, J. C. (2001). A meta-analysis of the verbal overshadowing effect in face identification. *Applied Cognitive Psychology, 15*(6), 603–616. <https://doi.org/10.1002/acp.728>
- Meister, I. G., Wienemann, M., Buelte, D., Grünewald, C., Sparing, R., Dambeck, N., & Boroojerdi, B. (2006). Hemiextinction induced by transcranial magnetic stimulation over the right temporoparietal junction. *Neuroscience, 142*(1), 119–123. <https://doi.org/10.1016/j.neuroscience.2006.06.023>
- Miller, M. B., & Gazzaniga, M. S. (1998). Creating false memories for visual scenes. *Neuropsychologia, 36*(6), 513–520. [https://doi.org/10.1016/S0028-3932\(97\)00148-6](https://doi.org/10.1016/S0028-3932(97)00148-6)
- Milliken, B., Tipper, S. P., & Weaver, B. (1994). Negative priming in a spatial localization task: Feature mismatching and distractor inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 20*(3), 624–646. <https://doi.org/10.1037/0096-1523.20.3.624>
- Mohler, C. W., Goldberg, M. E., & Wurtz, R. H. (1973). Visual receptive fields of frontal eye field neurons. *Brain Research, 61*(C), 385–389. [https://doi.org/10.1016/0006-8993\(73\)90543-X](https://doi.org/10.1016/0006-8993(73)90543-X)
- Mollon, J. D., & Perkins, A. J. (1996). Errors of judgement at Greenwich in 1796. *Nature, 380*(6570), 101–102. <https://doi.org/10.1038/380101a0>
- Mooney, C. M. (1957). Age in the development of closure ability in children. *Canadian Journal of Psychology/Revue Canadienne de Psychologie, 11*(4), 219–226. <https://doi.org/10.1037/h0083717>
- Mudrik, L., Breska, A., Lamy, D., & Deouell, L. Y. (2011). Integration Without Awareness. *Psychological Science, 22*(6), 764–770. <https://doi.org/10.1177/0956797611408736>
- Muggleton, N. G., Cowey, A., & Walsh, V. (2008). The role of the angular gyrus in visual conjunction search investigated using signal detection analysis and transcranial magnetic stimulation. *Neuropsychologia, 46*(8), 2198–2202. <https://doi.org/10.1016/j.neuropsychologia.2008.02.016>
- Mulligan, N. W., Spataro, P., & Picklesimer, M. (2014). The Attentional Boost Effect With Verbal Materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(4), 1049–1063. Retrieved from <http://cat.inist.fr/?aModele=afficheN&cpsid=28599188>
- Murray, L. J., & Ranganath, C. (2007). The Dorsolateral Prefrontal Cortex Contributes to Successful Relational Memory Encoding. *Journal of Neuroscience, 27*(20), 5515–5522. <https://doi.org/10.1523/JNEUROSCI.0406-07.2007>
- Nardo, D., Santangelo, V., & Macaluso, E. (2011). Stimulus-Driven Orienting of Visuo-Spatial Attention in Complex Dynamic Environments. *Neuron, 69*(5), 1015–1028. <https://doi.org/10.1016/J.NEURON.2011.02.020>
- Natale, E., Marzi, C. A., Girelli, M., Pavone, E. F., & Pollmann, S. (2006). ERP and fMRI correlates of endogenous and exogenous focusing of visual-spatial attention. *European Journal of Neuroscience, 23*(9), 2511–2521. <https://doi.org/10.1111/j.1460-9568.2006.04756.x>
- Navalpakkam, V., & Itti, L. (2005). Modeling the influence of task on attention. *Vision Research, 45*(2), 205–231. <https://doi.org/10.1016/J.VISRES.2004.07.042>
- Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106*(3), 226–254. <https://doi.org/10.1037/0096-3445.106.3.226>
- O’Doherty, J., Dayan, P., Schultz, J., Deichmann, R., Friston, K., & Dolan, R. J. (1997). A neural substrate of prediction and reward. *Science (New York, N.Y.), 275*(5306), 1593–9.

