CHAPTER SEVEN

When Do the Effects of Distractors Provide a Measure of Distractibility?

Alejandro Lleras*,[1], Simona Buetti*, J. Toby Mordkoff†
*Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL, USA
†Department of Psychology, University of Iowa, Iowa City, IA, USA
[1]Corresponding author: E-mail: alejandrolleras@gmail.com

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Abstract

We discuss how, at the present time, there is a large deal of confusion in the attention literature regarding the use of the label "distractor" and what may be inferred from experiments using distractors. In particular, investigators seem to use the concepts of distractor interference and distractibility almost interchangeably. In contrast, we argue at both the theoretical and empirical levels that these two concepts are not only different, but in fact mutually exclusive. To that end, a brief review of several subliteratures is presented, in which we identify some examples of the misuse of these terms. We also propose a new paradigm for the study of distraction, as well as present a contemporary general theory of visual attention that provides a better framework for understanding distractor-interference effects, as well as instances of true distraction.

1. INTRODUCTION

What is "distraction"? To borrow some from James' famous definition of attention, one could say that distraction is the taking possession of the mind in clear and vivid form by a thought or stimulus *that one never intended to process in the first place*. It is a thought or stimulus that takes us "out" of our intended task and drives our attention onto new thoughts or sensations. This definition seems quite close to our intuitions of what being distracted is like, and matches the vernacular definition of distraction (e.g. "the drawing away [of the mind or thoughts] from one point or course to another; diversion of the mind or attention", Oxford English Dictionary). It is also a definition that is implied by work in applied psychology, such as the recent studies on distracted driving (e.g. Cooper, Vladisavljevic, Medeiros-Ward, Martin, & Strayer, 2009; Strayer, Watson, & Drews, 2011). It certainly is an important concept in our everyday life, so it is to no surprise that we, in the attention field, may want to draw inferences about this concept from our investigations. One of the primary goals of this chapter is to point out where this effort has faltered and identify one reason why this has happened: the inappropriate assumption that the effects of distractors are always a measure of distraction.

The history of the term "distractor" is as old as the discipline of psychology itself. One can easily find papers using this term as far back as the nineteenth century (e.g. Darlington & Talbot, 1898). In the early days, distractors were understood to be that type of stimulus that can distract us from our main tasks and, thereby, disturb our performance. Darlington & Talbot (1898) were interested, for example, in testing whether music could be considered a distractor and used a weight-lifting task to assess the impact of music on performance. (Results suggested that, no, music was not a "distractor".) Another example was Tinker (1925) who studied whether the presence of bells ringing intermittently during an intelligence test would affect performance of the test, a marker that distraction hinders performance. (On average, it did not.) Yet, from the start, the early intuition that distraction ought to hinder performance was there and a significant debate arose as to what ought to be called a distractor (see Dulsky, 1932, *Psychological Review*). In fact, early efforts to study attention using distractors often failed "because it was impossible to obtain a satisfactory distractor" (Dulsky, 1932, p. 590). That said, what did come from those early years was a new way of talking about distractors: "distractor" is not a label to be used in relation to attention (or as a means to study *that* abstract concept), but rather in relation to performance. The rationale is simple: given that we don't know what attention is, but we do know how to measure performance, it is best to simply define distractors as those stimuli that hinder performance (Dulsky, 1932).

The goal of this chapter is to challenge this conception of "distractor," which is closely related to the modern use of this term. Our hope is to highlight the problems with this term, the confusion that it engenders and, hopefully, provide a way out of this state of affairs by creating a more modern context in which we can (a) redefine the study of distraction; (b) clarify the terminology that is used to study attention *and* distraction; and (c) identify current sources of confusion in the literature that are very much related to the confusability between the labels "distractor" and "distraction". We will begin by presenting a literature where the term distractor is heavily used (viz, visual search) in spite of the fact that the goal of this work is not to study distraction at all (but in fact attention). Along the way, we will argue that not all "distractors" are created equal and, thus, one must be careful when trying to extend the findings from laboratory visual search to real-world search tasks. Next, we will quickly discuss (and dismiss) an example of the use of the term "distractor" within the literature on redundancy gains. Then we will describe a relatively more nuanced case study regarding the perils of the use of the label "distractor": the Flanker Effect literature, a domain in which this term has gained a very prominent role. From this section, we will conclude that it is in fact *inappropriate* to make claims about the phenomenon of "distraction" from experiments using modern-day "distractors," in spite of our field's tendency to want to make such claims. One of our goals, too, is to differentiate the concept of "distraction" from that of "distractor interference," which are actually quite different phenomena.

We will next discuss the inattentional blindness paradigm, which might be a better way of studying and conceptualizing distraction than the previous paradigms. We will also describe data from an experiment using this methodology to highlight why it is so critical to acknowledge the difference between distractor interference and actual distraction. We will argue that distractor-interference effects reflect, at a basic level, an important degree of *success* by attentional selection (rather than a failure, as it frequently claimed). Even more, we will argue that the presence of a "Flanker Effect" should be taken as evidence in favor of early selection models of attention, rather than as evidence for late selection models, as it is commonly done.

The next section of this chapter will focus on a proposed new task to study distraction and distractibility using an eye-tracking methodology. We will present data from our laboratory showing that heightened cognitive focus reduces distractibility. And we will conclude by presenting, in rough strokes, the skeleton of a model of attention that incorporates the properties of attention highlighted in this chapter, as well as other factors like motivation and the need for inner focus when completing complex cognitive tasks.

2. WHEN DO "DISTRACTORS" CAUSE DISTRACTION?

2.1. Visual Search

2.1.1. Effect of Distractors on Search Performance

To answer the question of *when do distractors cause distraction?* we will begin with the most popular paradigm that uses the first of these terms: namely, visual search. Another reason for doing this is that attention is often thought of as being the opposite or the antidote to distraction, and the concept of attention has played a major role in our understanding of visual search from the very beginning.

In the context of visual search, the term "distractor" is used to refer to a majority of the elements within the display, and was first used by Shiffrin and Gardner (1972). The collection of all distractors (plus the target item, if there is one) is referred to as *set size*. Visual search is typically studied by measuring response time (RT and/or proportion correct) as a function of set size. In other words, distractors are a set of a priori possible targets that one must inspect in order to find the target in the display. We draw inferences about the workings of visual attention by inspecting the reaction time × set size function (e.g. Duncan & Humphreys, 1989; Treisman & Gelade, 1980; Wolfe, 1994). Notice that the distractors are stimuli created by the investigator to probe how attention works. Therefore, in most laboratory tasks concerning search, there is a certain degree of (purposeful) overlap between the distractors and target stimuli (e.g. all items share a common shape, or vary within a small set of colors, orientations, etc.), because the goal is to induce a *measurable* effect on performance, and performance, itself, is defined as a function of set size (i.e. the number of distractors). So, if one defines "distraction" as either "attention is being allocated to a nontarget stimulus" or "an effect on performance that is due to distractors," then, yes, visual search would provide data that are relevant to the study of distraction. But, as we will argue, what people really mean by "attention" in the context of visual search is very different from the kind of attention that is needed to avoid being distracted. And what people really mean by "distraction" is very different from the kinds of effects that distractors have on response time in visual search. But before discussing what can be learned about distraction from cases of visual search where distractors do have an impact on performance, we will address a related, but separate issue, regarding how the absence of such effects have been interpreted, and how we believe that they ought to be interpreted, in their relation to the concept of attention.

2.1.2. *When* Distractors *Do Not Impact Search Performance*

Most theories on attention that rely on visual search experiments indeed focus most of their explanatory efforts on accounting for performance when set size matters (e.g. Bundesen, 1990; Duncan & Humphreys, 1989; Treisman & Gelade, 1980; Wolfe, 1994). In fact, whenever the number of distractors is found to have no effect on RT (i.e. so-called flat search slopes), the experimental results are brushed under the attention rug: clearly, if performance was unaffected by set size, then attention must have not been involved in the processing of the display and the detection of the target. In fact, whenever we find a case where performance is not affected by set size, we refer to it as being the result of "preattentive" processing. Color pop-out is a fine example of this: if asked to look for a red apple among green ones, the number of green apples does not influence RT to find the red target: the red apple "pops out" from the green ones and we introspectively believe that our attention automatically moved to the red target apple. But did attention really have nothing to do with us finding that red apple? Evidence from at least two smaller literature within the attention field would argue that this conclusion is misguided: the contingent-capture literature (e.g. Folk, Leber, & Egeth, 2008; Folk, Remington, & Wright, 1994) and the priming of pop-out literature (e.g. Fecteau, 2007; Maljkovic & Nakayama, 1994, 1996). For now, simply consider the following data. In Wan and Lleras

(2010), subjects were asked to detect the presence of a color oddball item (i.e. the one item that differed from all others in color). Two different sets of color pairs were used. In one block of trials, participants were tested with red and green items, while, in a different block, the items were pink and fuchsia (two colors closely matched in luminance). Both color pairs produced visual pop-out: in both cases, RTs were unaffected by set size (3, 8, or 12), with search slopes of −0.09 ms/item for red among green and 1.19 ms/item for pink among fuchsia, neither of which was different from zero. So far so good: the standard interpretation would be that these pop-out discriminations were computed in preattentive fashion by the visual system. Yet, there is a kink with this interpretation. Overall, responses were much slower with the pink and fuchsia stimuli (mean RT = 698 ms) than with the red and green stimuli (565 ms). How are we to interpret this 133 ms increase in mean RT? At what point(s) in processing was this rather large delay added? And what were observers doing during this time? Were they waiting for preattentive vision to finish processing, without attending to the display? This seems implausible given other performance benchmarks of the attention system. For instance, saccades to sudden onsets that match our attentional template can be triggered extremely quickly, in the range of 130–150 ms (Hollingworth, Matsukura, & Luck, in press; Kirchner & Thorpe, 2006). Not only it is difficult to believe that participants would have an added processing difficulty in "preattentive" vision of a magnitude of 133 ms (during which attention would not be involved), but the overall magnitude of the RTs is also equally difficult to interpret. Preattentive vision is supposed to be "fast and automatic;" the sort of stuff that gets done "before we know it." How can this type of processing produce *detection* RTs on the order of 700 ms? Are we to infer that preattentive vision can sometimes be that slow? No, we would argue, even though this answer is at odds with the prevailing view in the field on how to interpret results from visual search experiments (e.g. Duncan & Humphreys, 1989). Attention is involved in finding a pop-out target, and some pop-outs are, in fact, rather hard to find.