<https://doi.org/10.1126/science.275.5306.1593>

- Oliva, A., & Torralba, A. (2006). Chapter 2 Building the gist of a scene: the role of global image features in recognition. *Progress in Brain Research*. [https://doi.org/10.1016/S0079-6123\(06\)55002-2](https://doi.org/10.1016/S0079-6123(06)55002-2)
- Ortiz-Tudela, J., Martín-Arévalo, E., Chica, A. B., & Lupiáñez, J. (n.d.). Semantic incongruity attracts attention at a pre-conscious level: evidence from a TMS study.
- Ortiz-Tudela, J., Milliken, B., Botta, F., LaPointe, M. R., & Lupiáñez, J. (2016). A cow on the prairie vs. a cow on the street: long-term consequences of semantic conflict on episodic encoding. *Psychological Research*. <https://doi.org/10.1007/s00426-016-0805-y>
- Palmer, Stephen E. (1975). The effects of contextual scenes on the identification of objects. *Memory & Cognition*, 3(5), 519–526. <https://doi.org/10.3758/BF03197524>
- Parmentier, F. B. R., Elsley, J. V., Andrés, P., & Barceló, F. (2011). Why are auditory novels distracting? Contrasting the roles of novelty, violation of expectation and stimulus change. *Cognition*, 119(3), 374–380. <https://doi.org/10.1016/J.COGNITION.2011.02.001>
- Peavler, W. S. (1974). Pupil Size, Information Overload, and Performance Differences. *Psychophysiology*, 11(5), 559–566. <https://doi.org/10.1111/j.1469-8986.1974.tb01114.x>
- Pedale, T., & Santangelo, V. (2015). Perceptual salience affects the contents of working memory during free-recollection of objects from natural scenes. *Frontiers in Human Neuroscience*, 9, 60. <https://doi.org/10.3389/fnhum.2015.00060>
- Peelen, M. V., & Kastner, S. (2014). Attention in the real world: toward understanding its neural basis. *Trends in Cognitive Sciences*, 1–9. <https://doi.org/10.1016/j.tics.2014.02.004>
- Peirce, J. W. (2007). PsychoPy-Psychophysics software in Python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. <https://doi.org/10.1016/j.jneumeth.2006.11.017>
- Petersson, K. M., Sandblom, J., Elfgren, C., & Ingvar, M. (2003). Instruction-specific brain activations during episodic encoding. *NeuroImage*, 20(3), 1795–1810. [https://doi.org/10.1016/S1053-8119\(03\)00414-2](https://doi.org/10.1016/S1053-8119(03)00414-2)
- Pezdek, K., Whetstone, T., Reynolds, K., Askari, N., & Et Al. (1989). Memory for real-world scenes: The role of consistency with schema expectation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15(4), 587–595. <https://doi.org/10.1037/0278-7393.15.4.587>
- Pinker, S. (2007). *The stuff of thought : language as a window into human nature* (1st ed.). Viking.
- Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, 118(10), 2128–2148. <https://doi.org/10.1016/j.clinph.2007.04.019>
- Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, 32(1), 3–25. <https://doi.org/10.1080/00335558008248231>
- Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, 2(3), 211–228. <https://doi.org/10.1080/02643298508252866>
- Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience*, 4(7), 1863–1874.
- Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory*, 2(5), 509–522. <https://doi.org/10.1037/0278-7393.2.5.509>
- Potter, M. C., & Fox, L. F. (2009). Detecting and remembering simultaneous pictures in a rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance*, 35(1), 28–38. <https://doi.org/10.1037/a0013624>
- Psychology Software Tools, I. (2012). E-Prime 2.0. Pittsburgh, PA. Retrieved from <http://www.pstnet.com>
- Rabovsky, M., Stein, T., & Abdel Rahman, R. (2016). Access to awareness for faces during continuous flash suppression is not modulated by affective knowledge. *PLoS ONE*. <https://doi.org/10.1371/journal.pone.0150931>
- Rafal, R. D., Danziger, S., Grossi, G., Machado, L., & Ward, R. (2002). Visual detection is gated by attending for action: evidence from hemispatial neglect. *Proceedings of the National Academy of*

-
- Sciences of the United States of America*, 99(25), 16371–5. <https://doi.org/10.1073/pnas.252309099>
- Rajaram, S. (1993). Remembering and knowing: Two means of access to the personal past. *Memory & Cognition*, 21(1), 89–102. <https://doi.org/10.3758/BF03211168>
- Rao, R. P., & Ballard, D. H. (1999). Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive field effects. *Nature Neuroscience*, 2(1), 79–87.
- Reeder, R. R., Perini, F., & Peelen, M. V. (2015). Preparatory Activity in Posterior Temporal Cortex Causally Contributes to Object Detection in Scenes. *Journal of Cognitive Neuroscience*, 27(11), 2117–2125. https://doi.org/10.1162/jocn_a_00845
- Rémy, F., Vayssière, N., Pins, D., Boucart, M., & Fabre-Thorpe, M. (2014). Incongruent object/context relationships in visual scenes: Where are they processed in the brain? *Brain and Cognition*, 84(1), 34–43. <https://doi.org/10.1016/J.BANDC.2013.10.008>
- Rensink, R. A., O'Regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science*, 8(5), 368–373. <https://doi.org/10.1111/j.1467-9280.1997.tb00427.x>
- Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: current research and theory* (pp. 64–99). New York, New York, USA: Appleton-Century-Crofts.
- Robertson, B. D., Hiebert, N. M., Seergobin, K. N., Owen, A. M., & MacDonald, P. A. (2015). Dorsal striatum mediates cognitive control, not cognitive effort per se, in decision-making: An event-related fMRI study. *NeuroImage*. <https://doi.org/10.1016/j.neuroimage.2015.03.082>
- Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General*, 104(3), 192–233. <https://doi.org/10.1037/0096-3445.104.3.192>
- Rosner, T. M., D'Angelo, M. C., MacLellan, E., & Milliken, B. (2015). Selective attention and recognition: effects of congruency on episodic learning. *Psychological Research*. <https://doi.org/10.1007/s00426-014-0572-6>
- Rosner, T. M., Davis, H., & Milliken, B. (2015). Perceptual blurring and recognition memory: A desirable difficulty effect revealed. *Acta Psychologica*, 160, 11–22. <https://doi.org/10.1016/j.actpsy.2015.06.006>
- Rossi, S., Hallett, M., Rossini, P. M., & Pascual-Leone, A. (2009). Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. *Clinical Neurophysiology*, 120(12), 2008–2039. <https://doi.org/10.1016/j.clinph.2009.08.016>
- Rossini, P. M., Burke, D., Chen, R., Cohen, L. G., Daskalakis, Z., Di Iorio, R., ... Ziemann, U. (2015). Non-invasive electrical and magnetic stimulation of the brain, spinal cord, roots and peripheral nerves: Basic principles and procedures for routine clinical and research application. An updated report from an I.F.C.N. Committee. *Clinical Neurophysiology*, 126(6), 1071–1107. <https://doi.org/10.1016/j.clinph.2015.02.001>
- Russo, J. E., & Doshier, B. A. (1983). Strategies for multiattribute binary choice. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, 9(4), 676–696.
- Ruz, M., & Lupiáñez, J. (2002). A review of attentional capture : On its automaticity and sensitivity to endogenous control. *Psicológica*, 23, 283–309.