Going back to the central issue of what distractors are and how they are used, it is clear that we (as vision scientists) have a very poor model for what goes on with attention when distractors fail to have a measurable effect on performance. This area of potential research has gone unrecognized for the most part, and is still in its infancy (with some exceptions, Purcell et al., 2010; Schall, Purcell, Heitz, Logan, & Palmeri, 2011; Townsend, 1972; Tseng, Glaser, Caddigan, & Lleras, submitted for publication; Wenger and Townsend (2000), who earlier recognized the perceived need to use different tools to analyze presumably parallel forms of processing). Yet, this is not surprising given that one of our principal tools to index attention *at work* has been the manipulation of set size. For instance, a very influential model of visual search, Similarity Theory (Duncan & Humphreys, 1989), is predicated on the idea that preattentive vision precedes attentive vision in time. Preattentive vision is parallel and capable of producing null effects of set size, but, almost by definition, is uninteresting for studying attention per se. The main thrust of the theory is in interpreting performance when distractors do affect RTs, because one can infer attentional processing times: for instance, the more similar targets are to distractors, the more complex the attentional involvement is in the search task (e.g. larger inspection times per item). So, the logic goes, the more that distractors impact RTs, the more attention is involved in determining performance. This assumption regarding the normal processing steps in vision (encoding, in some parallel, preattentive form, followed by identification, in a more serial, attentive form) is common to most theories of attention, both formal (e.g. Treisman & Gelade, 1980; Wolfe, 1994; Wolfe, Vo, Evans, & Greene, 2011) and computational ones (e.g. Itti & Koch, 2001; Navalpakkam & Itti, 2007; Peters, Iyer, Itti, & Koch, 2005; Townsend, 1972; Wenger & Townsend, 2000). But the lack of a set-size effect does not imply a lack of attentional processing. If a set-size effect implies attentional processing (A ergo B), it is an error in logic to argue that the absence of a set-size effect implies an absence of attentional processing (not A ergo not B). Those are not logically equivalent propositions. What we can be sure of is that, if attention is not involved, then one can never expect a set-size effect to emerge (not B ergo not A). That would be correct, but it is not the argument being made in these cases.

2.1.3. The End of Preattentive Vision

How can we understand attention when our principal tool of inquiry produces no results? Understanding attentional processing in pop-out situations will require newer methodologies (new computational models and new brain imaging techniques). But it is important to realize that it is a logical flaw to argue that because our tool (set-size manipulation) failed to influence performance, that attention was not involved in producing that performance. Thus, we cannot brush aside all forms of "parallel" searches under the preattentive rug. In fact, there is overwhelming evidence that *preattentive vision is dead*. And we are not the first ones to say so (e.g. Di Lollo, Kawahara, Zuvic, & Visser, 2001, "The pre-attentive emperor has no clothes", *JEP:General*). The general idea that there is a temporal order to visual processing whereby some processing always occurs prior to the allocation of attention is likely wrong. Biased competition theory (Desimone & Duncan, 1995), for example, suggests that attention can bias processing to favor one type of stimulus (or property) over another at an extremely early point. And, thus far, the evidence in favor of this proposal is quite strong. In fact, evidence suggests that top–down attention can bias neural processing before the onset of a visual stimulus, which can result in extremely fast eye movements (Hollingworth et al., in press; Kirchner & Thorpe, 2006), as well as produce parallel feature-based selection over the entire visual field (Bichot, Rossi, & Desimone, 2005; Serences & Boynton, 2007). Even more, thanks to fMRI, we now know that every possible layer of visual processing in the brain can be modulated by attention, not only at the cortical level (reference V1 and V2, which are now routinely shown to be modulated by attention), but even subcortical structures like the LGNshow modulations by attention (e.g. Kastner et al., 2004; O'Connor, Fukui, Pinsk, & Kastner, 2002), that entail as complex a computation as increasing the precision encoding of attended objects while completely filtering unattended objects (Fischer & Whitney, 2012).

Thus, given our understanding of attention, not only within the framework of biased competition, it stands to reason that (other than the processing in the retina) there is likely no strict temporal order to visual processing such that some degree of visual processing always occurs prior to the allocation of attention. Even the initial levels of visual processing are likely modulated by attention, under the right circumstances (e.g. Hillyard & Munte, 1984). That is not to say that there is not a lot of processing that goes on outside of the focus of attention. Jeremy Wolfe's most recent model of vision now includes a "nonselective" pathway in vision: a parallel route of visual processing that proceeds independently from attention and that is responsible for things like computing the sensation that the visual world is more than the object being attended, as well as extracting visual regularities from the world (Chong & Treisman, 2003, 2005a, 2005b; Choo & Franconeri, 2010; Haberman & Whitney, 2011). Whether there is such a pathway is a matter for debate, but what is clear is that there is a lot of *unattended vision* that goes on at any given point in time, and proposing that this form of processing is taking place simultaneously to *attended vision* is also likely correct.

The distinction between unattended and attended vision is, actually, critical for us to begin to form an understanding of "distraction". We can use a definition of distraction that follows our common intuition: distraction is when our current train of thought gets interrupted by a secondary train of thought, against our wish. One can study *cognitive* distractions: the occurrence of distracting thoughts, which can happen in a benign manner (as in the task-unrelated thoughts literature, Giambra, 1989; McVay & Kane, 2009, 2012; Smallwood, Obonsawin, & Heim, 2003) or even pathological manner (as in Obsessive compulsive disorder, Depression and Anxiety). However, we are here interested in perceptual distraction: when the occurrence of an event in the world comes to derail our train of thought or interfere with our task at hand. More specifically, we will use the domain of vision to understand this concept. In our terminology, *distraction* can be defined as times when a visual event that was initially processed by unattended vision forces the attention system to orient to it. This reorienting must occur at the cost of disengaging attention from whatever other object (in vision or thought) that was previously being attended. We will return to this definition after presenting theory and methodology that is currently used to assess "distractibility" (the study of distraction) in our field. But first we must dispense with visual search.

2.1.4. Nothing about Distraction Can be Learned from Visual Search Experiments

If we return to the question of what the use of distractors can tell us about distractibility in the domain of visual search, the answer is clearly *nothing*. This conclusion is, hopefully, not very controversial. Distractors are a group of stimuli that are, by design, meant to be inspected by attention because of their resemblance to the target stimulus. That is, it would be awkward to argue that seeing a red hat in my closet is a distraction from my search of a red scarf in said closet. If one has set a priority for detecting red items in the closet, seeing and evaluating a red item is not an episode of distraction, but is an integral step in achieving my goal. I want to inspect *all* red items with the hope that one of them is my scarf. Thus, visual search, in the traditional form, is not a methodology suited for studying or understanding distraction. In fact, it has been very difficult to translate what we know about visual search from our vision laboratories to visual search in the real world, precisely because in the real world, not all objects in a scene are a priori meant to be possible search targets. If we are looking for a fork in a kitchen, it is irrelevant how many appliances are in that kitchen. No one placed the refrigerator, oven or dishwasher in the room with the hope that people looking for forks would look at them. These items are not targets for the attention system, thus cannot be counted as distractors in the laboratory sense; however, if asked to identify all objects in a kitchen, most observers would likely count all appliances therein as being objects in the kitchen scene. Labeling all objects in a real-world scene as a priori targets of the search (i.e. as distractors) will always produce an overestimate of set size and may lead to the awkward conclusion that real-world search is more efficient than laboratory search. If one has a black-and-white styled kitchen, with all black-and-white utensils, appliances, and counters, searching for a red kitchen towel would produce a very efficient search (unaffected by the number of elements in the scene), whereas searching for a specific black utensil will likely be highly dependent on the number of objects in the room. And what we have learned about guidance in the laboratory is absolutely applicable to this real-world scene. It is merely complicated because every type of search target in a real-world scene determines the set size in that scene. In other words, the set size in a scene cannot be (and should never be) determined in the absence of a definition about what the search target in that scene will be. Once such a definition is provided (e.g. "look for a couch"), one can determine the subset of elements in the scene that will be a priori interesting to the attention system (e.g. all furniture items). We propose that we should use the term "candidates" to refer to this specific variety of distractors: the subset of items in a scene that might be a target. Again, candidates can only be defined once the target of search is known. Once a target of the type *furniture* has been defined, the number of windows, paintings, and toys on the floor are immediately discounted by that definition. Those objects could never be targets and will not be inspected in the search, so they are not what we here called "candidates". Very promising work in this arena has been recently conducted by Zelinsky et al. (Alexander & Zelinsky, 2011; Neider & Zelinsky, 2011) as well as Wolfe et al. (Wolfe, Alvarez, Rosenholtz, Kuzmova, & Sherman, 2011). Note that, by design, most of laboratory visual search tasks have situations where the set of candidates is the number of objects in the scene (what people have referred to as set size), whereas in the real world, the number of candidates is often substantially smaller than the number of objects in the visual scene.[1]

[1] A notable exception is the literature on the phenomenon known as Visual Marking (Watson & Humphreys, 1997). In this phenomenon, it is typically found that previewing half of the search items (say all green stimuli) for some time before the second set of search items (say, the blue items) is presented produces search efficiencies identical to those that are obtained when participants only see and search through the second set of search items (i.e. only blue items). Interestingly, this improved search efficiency in the "preview" condition is always accompanied by a substantial main effect, in the order of 50–150 ms. This visual marking effect is critically dependent on attention being allocated to the previewed items (Watson & Humphreys, 1997), and we would argue that it reflects the process of candidate selection (selecting all blue items as search candidates, while ignoring green items) and is central to this paradigm. In spite of its importance, most of the research on visual marking has focused overwhelmingly in the analysis of slopes, ignoring all intercept effects.

Definition

Candidates: A candidate is a stimulus that contains at least some of the defining attributes of a target. In both visual search and many selective-attention tasks, a candidate is an object that closely resembles the target in terms of its event-like descriptive characteristics. Does it belong to the same visual category of items than the target? Is it visually similar to the target? Does it have the same temporal characteristics as the target (i.e. it appears/disappears at the same time as a target)? Does it appear nearby or at a possible target location? As a result, which elements of a display are candidates can only be determined once a task is defined and the target of the attention system is determined. In visual search, the number of candidates is what determines the *functional* set size for a scene. Candidates are always highly relevant to the search task because of their status as "potential targets". Candidates do not have stimulus–response associations in a task, but they can nonetheless inform responses. For example, in a present/absent visual search task, every inspected and discarded distractor is further evidence that the response on the trial is more likely to be "absent". See Bundesen (1990) for a similar definition regarding relevant distractors: those that are similar to the target along the defining characteristics of the target.

2.2. Divided Attention

A very similar point can be made for the task that is often used to study divided attention—viz, the redundant-targets detection task (e.g. Miller, 1982; Mordkoff & Yantis, 1991). In these experiments, subjects are asked to respond to prespecified targets (usually letters), just as they are when doing visual search, but displays are always quite small (e.g. two letters at most) and some displays contain multiple instances of the same target. The key result from these tasks is the response-time advantage for trials with two targets, instead of only one, which is known as a "redundancy gain" (Raab, 1962).

What makes this task interesting here is how some researchers have interpreted the finding that a single target accompanied by a distractor can produce slower responses than a single target presented alone (e.g. Grice, Canham, & Boroughs, 1984; Grice & Gwynne, 1987). The slowing in the former case was said to be due to a "distraction decrement;" that is, the nontarget in the second display location was said to distract the observer by pulling resources away from the target. As it turned out, however, the slowing was actually caused by the nontarget being correlated with the absence of targets (Mordkoff & Yantis, 1991); when these correlations were eliminated, single-target trials produced exactly the same RTs whether or not a nontarget was also included within the display. In other words, there was no actual decrement in performance due to the nontarget item; the slowing of RT was caused by the information carried by this item, instead. Even more, we would here argue that this nontarget should not really be thought of as being a distractor, because it was a candidate, due to being in one of the very few locations in the entire display at which targets ever appear.

The second way in which this work might be relevant to the study of distraction is in how a distinction was made between nontargets that sometimes appeared with targets, which were called "distractors," and nontargets that never appeared with targets, which were called "noise". The main reason for keeping these two types of nontarget stimuli separate was to be able to calculate separate correlations between their presence and the correct response (Mordkoff & Yantis, 1991); these calculations were crucial to the demonstration that the so-called "distraction decrement" does not actually exist. But the use of two different labels for items that, on the surface, play identical (non-)roles in the task also shows that the idea that some nontargets are more equal than others is not completely new. When one adds in that these nontargets can carry different amounts of information—in the technical sense of the word—a few doubts should be raised about the use of the label "task-irrelevant" to refer to nontargets. But this is probably better explained in the context of the task to be discussed next.

2.3. Flanker Effect

2.3.1. Traditional View: The Flanker Effect Implies Late Selection

One can also study attention in the absence of location uncertainty, that is, when one knows where the target is going to be (e.g. Eriksen & Eriksen, 1974), yet there is uncertainty about the identity of the upcoming target. This experimental procedure has come to be known as the *Flanker Paradigm* and is typically a variation of the following set up: target position is defined a priori and participants are asked to report as quickly as possible the identity of the target, almost always a letter. Just as in visual search, the target is presented among "noise" elements that may be related to the target in some way. For example, in the original experiment, the noise elements could resemble the target in terms of their low-level features (target and noise letters looked alike) or in terms of response associations (noise letters were letters picked from the possible set of target letters). As in the visual search literature (Estes & Taylor, 1966), over the years, in this paradigm, the term "noise" element was replaced by "distractor" (or sometimes just "flanker" because the distractors tend to be presented on both sides of the target letter, flanking it). In other words, in this context, one uses the word "distractor" to refer to target-like stimuli (most often, exact copies of the possible targets themselves) that are presented at locations that are near to the target. The goal of this paradigm is to measure the degree to which attention can focus solely on the target item itself (a test for what is referred to as "early selection", Neisser & Becklen, 1975; Sperling, 1960; Treisman & Geffen, 1967). If performance is unaffected by the presence or identity of the distractors, then one can conclude that selective attention successfully "filtered out" the "irrelevant" information from the display. In most cases, however, it is found that response times are strongly modulated by the identity of these flanking distractors (e.g. evidence for so-called "late selection", Deutsch & Deutsch, 1963; Norman, 1968), an effect known as the Flanker Effect. This result is interpreted as evidence that the distractors have been processed to a sufficiently deep level of processing (at least to the level of stimulus identification) such that they, too, can activate response selection processes. In fact, the Flanker Effect is most often measured as the difference in RTs between two conditions: one in which the distractors activate the same response as the target for the trial (*compatible* or *congruent* condition) and one in which the distractors activate a different (incorrect) response from the target (*incompatible* or *incongruent* condition), with responses on incongruent trials typically being anywhere between 30 and 100 ms slower than on congruent trials. When a Flanker Effect is obtained, it is generally concluded that selective attention has failed in some way, allowing task-irrelevant items to be processed.[2]

2.3.2. The Flanker Effect is Not a Measure of Distraction

The Flanker Effect is an example of *distractor interference*, and it is not the only one. The Simon effect (Simon & Rudell, 1967) and the Stroop effect (Jaensch, 1929; Stroop, 1935) are also well-known examples of distractor interference. What these effects have in common is that one can consistently find evidence that some aspect of the distractor stimulus (or the distractor attribute) influences behavior. But is distractor interference a measure of distractibility? Hardly so. If we follow the logic presented above

[2] It should be noted that, with regard to the presence or absence of a Flanker Effect, the same logical error is being made as is for visual search. While the presence of a (significant) Flanker Effect is evidence that the flanking distractors were, indeed, processed, the absence of a Flanker Effect does not necessarily imply that the flankers were not processed. This point was made rather forcefully by Driver & Tipper (1989).

in the context of visual search, the Flanker Effect is no different. Distractors in this task are selected by the experimenter with the hope that, if they are processed, they can have a measureable effect on performance. To achieve a measureable effect on performance, the critical distractors in the flankers task are, in the vast majority of studies, exact replicas of one of the possible target stimuli. The rationale is simple: given that participants have a response associated with every target, we can hijack those stimulus–response associations to measure distractor processing. So, all we need to do is use targets (or target-like stimuli) as the distractors. Participants will know that they are not the target on any given trial because targets and distractors are always presented at different locations. Yet, if participants process those distractors, they will activate those stimulus–response associations and compete (with the information coming from the actual target) to determine the response on the trial. In sum, congruent and incongruent distractors in a flankers task are *by design* stimuli that fit the participants' task set. For example, if the participants' task is to identify whether a central letter is an X or an O, the critical distractors in most designs of a flankers task would be either Xs or Os. Thus, if one assumes that participants have a task set that stresses the importance of Xs and Os, it would be difficult to come up with more task-relevant stimuli than congruent and incongruent distractors (i.e. Xs and Os). Therefore, given that the critical distractors in this task are actually very much task-relevant, they cannot tell us *anything* about distractibility.

2.3.3. The Information Processing Tradition and the Flanker Task

Overall, this simple analysis of the flankers task reveals that most of the distractors used in these studies are by design task-relevant and they should be understood as such. However, there has been a tradition in this literature, going back more than 25 years, to describe the Flanker distractors as being *task-irrelevant*, instead (e.g. Lavie, Hirst, de Fockert, & Viding, 2004; Miller, 1987; see also Figure 7.4). To understand why, one must understand the theoretical tradition within which the initial studies on this topic were conducted. The dominant methodology in the mid-twentieth century experimental psychology was the detection of target signals embedded in noise (often interpreted in the terms of signal-detection theory). In fact, early studies on visual search refer to the distractor elements in those displays as "noise" elements (e.g. Estes & Taylor, 1966), just as Eriksen and Eriksen described them in their first report of the Flanker Effect. Furthermore, information theory was the theoretical backdrop to cognitive psychology. One viewed and studied the mind as an information processing problem, with an input signal that underwent several discrete transformations (or processing stages) inside the black box that was the mind before producing an overt response. Within this worldview, the "noise" stimuli used in tasks like the Flankers paradigm were irrelevant to the observer because they carried no information regarding which response should be made. Thus the term was born of distractors being task-irrelevant: the word "task" being a short-hand for "which response should be made" and the word "irrelevant" indicating that the distractor carried no information with regard to the task. In sum, the identity (or even presence) of distractors in a visual search or flanker task changed nothing to the fact that only the target signal determined the appropriate response on each trial. If, for example, the target on a given trial was the letter X, the response on that trial was to press the button associated with that specific letter, irrespective of any and all other noise letters in the display. The noise elements were irrelevant to the actions of the participant because *they carried no information about the required response on any given trial.* In that sense, perhaps a better label to qualify the distractors in a visual search or flankers task would be to say that distractors are *response uninformative*.[3]

A great deal of confusion would be avoided if a more precise term like this one was used, instead of the more misleading label task-irrelevant that has now come to be the dominant term for describing flankers. Another alternative would be to simply drop this qualifying term altogether from this literature. Distractors would simply be referred to as distractors, with no mention of their task relevancy, given that it is clear that they are task-relevant, in the way that we now use these terms. Here, however, we propose the use of the term *foil* to refer to congruent and incongruent distractors. It implies, as it should, that they were put in place in the experiment with the goal of somehow tricking or interfering with the participants' responses: in a Flanker task, foils are a close match to what participants are looking for. An exact copy, but just off in some minor way (like their location).

[3] Note that not all stimuli need be response informative to be considered task-relevant. Candidates are one such example: in visual search tasks where participants must report the identity of the target, candidates themselves are uninformative to the trial's response. A spatial cue in a Posner-type cueing paradigm is also an example of a task-relevant but response-uninformative stimulus: it tells observers where they might find items that contain response-related information. But the cue itself is not informative to the response.

Definition

Foil: A *foil* is a type of candidate that can cause a participant to produce the wrong response in a trial because foils have links to potentiated responses in a task. They often contain the same response-defining attributes as the set of targets. In a selective attention task, a foil is often an object that is identical to one of the possible targets but is not the target itself because of a priori reasons: it differs from the target along one (or several) defining characteristics. For instance, the target might be determined by its unique location, or the foil itself might have a unique prespecified location. A foil may also appear at a different point in time in a trial than the target (as in priming experiments). Foils are automatically selected by the attention system, to the extent that they are perceptually well represented. Selecting and rejecting foils is a critical part of what attention must do in order to properly respond on a given trial.

2.3.4. Why are Flankers Referred to as "Task-Irrelevant"?

But, why did the authors in this literature feel that they had to specify that, in their design, distractors were indeed task-irrelevant? That is because not all distractors in a flanker task need to be response-uninformative, though most are. Several papers have documented the "correlated Flanker Effect" (e.g. Miller, 1987; Mordkoff & Halterman, 2008): that is, one can, by design, pick a combination of target–distractor co-occurrence frequencies such that the identity of distractors can indeed tell the participant something about the response. For instance, say that the task is to identify a target letter (an A, B, Y, or Z, with A and B mapped to one response and Y and Z mapped to the opposite response), and that on 75% of the trials when the flankers are Ms, an A or B is the target, and on 75% of the trials when the flankers are Ns, a Y or Z is the target. The distractors in this task have no direct association with either response and they do not resemble the targets. Yet, their identity carries information about the likely response. As one can imagine, responding A/B on an A trial is faster and more accurate when the distractors are Ms than when they are Ns. This is the correlated Flanker Effect and it can also be observed in more subtle ways whenever there are contingencies in the design of the flanker task such that the identity of the distractors provides useful information of any sort (Mordkoff, 1996). In such cases, the distractors are response-informative and, as such, can be characterized as "task-relevant" by the older definition of task relevancy. So, it is easy to see why there was a need in the literature to differentiate between these two forms of Flanker Effects: the one that arises when distractors carry some information about the response (by design or by accident), which is the correlated-flankers effect, and the one that arises when the distractors carry no information about the response, but have an effect because they are the same stimulus as one of the actual targets, which is the traditional Flanker Effect.[4]

In a somewhat unfortunate turn of events, contemporary cognitive psychology has continued to use the original "task-irrelevant" modifier to describe distractors in a flanker task. It is unfortunate because most of us have moved beyond that use of the term "task relevancy" and use a more contemporary definition of relevance that implies a very different understanding of the role of distractors in the flankers task and their relationship to the study of distraction. The newer use of the term "task-relevant" arises from research on phenomena like attentional capture, task switching, and executive control. In attentional capture, for instance, people study what aspects of a stimulus make the stimulus more or less "attractive" to the attention system. Folk et al. (1994) demonstrated the phenomenon of *contingent* attentional capture: that a visually salient element captures attention to the extent that some of its defining characteristics match those characteristics that define the target stimulus. A moving stimulus draws attention to itself to the extent that the attention system is looking for moving-like things (e.g. targets that are moving or have sudden onsets, or some other stimulus property that also characterizes motion). These *attentional control settings* are determined by the task demands, and, some would argue also by the *behavioral urgency of certain stimuli* (e.g. Franconeri, Alvarez, & Enns, 2007; Lin, Franconeri, & Enns, 2008; von Mühlenen & Lleras, 2007).

In sum, we now use the term "task-relevant" to describe the level of overlap between distractors and targets, either in terms of their visual characteristics or their functional description with respect to the task characteristics (Are they both sudden onsets? Do they appear in tandem? Does one precede the other? At the same or different locations? etc. See also Yantis & Egeth, 1999).

[4] It is worth noting that, by the information theory-based definition of task relevance, all the nontargets in nearly every published visual search study have actually been highly relevant, since each item that is identified as not being a target increases the likelihood that any given not-yet-identified item is a target. Likewise, the total number of items in the display is equally relevant, because, as more items are included, the odds of any particular item being a target are reduced. In other words, reverting to the old definition of task relevance is not going to change our earlier argument that the nontargets in a visual search display are not a source of distraction, even when they cause responses to be slower.