- Sampanes, A. C., Tseng, P., & Bridgeman, B. (2008). The role of gist in scene recognition. *Vision Research*, 48(21), 2275–2283. <https://doi.org/10.1016/j.visres.2008.07.011>
- Samson, A. C., Hempelmann, C. F., Huber, O., & Zysset, S. (2009). Neural substrates of incongruity-resolution and nonsense humor. *Neuropsychologia*, 47(4), 1023–1033. <https://doi.org/10.1016/j.neuropsychologia.2008.10.028>
- Santangelo, V. (2015). Forced to remember: When memory is biased by salient information. *Behavioural Brain Research*, 1–10. <https://doi.org/10.1016/j.bbr.2015.01.013>
- Santangelo, V., di Francesco, S. A., Mastroberardino, S., & Macaluso, E. (2015). Parietal cortex integrates contextual and saliency signals during the encoding of natural scenes in working

-
- memory. *Human Brain Mapping*, 36(12), 5003–5017. <https://doi.org/10.1002/hbm.22984>
- Schall, J. D., & Hanes, D. P. (1993). Neural basis of saccade target selection in frontal eye field during visual search. *Nature*, 366(6454), 467–469. <https://doi.org/10.1038/366467a0>
- Scharlau, I. (2007). Perceptual latency priming: A measure of attentional facilitation. *Psychological Research*, 71(6), 678–686. <https://doi.org/10.1007/s00426-006-0056-4>
- Schooler, J. W., & Engstler-Schooler, T. Y. (1990). Verbal overshadowing of visual memories: Some things are better left unsaid. *Cognitive Psychology*, 22(1), 36–71. [https://doi.org/10.1016/0010-0285\(90\)90003-M](https://doi.org/10.1016/0010-0285(90)90003-M)
- Schvaneveldt, R. W., & Meyer, D. E. (1973). *Retrieval and comparison processes in semantic memory. Attention and performance IV*. New York: Academic Press.
- Sebastián-Gallés, N. (2000). *LEXESP: Léxico informatizado del español*. Edicions Universitat Barcelona.
- Serences, J. T., Shomstein, S., Leber, A. B., Golay, X., Egeth, H. E., & Yantis, S. (2005). Coordination of Voluntary and Stimulus-Driven Attentional Control in Human Cortex. *Psychological Science*, 16(2), 114–122. <https://doi.org/10.1111/j.0956-7976.2005.00791.x>
- Shore, D. I., Spence, C., & Klein, R. M. (2001). Visual Prior Entry. *Psychological Science*, 12(3), 205–212. <https://doi.org/10.1111/1467-9280.00337>
- Shulman, G. L., Astafiev, S. V., McAvoy, M. P., D’Avossa, G., & Corbetta, M. (2007). Right TPJ deactivation during visual search: Functional significance and support for a filter hypothesis. *Cerebral Cortex*, 17(11), 2625–2633. <https://doi.org/10.1093/cercor/bhl170>
- Shulman, G. L., Astafiev, S. V., Franke, D., Pope, D. L. W., Abraham, Z., Mcavoy, M. P., & Corbetta, M. (2010). Networks, 29(14), 4392–4407. <https://doi.org/10.1523/JNEUROSCI.5609-08.2009>. Interaction
- Silva, M. M., Groeger, J. A., & Bradshaw, M. F. (2006). Attention–memory interactions in scene perception. *Spatial Vision*, 19(1), 9–19. <https://doi.org/10.1163/156856806775009223>
- Simon, J. R., & Small, A. M. . J. (1969). Processing Auditory Information: Interference From an Irrelevant Cue. *J Appl Psychol*.
- Simons, D. J., & Rensink, R. A. (2005). Change blindness: past, present, and future. *Trends in Cognitive Sciences*, 9(1), 16–20. <https://doi.org/10.1016/j.tics.2004.11.006>
- Spotorno, S., Tatler, B. W., & Faure, S. (2013). Semantic consistency versus perceptual salience in visual scenes: Findings from change detection. *Acta Psychologica*, 142(2), 168–176. <https://doi.org/10.1016/j.actpsy.2012.12.009>
- Stein, T., & Peelen, M. V. (2015a). Content-specific expectations enhance stimulus detectability by increasing perceptual sensitivity. *Journal of Experimental Psychology: General*, 144(6), 1089–1104. <https://doi.org/10.1037/xge0000109>
- Stein, T., & Peelen, M. V. (2015b). Content-specific expectations enhance stimulus detectability by increasing perceptual sensitivity. *Journal of Experimental Psychology: General*, 144(6), 1089–1104. <https://doi.org/10.1037/xge0000109>
- Stein, T., Reeder, R. R., & Peelen, M. V. (2016). Privileged access to awareness for faces and objects of expertise. *Journal of Experimental Psychology: Human Perception and Performance*, 42(6), 788–798. <https://doi.org/10.1037/xhp0000188>
- Stein, T., Siebold, A., & van Zoest, W. (2016). Testing the idea of privileged awareness of self-relevant information. *Journal of Experimental Psychology: Human Perception and Performance*, 42(3), 303–307. <https://doi.org/10.1037/xhp0000197>
- Stein, T., & Sterzer, P. (2012). Not just another face in the crowd: Detecting emotional schematic faces during continuous flash suppression. *Emotion*, 12(5), 988–996. <https://doi.org/10.1037/a0026944>
- Stirk, J., & Underwood, G. (2007). Low-level visual saliency does not predict change detection in natural scenes. *Journal of Vision*, 7, 1–10. <https://doi.org/10.1167/7.10.3>. Introduction
- Storm, B. C., Bjork, E. L., Bjork, R. A., & Nestojko, J. F. (2006). Is retrieval success a necessary condition for retrieval-induced forgetting? *Psychonomic Bulletin & Review*, 13(6), 1023–1027. <https://doi.org/10.3758/BF03213919>

- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. <https://doi.org/10.1037/h0054651>
- Summerfield, C., Egner, T., Greene, M., Koechlin, E., Mangels, J., & Hirsch, J. (2006). Predictive Codes for Forthcoming Perception in the Frontal Cortex. *Science*, *314*(5803), 1311–1314. <https://doi.org/10.1126/science.1132028>
- Swallow, K. M., & Jiang, Y. V. (2010a). The Attentional Boost Effect: Transient increases in attention to one task enhance performance in a second task. *Cognition*, *115*(1), 118–132. <https://doi.org/10.1016/j.cognition.2009.12.003>
- Swallow, K. M., & Jiang, Y. V. (2010b). The Attentional Boost Effect: Transient increases in attention to one task enhance performance in a second task. *Cognition*, *115*(1), 118–32. <https://doi.org/10.1016/j.cognition.2009.12.003>
- Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychophysics*, *50*(2), 184–193. <https://doi.org/10.3758/BF03212219>
- Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, *51*(6), 599–606. <https://doi.org/10.3758/BF03211656>
- Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica*, *135*(2), 77–99. <https://doi.org/10.1016/J.ACTPSY.2010.02.006>
- Theeuwes, J. (2013). Feature-based attention: it is all bottom-up priming. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *368*(1628), 20130055. <https://doi.org/10.1098/rstb.2013.0055>
- Todorovic, A., van Ede, F., Maris, E., & de Lange, F. P. (2011). Prior expectation mediates neural adaptation to repeated sounds in the auditory cortex: an MEG study. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *31*(25), 9118–23. <https://doi.org/10.1523/JNEUROSCI.1425-11.2011>