To sum up, in our terminology (and in agreement with the attention capture literature), candidates are always task-relevant. So are foils. In a later section, we will expand on the theoretical and applied consequences of using the term "task-irrelevant distractors" in a flankers task, but for now, let us finish on the following point. Congruent and incongruent distractors in a flanker task are not task-irrelevant by the current definition of task relevancy because they are exact replicas of the target and resemble the target in every possible functional way, save for the fact that they appear at a different location than the target. Thus, as with visual search, nothing about distraction and distractibility can be learned from studies on the Flanker Effect. Of course, by the same logic, one can also argue that little about distractibility can be learned from studies on attentional capture, because, in that paradigm, distractor stimuli most often fall clearly within the "task-relevant" category of stimuli. Therefore, we are going to have to turn to a very different kind of task if we hope to learn anything about actual distraction.

2.4. A Different Form of Distractor: The Inattentional Blindness' "Critical Stimulus"

2.4.1. The Unexpected Event Paradigms

Most often, the phenomenon known as "inattentional blindness (IB)" is studied with a paradigm that is a variant of the original experiments by Mack and Rock (1998): participants are asked to do a fairly engaging visual discrimination (e.g. deciding which of the two arms of a cross is longer, when the two arms are actually almost identical in length) in a brief period of time. After the participants have completed a few trials of this task, experimenters present an unexpected "critical stimulus" within the display: an unexpected visual object that is completely unrelated to the task at hand. It can be, for instance, a small square near fixation. After participants complete the response on this critical trial (also known as the "inattention trial"), experimenters ask the subjects whether they saw anything unexpected on that last trial. Henceforth, we will refer to this overall experimental framework as the *unexpected event paradigm*. The term "inattentional blindness" refers to the finding that quite often, people fail to report the unexpected stimulus.[5] Importantly, after the inattention trial, participants complete a few additional trials, including a final trial in which they are told to completely

[5] The label "inattentional blindness" was applied prematurely and is rather unfortunate, in that it strongly suggests that the unexpected stimulus is not seen. Subsequent work (e.g. Moore & Egeth, 1997) has indicated that the unexpected stimulus is, indeed, perceived, but never reaches awareness and/or is quickly forgotten. But we are stuck with the name for the paradigm.

ignore the stimulus for their primary task (i.e. the cross in our example) and just focus on trying to detect any other objects in the display. In this last trial (referred to as the full attention trial), participants are typically at ceiling at detecting the critical stimulus. This is important because it guarantees that the critical stimulus is actually perfectly visible. Furthermore, it allows the experimenters to conclude that the reason why participants failed to be aware of the critical stimulus was that they were completely immersed in processing a different object (the cross) at the time it appeared.

This is not the only paradigm in which inattentional blindness has been studied. Neisser had earlier pioneered the use of video to study the same phenomenon (Neisser, 1979; Neisser & Becklen, 1975) asking participants to attend to one of the two superimposed movies. Participants were, as one would suspect, quite unaware of unexpected events in the unattended film. The video paradigm was also popularized recently by Simons et al. who demonstrated that one does not need two superimposed videos to create inattentional blindness: grabbing a cue from Mack and Rock (1998) and Simons and Chabris (1999) showed that simply asking participants to be intensely engaged in some attentive task (like counting the number of bounces and passes of a basketball) would trigger inattentional blindness to unexpected events occurring in that same video. The added benefit of this technique is that unexpected events can be prolonged in time (the time it takes a gorilla to walk across a scene, and pump its chest a few times), as long as they start and finish while participants are engaged in the attentive task. Follow-up experiments also showed that the likelihood participants will become aware of the critical stimulus increases the more the critical stimulus resembles the events in the attentive task. For instance, people counting bounces and passes in a team of people wearing black t-shirts will be more likely to detect the appearance of a (black) gorilla, than those counting passes in a team wearing white t-shirts (for a similar demonstration, see Most et al., 2001).

In this sense, unexpected event paradigms do hold promise for the study of distractibility. Why? Because they allow one to ask the question: will an observer's train of thought be interrupted by a secondary event, against the observer's own goals to concentrate on a primary task. In fact, the unexpected event paradigm has inspired a number of applied investigations into issues relating to distractibility. In the driving domain, Strayer et al. (e.g. Strayer & Drews, 2007) have proposed that talking on a cell phone produces a form of inattentional blindness (to the extent that people overly concentrate on the cell phone conversation) such that participants will be less likely to remember or identify objects that they actually fixated during the driving task, if they were talking on the cell phone when those objects appeared. In other words, the work of Strayer et al. suggests that the additional cognitive load involved in having a cell phone conversation creates a situation where participants are less likely to attentively experience the objects that their eyes fixate during driving. This is perfectly in line with Mack and Rock's initial account of inattentional blindness but extends that account to attentionally engaging events outside of the realm of vision. That is to say, whereas one could have interpreted the initial findings of inattentional blindness as reflecting a limitation of *visual* attention, the findings in the applied literature suggest that they are more general than that. We do not fail to see the critical stimulus in the unexpected event paradigm (or the gorilla in Simons & Chabris' video) because our visual attention cannot be focused on two visual aspects of the scene at once. Rather, we fail to see the critical stimulus because our attention system (irrespective of modality) has a difficult time doing two things at once: processing the information required in the demanding primary task, as well as encoding and responding to the unexpected stimulus.

2.4.2. Recruitment of "Central" Resources and the Ensuing Blindness

Elegant evidence in support of the idea that a "central" limited resource is responsible for inattentional blindness was found by Fougnie and Marois (2007). They asked participants to do a task where they had to either rehearse in memory a set of letters (the maintain condition) or reorganize them in alphabetical order (the manipulate condition). Shortly after the letters were presented to the participants, an unexpected critical stimulus was presented in the display. Only 35% of participants failed to detect the unexpected stimulus in the maintain condition, whereas 68% of participants in the manipulate condition missed it. There was no difference between groups in the full attention trial and participants were near ceiling at detecting the critical stimulus on that trial. This evidence suggests that the degree of involvement of central executive resources in a primary task determines the degree to which participants will become aware of unexpected and a priori unattended events in the world. In a clever follow-up experiment, Fougnie and Marois presented the critical stimulus toward the end of the retention interval, at a time where participants in the manipulate condition would have already finished reorganizing the letters in memory. In this experiment, there were no differences in the degree of inattentional blindness across groups, presumably because the central executive was no longer actively engaged by the reorganization task (i.e. by the time the Critical Stimulus appeared, participants were just rehearsing the ordered letters in memory).

Overall, this brief (and admittedly selective) glance at some of the inattentional blindness literature suggests that distractibility may depend on the degree to which we are currently engaged in a centrally demanding task: the more engaged we are in that task, the less *distractible* we are by unexpected events (see also Macdonald & Lavie, 2008, 2011). To touch back briefly on an issue raised in the section on visual search, all evidence suggests that visual processing proceeds normally even in the absence of attention. Visual processes like perceptual grouping and surface completion (and others) are all performed even in the absence of attention, as operationalized by the occurrence of inattentional blindness (e.g. Moore & Egeth, 1997; Moore, Grosjean, & Lleras, 2003). This is important because it underscores the need for revisiting some visual attention theories. We can be fairly confident that (1) vision unfolds with or without attention, which is the reason we have a rich phenomenal experience of the visual world even though we cannot attend to it in its entirety at any given moment; (2) attention can access any level of visual processing to bias processing in a particular direction; and (3) therefore, there seems to be no need to assume or propose some form of uniquely preattentive processing that must precede attention in time. There are no proto-objects (Rensink, 2000); there is no massive parallel preattentive vision (Treisman & Gelade, 1980). We believe that any model of attention that assumes so is likely misguided.

Returning to the issue of distraction, the question is: why do we experience inattentional blindness in the first place? What factors determine whether we do? Is inattentional blindness a failure of some sort or might it reflect an efficient, calculated tradeoff, instead? These are complex question and we will attempt to offer a possible answer to them in Section 3 of this chapter. But first, let us reexamine the issue of task relevance in the stimulus, using a simple inattentional blindness paradigm.

2.5. Empirical Study: Comparing the Salience vs the Relevance of a Distractor

There has already been evidence in the inattentional blindness literature that the degree of visual similarity between the critical stimulus and the stimulus in the attentionally engaging task determines the degree of inattentional blindness to the critical stimulus (Most et al., 2001; Most, Scholl, Clifford, & Simons, 2005). Here, we just want to reiterate this point in a less subtle variation. Rather than comparing stimuli that vary along their color, we will simply compare two different critical stimuli: one will be clearly task-relevant (it will be a foil), the second one will not. However, the irrelevant stimuli will be significantly more luminant than the first. Here then, we are pitting the salience of a stimulus (in terms of its overall luminance) against the relevance of a stimulus (in terms of the task set). The question is: can we create inattentional blindness when the critical stimulus is a foil (i.e. task-relevant)? If not, then this is evidence that task-relevant stimuli (like the distractors used in the flankers paradigm) are not good stimuli to use when one wants to draw conclusions about distractibility. That is because such evidence would show that task-relevant stimuli are never *unattended* in the first place. To answer this question, we will use two possible critical stimuli (CS) a bright-white square and a white letter. The main task of the participants will be (as in a flankers task) to identify the letter in the center of the display. The task-relevant critical stimulus will be simply a traditional flanker (i.e. a foil, one of the possible target letters, presented slightly above, below, to the right or left of the target). We will compare performance in this condition to performance in a condition where, rather than a letter, we present a white square that is 1.5 times larger than the letter. Because the square is completely filled-in with white, and the letter is only drawn with a small portion of the pixels used to fill up the square, we can be certain that the square is substantially more luminant than the letter. Thus, if we are correct that stimuli which are highly relevant to the task are almost always selected by our attention system (as something that attention *should* select from the display), one would expect very small levels of inattentional blindness to the foil version of the CS. In contrast, given that the square is completely irrelevant to the letter-identification task, one would expect a much larger degree of inattentional blindness to the square, in spite of its much larger visual presence in the display.

Eighty four subjects were asked to complete a brief five-trial study, using a traditional unexpected event paradigm. Participants were told that their task was to identify a briefly presented letter and report its identity. The letter could be an A or an E, in lower or upper case, although the letter case was irrelevant to the response. To make matters challenging, the letter (about 1° of visual angle in extent) was preceded by a ~100 ms long random-dot mask (about 2° of visual angle in extent), which was immediately followed by the letter (presented only for ~70 ms), which was in turn immediately followed by a new random-dot pattern mask that stayed on the screen until participants had recorded a response. In the first three trials of the experiment, those were the only visual events in the display, and participants completed the task with a good degree of accuracy. Average accuracy in the letter identification task in the first trial was 74%, and rose to 90% and 92% on the second and third trials, respectively. By the third trial, participants had a mean response time of 1470 ms (st. dev. 316 ms), which is not unusually long given that response time was not stressed in the task.

Then came the unexpected event trial: the critical stimulus was presented on the screen at the same time as the first random-dot mask and remained on the display until the target letter was replaced by the second random-dot mask. In all, the critical stimulus stayed on the screen for 160 ms, more than twice the duration of the target. The critical stimulus was presented 2° of visual angle away from the mask and could appear above, below, to the right or left of it.