- Torralla, A., Oliva, A., Castelhana, M. S., & Henderson, J. M. (2006). Contextual guidance of eye movements and attention in real-world scenes: The role of global features in object search. *Psychological Review*, *113*(4), 766–786. <https://doi.org/10.1037/0033-295X.113.4.766>
- Torres-Quesada, M., Funes, M. J., & Lupiáñez, J. (2013). Dissociating proportion congruent and conflict adaptation effects in a Simon-Stroop procedure. *Acta Psychologica*, *142*(2), 203–10. <https://doi.org/10.1016/j.actpsy.2012.11.015>
- Torres-Quesada, M., Milliken, B., Lupiáñez, J., & Funes, M. J. (2013). Proportion Congruent Effects in the Absence of Sequential Congruent Effects. *Psicologica: International Journal of Methodology and Experimental Psychology*, *35*(1), 101–115. Retrieved from <http://eric.ed.gov/?id=EJ1022043>
- Treisman, A., & Souther, J. (1985). Search asymmetry: A diagnostic for preattentive processing of separable features. *Journal of Experimental Psychology: General*, *114*(3), 285–310. <https://doi.org/10.1037/0096-3445.114.3.285>
- Tsuchiya, N., & Koch, C. (2005). Continuous flash suppression reduces negative afterimages. *Nature Neuroscience*, *8*(8), 1906. <https://doi.org/10.1038/nn1500>
- Tulving, E., & Kroll, N. (1995). Novelty assessment in the brain and long-term memory encoding. *Psychonomic Bulletin & Review*, *2*(3), 387–90. <https://doi.org/10.3758/BF03210977>
- Tulving, E., Markowitsch, H. J., Craik, F. I. M., Habib, R., & Houle, S. (1996). Novelty and Familiarity Activations in PET Studies of Memory Encoding and Retrieval. *Cerebral Cortex*, *6*(1), 71–79. <https://doi.org/10.1093/cercor/6.1.71>
- Tulving, E., & Schacter, D. L. (1990). Priming and Human Memory Systems. *Science*. American Association for the Advancement of Science. <https://doi.org/10.2307/2873625>
- Underwood, G., & Foulsham, T. (2006). Visual saliency and semantic incongruity influence eye movements when inspecting pictures. *Quarterly Journal of Experimental Psychology (2006)*, *59*(11), 1931–49. <https://doi.org/10.1080/17470210500416342>
- Underwood, G., Templeman, E., Lamming, L., & Foulsham, T. (2008). Is attention necessary for object identification? Evidence from eye movements during the inspection of real-world scenes. *Consciousness and Cognition*, *17*(1), 159–170. <https://doi.org/10.1016/j.concog.2006.11.008>

-
- Valero-Cabré, A., Payne, B. R., & Pascual-Leone, A. (2007). Opposite impact on 14C-2-deoxyglucose brain metabolism following patterns of high and low frequency repetitive transcranial magnetic stimulation in the posterior parietal cortex. *Experimental Brain Research*, 176(4), 603–615. <https://doi.org/10.1007/s00221-006-0639-8>
- van Kesteren, M. T. R., Rijpkema, M., Ruiter, D. J., & Fernández, G. (2010). Retrieval of associative information congruent with prior knowledge is related to increased medial prefrontal activity and connectivity. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, 30(47), 15888–94. <https://doi.org/10.1523/JNEUROSCI.2674-10.2010>
- van Kesteren, M. T. R., Ruiter, D. J., Fernández, G., & Henson, R. N. (2012). How schema and novelty augment memory formation. *Trends in Neurosciences*, 35(4), 211–219. <https://doi.org/10.1016/j.tins.2012.02.001>
- VanRullen, R., & Thorpe, S. J. (2001). The Time Course of Visual Processing: From Early Perception to Decision-Making. *Journal of Cognitive Neuroscience*, 13(4), 454–461. <https://doi.org/10.1162/08989290152001880>
- Verguts, T., & Notebaert, W. (2008). Hebbian learning of cognitive control: dealing with specific and nonspecific adaptation. *Psychological Review*, 115(2), 518–25. <https://doi.org/10.1037/0033-295X.115.2.518>