Let us begin by establishing whether or not our main task and stimuli can, indeed, produce inattentional blindness by looking at performance in the group of subjects that was assigned to the square critical stimulus (which was approximately 0.75° of visual angle), a stimulus that was very much like the critical stimulus in many of Mack & Rock's original studies. How many participants reported seeing the unexpected square? Only 18 out of 42 participants (43%). When forced to guess the location of the unexpected stimulus, 17 out of 42 correctly reported its location. In other words, we produced a substantial degree of inattentional blindness to the square. Did the onset of the unexpected square interfere with the participants' effort in the primary task? Trial 4 accuracy was 97%, so, at first sight, one would argue that it did not. A post hoc RT analysis (limited by the variability of a one-observation/participant measure) suggested that it did not: subjects who did not report seeing the square responded to the letter target with an average RT of 1450 ms (st. dev. 600 ms), well in line with their performance on Trial 3. In other words, even though an unseen stimuli could theoretically have affected their RT (e.g. Moore et al., 2003), it failed to do so. In contrast, there was some suggestion in the data that those who did see the square actually slowed down in their response to the letter: the RT for the 18 participants that did see the square was 1661 ms (st. dev. 510 ms). The difference failed to reach significance, mostly because of the inherent variability in the measure. Finally, it should be noted that in the full attention trial, 40 out of 42 observers saw the square, and 38 out of 42 correctly reported its location. So, about 90% of subjects had no trouble seeing the square when not attentively engaged in the central letter task.

Overall, we can conclude that with our task parameters, and using a task-irrelevant stimulus, we can create substantial levels of inattentional blindness (almost 50%, the difference in detection between full attention and inattention trials). What happens when we replace the white square with a much smaller *foil* (i.e. a task-relevant letter)? In this task-relevant group, the critical stimulus was either the capital letter A or E. It should be noted that the two experimental groups were ran simultaneously and that our research assistants were blind to the experimental condition. This is important because it guarantees that all participants received the same instructions and that research assistants could not knowingly or unknowingly affect the outcome of the experiment. So, was this smaller "flanking" letter treated differently by the attention system of our subjects than the square? Absolutely: 34 out of 42 (81%) participants reported seeing the distractor letter, almost twice as many subjects who saw the square. Did the onset of this letter affect their performance in the central letter identification task *before they even knew we would ask questions about this unexpected letter?* Yes, again. Remember, when the critical stimulus was a square, participants in Trial 4 identified the target letter almost perfectly (97% correct). When the critical stimulus was a foil (one of the possible targets), target identification performance dropped to a dismal 69% (chance being 50%). RTs also substantially increased to 2022 ms and were highly variable (st. dev. 1408 ms). Importantly, it was only after participants had completed this response that we asked whether they had seen an unexpected event in the display. By the time we asked, all performance indicators suggested that yes, indeed, the foil had by and large not gone unnoticed. How visible was the foil? In the full attention trial, 40 out of 42 participants reported seeing the foil and 38 out of 42 (90%) correctly reported the foil's location. So, the a priori visibility of the square and letter foil was well matched across conditions, both were at 90%. Given that 81% of participants reported seeing the letter in the inattention trial, our results suggest that for the most part, there was little-to-no inattentional blindness in this condition. In sum, the attention system spontaneously detected and selected the foil (letter distractor), even though participants knew nothing about the possibility that a letter might appear in the periphery, and the act of selecting this letter substantially impacted their performance in the primary task.

Knowing that participants were not blind to the foil, one can do a second pass at the results and ask the question: was there a Flanker-like congruency effect in our experiment? Was the main letter identification task modulated by the congruence between target and foil? Yes again.

The average RT in Trial 4 for participants who had a congruent target–foil relation was 1743 ms (st. error = 175), whereas RT for participants who had an incongruent relation was 600 ms slower: 2359 ms (st. error = 425). When accuracy is analyzed, we found that 100% of participants in the congruent condition reported the correct letter. In contrast, only 31% of responses were correct in the incongruent condition. Finding an accuracy rate below chance suggests that participants were actually reporting the identity of the foil, not that of the target letter. If one recodes performance as a function of foil identity, participants' accuracy on Trial 4 becomes 90.5%, perfectly in line with their performance on Trial 3. This is interesting. The evidence from this experiment suggests not that the foil interfered with the target, but that, in fact, the target may have interfered with the foil (in terms of producing elevated response times). The results further suggest that the Flanker Effect may very well be a failure to select the appropriate of several potential targets (Lachter, Forster, & Ruthruff, 2004; Yigit-Elliott, Palmer, & Moore, 2011).

From this simple experiment we can conclude that, as we had hinted, using one of the possible target letters as a distractor in a selective attention task makes that distractor task-relevant, by our contemporary standards of what "task relevancy" means, but more importantly, by empirical standards as well. In fact, in Section 3 we will propose that when we ask the attention system to identify the presence of As or Es on a display, it will likely do so over the entire display, provided that there is sufficient signal to represent letters in the periphery (i.e. that there is no crowding and that the letters are sufficiently large to be accurately represented). So, the so-called "task-irrelevant" distractors in flankers task are actually always selected by our attention, precisely because they are actually very much task-relevant. Given that the presence and identity of such distractors alters our performance on the primary task (identifying the central target), does that mean that these distractors are *distracting* us in a Flanker Task?

2.6. Distraction or Distractor Interference?

2.6.1. The Current State of Confusion

In 2010, Lavie wrote a brief review on "Attention, Distraction and Cognitive Control under Load" (Lavie, 2010). The title is important because it identifies the concept of distraction as one of the central topics of the article. The conclusions of the article are as follows. If one wants to reduce the likelihood of distraction (at work, for example), it is advisable to work in a perceptually loaded environment. This means we should increase clutter in our desks. Further, we might be tempted to infer that adding clutter (or otherwise increasing perceptual load) would be advised for situations where attentional focus is required, such as driving, but – as even Lavie (2010) admits – this advice would best be not taken. At gut level, this proposal sounds just wrong and ill-advised. Another important finding to come out of the review is that *increased cognitive load* creates more distractibility. We have not yet defined cognitive load here, but it can intuitively be thought as reflecting the cognitive difficulty of a task or the additional cognitive difficulty brought on by a secondary task. So, one should try to work under conditions of low cognitive load to avoid distractibility. While at first this sounds reasonable, let us translate the technical jargon in this conclusion: Lavie proposes that when we are mentally busy, we are at *our most distractible*, and the more we try to concentrate, the more distractible we will be. This is why she proposes that we should try to work under conditions of low mental load. But, what would be the point of concentrating on a task if not to shut out the world and protect our thoughts from worldly distractions? Lavie's "cognitive load" proposal again is not only counterintuitive, but it is a proposal that flies in the face of the entire inattentional blindness literature (in addition to being at odds with data from her own lab, Macdonald & Lavie, 2008, 2011): if nothing else, the theoretical and applied literature on this phenomenon has taught us that we are *insensitive* to otherwise easily visible events when we are highly focused on a cognitive task, it be judging the lengths of the arms of a cross (Mack & Rock, 1998), getting ready to produce a list of complicated navigation instructions (Simons & Levin, 1998), identifying a briefly presented letter (above), alphabetizing a list of letters (Fougnie & Marois, 2007) or talking on the cell phone (Strayer & Drews, 2007).

So, what gives? We propose that these conclusions (all based on soundly conducted experiments and robust effects) arise from a fundamental misunderstanding of the term "task-irrelevant distractor" and confusion between the concepts of *distraction* and *distractor interference*. Lavie (2010) calls the Flanker Effect: "the most conventional laboratory index of distraction" (p. 144). Lavie's Load Theory was entirely inspired by results from Flankers experiments and most of her work on attention uses variations on "task-irrelevant distractor" paradigms in which the distractors are not really task irrelevant. We have already suggested these are not appropriate paradigms for studying distraction. Distraction is the concept about how events or thoughts that we have *no* a priori *intention* of attending to or thinking about, come nonetheless to be attended or thought of. To reiterate, foils in a flanker task are task-relevant by design, so they fail the basic litmus test to be informative regarding the phenomenon of distraction. Our attention is actively set to select and scrutinize foils.

Thus, (1) we should not be surprised if they end up influencing behavior, and (2) they do not really distract us, as much as they *interfere* with our stated goal of reporting the identity of only one letter in the display (the target). We propose that there is a fundamental difference between these two ways in which our thoughts can be affected by an event (or thought): distraction, which we already defined, and distractor interference. Unlike distraction, *distractor interference* refers to the impact on performance of stimuli that are a priori *relevant* to our behavior but not the target of our task.

Let's return to the example of a visual search task: if the goal is to find a red circle and we bias our visual attention to select red items, the degree to which the number of distractors will *interfere* with our task of finding the red target will be determined by the level of functional overlap (or task relevance) between the distractors in the display and the target. If all distractor shapes are blue, there will be no distractor interference in this task and participants will find the target irrespective of set size. If, on the other hand, there are also red square distractors, these red distractors (because they are candidates) will interfere with our goal of finding the red circle, and RTs will increase with set size. Unless of course, we can bias our attention system to find the target in terms of its shape (rather than its color), in which case, there will be no functional overlap between our a priori *intentions* (of finding circles) and the distractors (squares). In Section 4 of this chapter we will review how we believe selection works in these simple examples. For the time being, it is important to recognize that the set-size effect in visual search is an example of distractor interference, not one of distraction. We are not *distracted* by the distractors, we are *interfered with* by the distractors, and in particular, by those distractors that are relevant to our task of finding the target. In our new terms, we inspect any and all and only candidates.

The same is true with the Flanker Effect and this follows because the flanker task is functionally equivalent to a visual search task without spatial uncertainty (Eriksen & Eriksen, 1974). In other words, it is incorrect to say that we are distracted by foils in a flanker task, we are simply interfered with by them. From this perspective, it is also easy to understand why the actual number of objects in a real-world scene will always be larger than the *functional* set size for any given visual search in that scene (the number of candidates). The functional set size will be determined by the number of objects that are a priori of interest to us in the scene. Looking for a person in a room filled with various furniture items will be accomplished without any effect of the number of pieces of furniture because the furniture cannot exert any distractor interference with our search task since they bear no functional overlap with our task settings (for finding a person). But, if we are looking for a specific furniture item, then furniture items will be a priori items of interest to attention and will produce distractor interference effects (a significant set-size effect), whereas the number of persons in the room will be irrelevant to performance in that case.

Returning to Lavie's arguments, as explained earlier, we believe that extrapolating from Flanker tasks to the domain of distraction is inappropriate. The problem is that, while the flankers might not be providing information in the sense of information theory, they are highly task-relevant because they are foils—i.e. they are very much like the targets. This greatly contrasts with the truly irrelevant stimuli that are used in most experiments on inattentional blindness, such as the presentation of an unexpected square. Even more, the data from our small experiment confirmed that attention does treat those two situations extremely differently: when we are looking for As and Es, the presentation of an A or E near the target location will not go unnoticed, whereas the presentation of a bigger, brighter white square can be completely ignored. Thus, the foil in a flanker task *will be* processed, which in a way is the point of the Flanker Effect. But, as our results suggest, one cannot generalize between situations with flanking foils (which are actually task-relevant) to those obtained with flanking squares (which are substantially less task-relevant). The two types of distractors are treated in a profoundly different manner by the attention system.