- Verguts, T., & Notebaert, W. (2009). Adaptation by binding: a learning account of cognitive control. *Trends in Cognitive Sciences*, 13(6), 252–7. <https://doi.org/10.1016/j.tics.2009.02.007>
- Verleger, R., Jaskowski, P., & Wascher, E. (2005). Evidence for an Integrative Role of P3b in Linking Reaction to Perception. *Federation of European Psychophysiology Societies*, 20(2), 165–181. <https://doi.org/10.1027/0269-8803.19.3.165>
- Vo, M. L. H., & Henderson, J. M. (2009). Does gravity matter? Effects of semantic and syntactic inconsistencies on the allocation of attention during scene perception. *Journal of Vision*, 9(3), 24–24. <https://doi.org/10.1167/9.3.24>
- von Restorff, H. (1933). Über die Wirkung von Bereichsbildungen im Spurenfeld. *Psychologische Forschung*, 18(1), 299–342. <https://doi.org/10.1007/BF02409636>
- Vossel, S., Geng, J. J., & Fink, G. R. (2014). Dorsal and ventral attention systems: distinct neural circuits but collaborative roles. *The Neuroscientist: A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, 20(2), 150–9. <https://doi.org/10.1177/1073858413494269>
- Vossel, S., Weidner, R., Thiel, C. M., & Fink, G. R. (2009). What is “Odd” in Posner’s Location-cueing Paradigm? Neural Responses to Unexpected Location and Feature Changes Compared. *Journal of Cognitive Neuroscience*, 21(1), 30–41. <https://doi.org/10.1162/jocn.2009.21003>
- Wacongne, C., Labyt, E., van Wassenhove, V., Bekinschtein, T., Naccache, L., & Dehaene, S. (2011). Evidence for a hierarchy of predictions and prediction errors in human cortex. *Proceedings of the National Academy of Sciences of the United States of America*, 108(51), 20754–9. <https://doi.org/10.1073/pnas.1117807108>
- Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, 14(5), 779–804. <https://doi.org/10.3758/BF03194105>
- Watkins, O. C., & Watkins, M. J. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning & Memory*, 1(4), 442–452. <https://doi.org/10.1037/0278-7393.1.4.442>
- Wessel, J. R., & Aron, A. R. (2017). On the globality of motor suppression: unexpected events and their influence on behavior and cognition. *Neuron*, 93(2), 259–280. <https://doi.org/10.1016/j.neuron.2016.12.013>
- Wolfe, J. M. (1994). Guided Search 2.0 A revised model of visual search. *Psychonomic Bulletin & Review*, 1(2), 202–238. <https://doi.org/10.3758/BF03200774>
- Yabe, H., Tervaniemi, M., Reinikainen, K., & Näätänen, R. (1997). Temporal window of integration revealed by MMN to sound omission. *Neuroreport*, 8(8), 1971–4. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9223087>
- Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual

-
- search. *Journal of Experimental Psychology: Human Perception and Performance*, 10(5), 601–621. <https://doi.org/10.1037/0096-1523.10.5.601>
- Yoshida, M., Itti, L., Berg, D. J., Ikeda, T., Kato, R., Takaura, K., ... Isa, T. (2012). Residual Attention Guidance in Blindsight Monkeys Watching Complex Natural Scenes. *Current Biology*, 22(15), 1429–1434. <https://doi.org/10.1016/J.CUB.2012.05.046>
- Zhang, L., Tong, M. H., Marks, T. K., Shan, H., & Cottrell, G. W. (2008a). SUN: A Bayesian framework for saliency using natural statistics. *Journal of Vision*, 8(7), 32.1-20. <https://doi.org/10.1167/8.7.32>
- Zhang, L., Tong, M. H., Marks, T. K., Shan, H., & Cottrell, G. W. (2008b). SUN: A Bayesian framework for saliency using natural statistics. *Journal of Vision*, 8, 32.1-20. <https://doi.org/10.1167/8.7.32>
- Zhang, X., Zhaoping, L., Zhou, T., & Fang, F. (2012). Neural Activities in V1 Create a Bottom-Up Saliency Map. *Neuron*, 73(1), 183–192. <https://doi.org/10.1016/J.NEURON.2011.10.035>