In sum, one cannot, as Lavie does, extend the findings from traditional congruent and incongruent flanking stimuli (the sort that produce Flanker Effects) to task-irrelevant stimuli (the sort that cannot produce distractor interference), like those in most real-life situations pertaining to actual distraction. In fact, we want to argue that finding a Flanker Effect in an experiment is, to some important degree, a measure of the *success* of our attention system (not of its failures) because it demonstrates the degree to which our attention and information-processing system is able to simultaneously perform the task (with accuracies close to 100%) while also picking up several other candidate stimuli from the display. So, whereas Lavie (and many others before her) has characterized the presence of a Flanker Effect as a *limitation* of the selective attention system, we propose that it might index its efficiency. The Flanker Effect is not to be interpreted as evidence that attention works as a late selection filter. Just the opposite: it is clear evidence of attention working as an early filter, a filter whose setting is determined by our goals.

2.6.2. Distractor Interference as a Measure of Attentional Success

Case in point: a beautiful study by Torralbo and Beck (2008) demonstrated that larger Flanker Effects are found when there is less cortical competition for representation among items in the display. In other words, when the brain can (without the need for biased competition, i.e. constrained spatial attention) represent all letters in the display, there will be larger Flanker Effects, precisely because the brain can successfully represent and select the relevant items in the display, and these representations have, in turn, an opportunity to independently activate response selection processes. The fact that this opportunity exists is what gives rise to distractor interference. Well-represented/identified distractors can activate stimuli–response associations and thereby interfere with our goal of producing a response to the target only. In contrast, when display items are poorly represented, our attention system ends up having to bias the competition to each stimulus separately (via spatial attention, which is effortful and works in serial manner) and thus there are fewer opportunities for distractor interference to arise. In other words, we believe that the *presence* of a Flanker Effect reflects to some degree a level of attentional success: it reflects the success of selecting multiple stimuli from a display. Which stimuli? Those that are relevant to our task, those that we a priori set our system to select from the display. Certainly, the *magnitude* of the Flanker Effect is likely determined by a number of factors (e.g. how small can we make our "spotlight" of spatial attention; the spatial arrangement of targets and distractors; is the target at fixation and distractor in periphery or vice versa; as well as a host of grouping and segregation cues that may further help attention to discard distractors, like color, etc.). The point here, though, is that the fact that there is an *opportunity* for distractor interference should be interpreted as evidence that attention is efficiently selecting from the display the things it cares about.

2.6.3. Connecting Flanker Experiments to Real-World Situations

This is why the recommendations from Lavie are, ultimately, exactly the opposite of what they should be. When she proposes that we should all work with highly cluttered displays (i.e. displays with high perceptual load) so that we can *avoid* Flanker Effects (i.e. in her worldview, *avoid distraction*), her recommendation is exactly opposite to what her data suggest we should do. We should actively seek display arrangements that are conducive to Flanker Effects precisely because the conditions that produce Flanker Effects are those in which we can effortlessly select several *task-relevant* objects from the display in parallel, whenever we need to find them. We will not select task-irrelevant objects, just like we do not select blue circles when looking for a red one, or just like we do not tend to select a square when looking for a letter.

With regards to her second recommendation, Lavie proposes that we should work under conditions of low cognitive load to prevent distractibility by "task-irrelevant" stimuli that is observed under high cognitive load. Again, this is exactly opposite to what one should conclude. She is again confusing distractor interference with distractibility. Distractibility is what has been measured in the inattentional blindness literature: when cognitive engagement is high, we are less sensitive to truly task-irrelevant distractors. And, if cognitive engagement is on the primary task (i.e. on identifying a letter), this will make it more likely that our system will pick up information from the world that is relevant to our task, which is exactly what one should hope it would do. This is also why there was almost no inattentional blindness to letters in our experiment. And what the literature on inattentional blindness has taught us is that a high level of cognitive engagement in the main task comes at the "cost" of less processing of truly task-irrelevant events in the world, so much so, that we can even become completely unaware of otherwise easily detectable events. And this is why our participants failed to see the square. In sum, when we concentrate on a task, (1) we are more likely to select the information that we are looking for in order to complete our task; and (2) we are less likely to select completely irrelevant information—i.e. less likely to be distracted. Countless real-life examples come to mind. When we are engrossed in a TV show, we may fail to hear the teapot whistling (task-irrelevant stimulus). When we are focused on writing a manuscript, we may fail to hear the clock in our office ticking. And when we are focused on a computer project and we want to look for folders on our desktop, we will not be distracted by the background image on our monitors, yet we will likely quickly know *where* all the folders on our desktop are.

Before we move on to the next brief section of this chapter, we want to point out that Lavie is not the only investigator to have misused the term "task-irrelevant" to qualify distractors or to have confused the concepts of distractor interference with that of distraction. Another visible example is Kim, Kim, and Chun (2005), *Proceedings of the National Academy of Sciences* who write "Concurrent working memory load can reduce distraction". Instead of using a Flanker Task to draw this conclusion, they used several variations of a Stroop task. In other words, they were measuring effects of task-relevant stimuli (foils) on target processing. This is not a measure of distraction; it is a measure of distractor interference. To be clear, we are not questioning the replicability of the results in any of the several dozen papers on perceptual load, or any paper on the Stroop effect, or Simon Effect.

These are all tasks that ask the same question: to what degree aspects of a task-relevant stimulus impact target processing. They measure distractor interference. Yet, in our haste to extend our results to the real world, to claim that our experiments can be applied to important real-life challenges, like the understanding of distraction and distractibility, we might be tempted to substitute one term for the other. This is wrong. This is not to say that the results from these experiments do not inform important real-world decisions like, for example, how to design a high-efficiency workplace. They clearly do, as we reviewed in the paragraph above. That said, we must be more careful about what the conclusions that we can draw about our experiments are and avoid overreaching in our explanatory power. To avoid making such mistakes, we believe it is important that we start being more mindful in the use of terms in our discipline, like distraction, distractibility and task (ir)relevance. Or we risk drawing the exact opposite conclusions from our data, as Lavie (2010) has done, or perhaps more subtle, use the results of our experiments to make inferences about phenomena that they cannot inform (as Kim et al., 2005). To this end, we have proposed the use of new terms, candidates and foils, to identifying different types of distractors. These labels are useful because they also help us to determine the explanatory bounds of the effects observed with each type of distractor.

3. A BRIEF CASE STUDY ON DISTRACTION

3.1. Limitations of Unexpected Event Paradigms

We have reviewed one set of experimental paradigms that has been useful in bringing about an initial understanding of distraction: the unexpected event paradigm that produces inattentional blindness. Unfortunately, though powerful, there are two main problems with this particular paradigm if one wants to further explore the issue of distraction. The first concern is simply a question of methodology: the typical unexpected event paradigm produces only one observation per subject. Though one can draw some important theoretical inferences from these experiments (as we have done above), it remains a fundamentally limiting paradigm. The main reason is that, once participants are made aware of the fact that the experimenters will be asking questions about the critical stimulus, they start attending it on every trial. Because of this, the critical stimulus becomes extremely relevant to the subject, so we can no longer argue that future instances of similar stimuli will be treated in the same "unattended" fashion as the first instance was. Good evidence for the "incorporation" of the critical stimulus into the main attentive task can be seen in Moore, Lleras, Grosjean, and Marrara (2004). In that experiment, participants were asked to report the identity of a centrally presented letter (forward and backward masked). In addition to the target letter, a small dot could appear either to the right or to the left of the target. Participants completed a first block of 64 trials with this setup, followed by a short block of trials where we tested participants' awareness for the small lateralized square, as in an inattentional blindness experiment. Only 16% of participants reported having seen the square in the inattentional blindness trial. Critically, participants were asked to complete a second full set of 64 trials, identical in every way to the first block of trials. We used the accessory Simon effect (e.g. Simon, Acosta, Mewaldt, & Speidel, 1976) as a measure of distractor processing (via distractor interference). Whereas the square did not produce any interference on the letter identification task *before* the inattentional blindness trial, it produced robust levels of distractor interference in the second block of trials. In other words, participants in the first block of trials were unaware of the square (as assessed by the inattentional blindness results) and therefore it failed to impact performance. In contrast, once we asked questions about the square, they not only became aware of it, but incorporated it into their task. From then on, the presence of this square interfered with the responses to the central target on every trial.

A second problem with the unexpected event paradigm is one of generalizability. It is true that the paradigm does reflect a setting that one may find often in the real world (when one is effortfully attending to one event and a completely unexpected event takes place). Yet, there is the perhaps far more common situation of being in a busy environment (and *knowing* some of the characteristics of the environment) while trying to effortfully engage in some mental activity. For instance, one may be trying to read an important email from work while children are playing around. Or one may be talking on the cell phone while driving. In both cases, one is well aware of the characteristics of the environment. And one may decide to only pay attention to one thing (i.e. ignore the children in the first example) or pay mostly attention to one thing (i.e. momentarily decreasing attention to the driving). How will we react to events along these unattended (or significantly underattended) channels of information? This is an important question that has been asked as far back as Treisman (1960). And one that deserves being asked. With respect to the domain of driving, Strayer et al. have shown, for example, that drivers talking on the phone are 10 times more likely to fail to come to a stop at a four-way intersection, and they are significantly less likely to remember traffic-related events that occurred during their driving (in a simulator) than when the events appeared and they were not talking on the phone (Strayer & Drews, 2007). What Strayer et al. argue is that this is because of inattentional blindness: drivers actually are less aware of the world while on the phone, and this decreased level of awareness does not appear to be mitigated by the traffic relevance of worldly events. That is, once drivers start underattending the driving environment, they seem to lose sensitivity to the driving relevance of events in the world. But one must highlight a certain incompatibility between Strayer's findings and those in the inattentional blindness' laboratory: whereas Strayer and Drews' findings suggest that the relevance of events is not associated with drivers' awareness of those events, the inattentional blindness literature shows that relevance does impact awareness. Clearly, more research needs to be done to understand underattended perception in a paradigm where we can systematically manipulate such things as the degree of cognitive difficulty in a task (cognitive load), the cognitive engagement in a task (motivation), as well as the relevance of events in the unattended/underattended channels of information. Below, we propose one such paradigm.

3.2. A New Paradigm

We here propose a simple paradigm to study actual distraction—i.e. the ability of information in unattended or underattended channels to draw attention onto itself while the observer is actively engaged on a primary task (Lleras & Buetti, 2012a,b). In this task, we ask participants to perform a sustained cognitive task: each trial lasted about 1 min. In the experiments below, we asked participants to perform a 1-back, 2-back, or running arithmetic task. The task-relevant stimuli for this task were presented auditory once every 3 s and each stimulus itself lasted somewhere between 500 and 800 ms. In other words, the participant had between 2200 and 2500 ms of time between task-relevant stimuli. They used this time to perform the required cognitive operation in their minds. The critical manipulation is what happened on the display while participants were focused on performing this ongoing task. We informed participants that while they were performing this cognitive task, completely irrelevant photographs would appear on the computer monitor. They were told that they could ignore those pictures and that they would not be tested on them at any point. There were 360 photos, all taken from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008). They were selected as being somewhat neutral on valence and not arousing; they were mildly interesting photos. The images appeared 1800–2300 ms after the offset of the previous task-relevant stimulus and 700–1200 ms before the onset of the next task-relevant stimulus. Images could appear at one of the four possible locations (above, below, to the right or left of the center of the display). Only one image was present at a time. When a new image appeared, it always appeared at one of the three unoccupied locations. An image disappeared exactly at the time the next image in the sequence appeared.

To summarize the experimental task, participants engaged in a complex cognitive task for a period of 1 min at a time. While they did this, images appeared every now and then on the display. Importantly, when a new image appeared, it was the only event in the world, the only "interesting" location to look at on the monitor and its presentation was isolated in time from the presentation of the task-relevant stimuli (that is, it did not compete with other stimuli for sensory attention). A schematic of the trial events is shown in Figure 7.1(a). Figure 7.1(b) and (c) show results from this task in three versions of the task. The experimental stimuli and events were identical in all three experiments. The only thing that differed was the task we asked participants to perform on the task-relevant stimuli. The task-relevant stimuli were a set of audio files with someone's voice reciting a simple mental operation ("plus one", "minus one", "plus two",… up to "minus five"). First group of participants performed a 1-back task on the list of operations, that is, they counted the number of times the same math instruction was presented twice in a row. This was a "low-cognitive load" group. A second group of participants performed a 2-back task on the operations, that is, they counted the number of times in the 1 min trial, the current operation was the same as the operation before the last one. This was a "high-cognitive load" group. Finally, a third group of participants was asked to actually compute all the math operations starting from a three-digit number that was presented to them at the start of the 1 min trial (a running arithmetic task). This was also a "high-cognitive load" group.

As can be seen from Figure 7.1, the data we collect is simply a measure of where people look when a new and very salient photograph suddenly appears in the display. The results speak for themselves. As one would expect (and as would be predicted by all theories of visual attention), when participants are only doing a very easy cognitive task (one that only requires rehearsal of auditory information), participants spontaneously look at our photos: 75% of the time, within 200 ms of a new image appearing, their eyes land on the photo. No surprise there. In fact, if there is a surprise is that the percentage is this *low*: one might have expected something closer to 100%. Be that as it may, it provides us with a baseline level of performance:

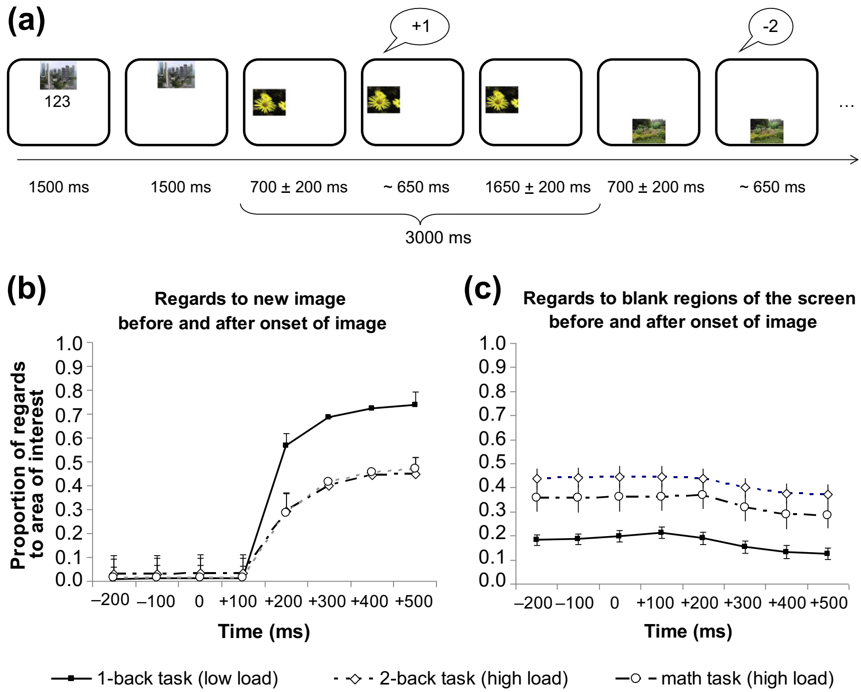

Figure 7.1 Oculomotor capture during mental engagement. (a) Schematic of events in a trial. Every 3 s, participants heard a new operation. The sound file lasted on average 650 ms. A new image always appeared at an unoccupied location, on average 1650 ms after the end of the sound file. (b) Proportion of regards to the new image within 500 ms after image onset (time = 0). Participants reflexively oriented to about 75% of images in the 1-back task, whereas they oriented to fewer than 50% of new image onsets both in the 2-back and math tasks. (c) Proportion of regards directed to empty regions of the display as a function of time across the three cognitive load conditions. All three experimental groups showed a gross insensitivity to the image onset (time 0). If a participant had been looking at an empty region of the display before the image onset, he/she continued to do so after the onset. Furthermore, the degree of regards to "nothing" was about twice as likely in the high-cognitive load conditions as it was in the low-load condition. (For color version of this figure, the reader is referred to the online version of this book.)

these irrelevant (though admittedly expected) images are inspected on a vast majority of instances. However, this is not what happens when we increase the degree of cognitive effort on the main task. The data also show that when people have to actively engage executive resources and apply them to the auditory information, their spontaneous regards of the new images drop to <50%. This is remarkable. Not only did their regards to new images significantly decrease (Figure 7.1(b)), but there is a large percentage of regards to "nothing" (completely blank regions of the monitor, Figure 7.1(c)), and these regards are completely unaffected by the appearance of the new image: when participants were looking at nothing, they continued to do so after the onset of the image. The conclusion is simple. In identical environments, when participants engage in cognitive tasks that require some degree of executive control, they spontaneously withdraw their attentiveness from irrelevant events.

3.3. Discussion

This new task to study distraction is interesting because it reproduces a real-life situation in which one is trying to complete a mental task, and is focused on doing so, while there are ongoing events in the world. Interestingly, one has a general idea about the structure of the environment: here, that images appear with a certain frequency and that one can ignore them, inasmuch as one wants to ignore them, since they do not inform our decision making on the primary task. The results suggest that we are sensitive to some degree to the cognitive demands of a task and that we tradeoff attention, giving more to our thoughts and less to the world, when cognitive demands are high. Interestingly, this does not seem to be the end of the story. It is difficult to compare performance and mental effort across the two high-cognitive load tasks (perhaps separate measures of effort and mental workload like hear-rate variability and skin conductance would be informative). So, to further investigate the effect of cognitive demands on attention, we performed a follow-up analysis on the math task, because we had a level of control over the actual cognitive difficulty of specific math operations. We measured on a separate, self-timed task, how long it took participants to complete each of the math operations in the experiment. For instance, it took our participants 1.7 s to complete a +1 operation on a three-digit number, whereas it took twice as long to complete a −5 operation (3.2 s). These data suggest a higher degree of cognitive effort is required to complete +5 operations compared to +1 operations. When we analyzed regards as a function of the difficulty of the math operation, we found no measurable effect of the difficulty of the operation on the likelihood that participants will look at the next new image when it appears (Figure 7.2). Thus, even though for our participants it is substantially easier to add 1 to a three-digit number than to add 5, the complexity of this operation does not determine whether they will look or not at the next new image on the screen. This suggests that the "tradeoff" between attentiveness to the outside world (images) and attentiveness to the mental world (cognitive operations)

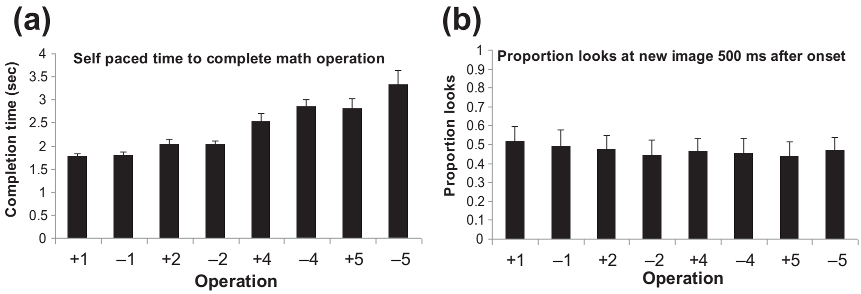

Figure 7.2 Analysis of the math task. (a) Participants completed at the end of the experiment a self-paced version of the main experiment, where they had a chance to advance the operations at their own pace. No images were presented on the screen. Operation times varied greatly as a function of the operation. (b) Proportion regards on the new image, 500 ms after its onset. Comparing panels (a) and (b) demonstrates that in spite of large differences in the degree of difficulty of specific math operations, the type of math operation participants were performing when the image appeared had no impact on their likelihood to look at the new image.

is not driven by a moment-by-moment need for cognitive resources, but by an a priori and general investment of resources. That is, it appears that the actual cognitive resources required to complete a task do not determine the level of distractibility of an individual, rather, it seems that the degree of *anticipated effort* is what determines it. In other words, we believe it is the amount of resources that participants voluntarily set aside to commit to their primary task that determines the attentional tradeoff between thoughts and outside world. The present cognitive difficulty of a task may only play an indirect role in this tradeoff; initially, it may help to calibrate the degree of concentration (effort) to invest in the primary task ("this is going to be tough, I better concentrate"), and it may interact with the degree of motivation of participants ("this is too hard").

Evidence in favor of "effort calibration" in a cognitive task has been documented in the abbreviated vigilance task literature (e.g. Helton & Russell, 2012; Temple et al., 2000) in which participants are asked to engage in brief, but cognitively demanding tasks for periods of about 2 min (each with about 110 events of interest) (Figure 7.3). Performance in the first 2 min trial or "period of watch" (as it is called) is typically superior than performance at all subsequent 2 min trials, as if participants had initially engaged in the task with great motivation, but after the first 2 min trial had decided to settle at a more comfortable, less arduous level of engagement. Similarly, Silvia, Jones, Kelly & Zibaie (2011) produced good evidence that motivation and cognitive difficulty interact to determine performance (see also Gendolla &

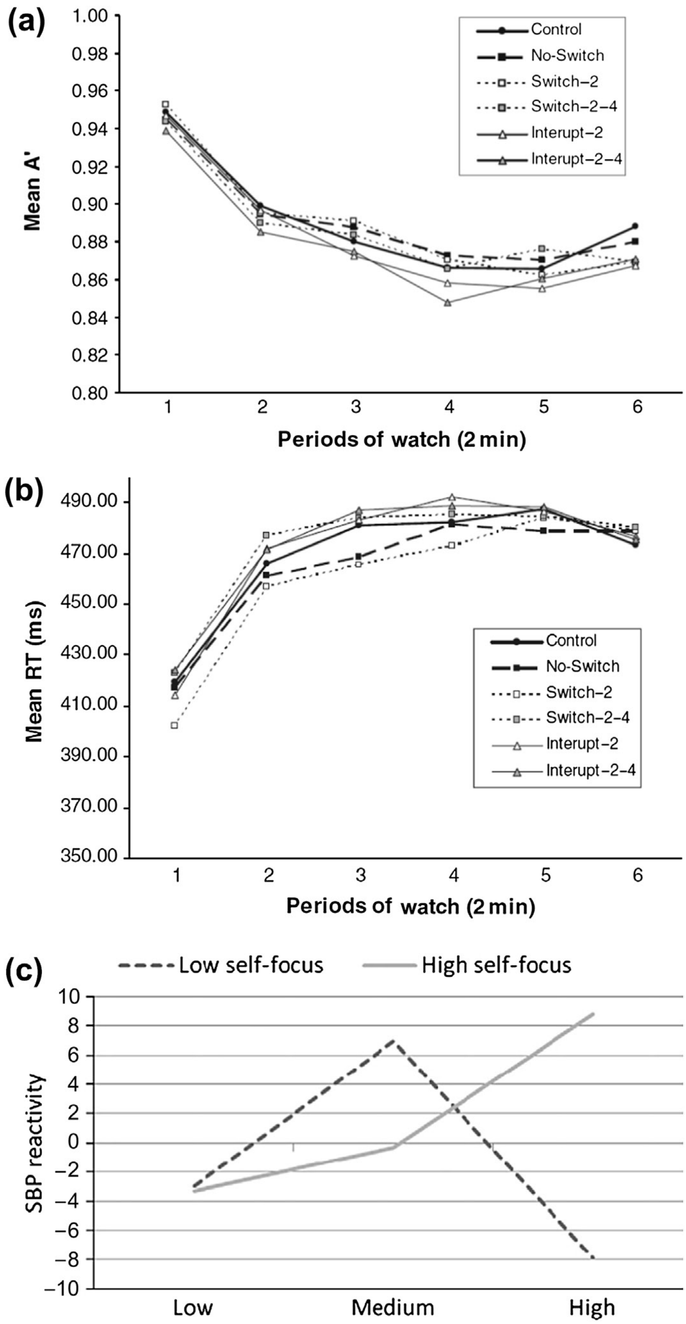

Figure 7.3 (a) Figure 3 from Helton & Russell (2012) showing performance (as indexed by A') in a demanding sustained attention task, as a function of periods of watch.

Richter, 2010; Silvia, McCord, & Gendolla, 2010). In their paper, Silvia et al. assessed motivation in terms of a personality trait ("self-focused attention"), which has been shown to reflects participants' willingness to exert effort in a task, as well as their own level of trait motivation (e.g. Carver & Scheier, 2001; Duval & Silvia, 2001). The authors manipulated the difficulty of a task by changing the response window (long, medium and short = easy, medium and difficult, respectively), using a perceptual discrimination that was difficult to begin with. They measured systolic blood pressure (SBP) reactivity, which is a good physiological marker of effort (e.g. Bongard, 1995; Smith, Ruiz, & Uchino, 2000). Participants high in self-focused attention showed increased SBP reactivity as the difficulty of the task increased. In contrast, for participants low in self-focused attention, SBP reactivity increased from low to medium task difficulty levels, and then it dropped when task difficulty became high. This is evidence that some people can motivate themselves to exert larger effort in difficult tasks than others. Here we propose that this decision of how much effort to put into a task is as critical a determinant of their distractibility as is the cognitive requirements of the attentive task. Note that we believe motivation can also be directly manipulated by incentives or pressure, and we believe those manipulations would result in the same effects on attention. There is a need for research along these lines.

Periods of watch are 2 min intervals during which performance is evaluated. The entire experiment lasts 12 min. (b) Figure 4 from Helton & Russell (2012) showing mean reaction time in the same task. As can be seen from these two figures, participants initially engage strongly in the task (first 2 min), both in terms of their initial effort to be accurate (higher A′) and fast (slower RT). However, performance drops quickly after that initial period and there is little-to-no change in the remaining five periods of watch, either in terms of accuracy or RT. Notice that this is the opposite of a speed-accuracy tradeoff: participants become both less accurate and slower, even though nothing has changed about the task. This is evidence of voluntary changes in effort (or engagement) in the task, as participants calibrate their effort, and settle into the task. (c) Figure 1 from Silvia et al. (2011). Systolic blood pressure reactivity (an index of incurred effort) as a function of task difficulty (low, medium and high) for participants either low or high in self-focus attention, which is a measure of how people evaluate their performance with respect to their own standards and how they motivate themselves to achieve (or not) those standards. People high in self-focused attention will try harder than people low in self-focused attention as success is more significant to them and they will motivate themselves endogenously to achieve better performance. As can be seen, people high in self-focus increase the degree of effort they put in the task as task difficulty increases from low to medium and from medium to high. In contrast, participants low in self-focused attention try harder when difficulty goes from low to medium, but when difficulty further increases to high levels, they stop trying, and SBP reactivity simply drops. *(All figures reprinted with permission).*

4. A THEORY OF ATTENTION AND DISTRACTIBILITY

4.1. The Need for Inner Focus

Glenberg, Schroeder, and Robertson (1998) presented a wonderful demonstration of the spontaneous tradeoff between attention to the world and attention to our thoughts. In their experiments, participants were asked to do a series of remembering tasks that varied in difficulty. The specific questions were about autobiographical events or general knowledge. In Experiment 3, participants viewed such questions on a computer monitor and the investigators rated the number of times people spontaneously averted their gaze from the monitor (e.g. closed their eyes or looked away). Their results showed that the more people averted their gaze, the better their performance in the memory task. In Experiment 4, they converted this measure to a manipulation: in some conditions, they asked participants to close their eyes while thinking of the answer to the question. They found that people performed better at both the memory task and on a set of simple math problems, as well, when they closed their eyes than when they kept their eyes open. Together, these results are good indicators of two main characteristics of our attention system. First, when we have a need to concentrate on some internal cognitive process, we tend to actively prevent the encoding of potentially distracting information. Second, the prevention of encoding of potentially distracting information is, in fact, functional: we are better thinkers when we shut our eyes. This explains why we tend to avert our gaze from a listener when we are about to start speaking (e.g. Beattie, 1978a,b; Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle, 2002; Doherty-Sneddon & Phelps, 2005; Ehrlichman, 1981; Goldman-Eisler, 1967): we are actively trying to shut down a large source of potential distraction (our listener's face) while we are engaged in trying to plan new sentences.

Thus, our instinct to move our eyes away from potential sources of distractions is both a reflection of our intuitive understanding of the hazards of the environment (where distracting information may be found) as well as an effective strategy for controlling the allocation of cognitive resources in times of need. Interestingly, Glenberg et al.'s results also showed that when overly difficult questions were used (such as questions to which people knew they did not know the answer for example), people no longer averted their gaze. They had stopped trying to do the task. They knew that a momentary boost of cognitive focus would not change the fact that they did not know the answer to the question posed. So, they no longer engaged in gaze aversion. This makes it clear how gaze aversion is not merely a reaction to heightened cognitive demands; it is strategic in nature. We propose that the attentional system has an executive component that is sensitive to *anticipated* cognitive demands (and whether said demands will exceed capacity), as well as *motivational* states to bring about a tradeoff between sensory attention (i.e. attention to world events) and mental attention (i.e. attention to inner cognitive processing). And we propose that it is this tradeoff, when pushed to extremes, that leads to the more blatant failures of awareness observed in inattentional blindness and when driving while talking on the phone. In a momentary need for extreme inner focus, attention to the world suffers.

The need to reorient attention inward may also help explain other psychological phenomena, such as the attentional blink (Raymond, Shapiro, & Arnell, 1992). This phenomenon refers to the finding that people often miss the second of two successive targets, at least when those targets are presented embedded in a rapid visual stream of distractors and the second target appears 200–500 ms after the first one. There are several theories as to why the attentional blink occurs, but most models agree that the blink itself seems to be tightly linked to the need to "save" information from the first target in working memory, so that it can be accessible for response later on. Functionally, this seems like a brief but acute need for inner focus: upon detection of the first target, and given the presence of so many distractors (the other letters in the stream), the participant may need to effortfully pick and store the detected target in working memory. If it is true that an acute need for inner processing triggers a disengagement from potential sources of distraction, then the need to store the first target, once it is detected ("Oh, that's a target! I need to remember it."), in the face of rapid steam of stimuli, may be what causes the blink to occur. This account is not novel per se. What is new is the explicit presentation of a framework from which to understand why consolidation into working memory (or any other demanding and inwardly directed process) would create a blink in the first place (as several theories have argued, Bowman & Wyble, 2007; Chun & Potter, 1995; Craston, Wyble, Chennu, & Bowman, 2009; Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Raymond et al., 1992; Shapiro, Caldwell, & Sorensen, 1997).

4.2. Predicting Inattentional Blindness

We believe our proposed framework for attention allows us to reframe one of the principal challenges in the inattentional blindness literature: how to predict when a given participant will fail to report an unexpected stimulus.

Several studies have shown that more difficult (primary) tasks lead to more blindness (e.g. Cartwright-Finch & Lavie, 2007; Fougnie & Marois, 2007; Simons & Jensen, 2009). But performance in the primary task alone is not a good predictor of inattentional blindness (Cartwright-Finch & Lavie, 2007; but see Simons & Jensen, 2009). In fact, Simons & Jensen (2009) recently demonstrated that someone's skill at a task also fails to predict the degree of blindness. Why is that? The attentional tradeoff we propose is sensitive to the anticipated need for executive control, as well as the motivational state of the participant. The anticipated need for executive control will depend on a number of factors. The self-perceived skill of a participant at a task will play a big role in determining need: cigar-rolling experts will require less-executive oversight of the activity than a beginner, thus, one would predict that the expert will be less likely to suffer from inattentional blindness while engaged in this activity. Once an anticipated need is identified, one must ask the question: how well can the participant fulfill that request? Does he have the ability to precisely match the need with the corresponding resources? It is possible and more research is needed to answer this question, but it is also likely that participants spontaneously assign resources in gross fashion: "I will focus on this task" vs "I will focus on this task a lot," rather than "I will focus on this task with 47% of my resources" vs "I will focus on this task with 66% of my resources." This is not to say that participants are incapable of allocating their attention in fine quanta, but that it is more likely that they spontaneously allocate in relatively large chunks. This may also be a reason why experimental manipulations of the degree of difficulty of the attentive task (aimed at capturing incremental levels of attentiveness in the participants) may not lead to a nicely titrated relationship with performance. It may also explain why the actual difficulty of the mental arithmetic task failed to influence gaze aversion in the task presented above: participants are either attentive to the math task or they are not, as they anticipate a need for focusing on it to succeed. But once that determination has been made, whether a specific operation is easy (+1) or hard (−5) is unlikely to change their overall attentive engagement to the task (Figure 7.2).

Finally, the amount of attentiveness to the main task (and ergo the degree of unattentiveness to the rest of the world) will also be determined by motivational and personality characteristics of each individual. As shown by Silvia et al. (2011), once a task becomes too difficult, some people will continue to increase their effort to match the demands of the task, whereas others will simply stop trying. Factors like the self-focused attention trait (as suggested by Silvia et al.), as well as conscientiousness (e.g. Trautwein, Lüdtke, Roberts, Schnyder, & Niggli, 2009), will probably be important factors to determine engagement in the attentive task. If one thinks back to experts performing a task that does not require (of them) lots of executive control, one might still see differences in inattentional blindness as determined by their conscientiousness: in spite of their expertise, conscientious experts may deliberately pay more attention to the task, even if they do not need to. And of course, this is likely to change as a function of both intrinsic and extrinsic motivation. If there is a high reward to perform well in the attentive task, one would expect that individuals more responsive to rewards will be more attentive and thereby exhibit larger degrees of inattentional blindness.

In sum, if one wants to predict performance in any situation that would seem to be parallel to inattentional blindness, there are a number of factors that will need to be considered and measured. Failure to take these factors into account will likely produce just noise. Take the Simons and Jensen result, for example, that skill at a motion tracking task failed to predict inattentional blindness. Skill was rated as the speed at which a participant could accurately track to a level of 75% accuracy. Importantly, all subjects in the inattentional blindness task were tested with stimuli moving at a speed that fell more or less at the half-way point of skills in the participant pool. At one end of the spectrum, one is measuring people low in skill at the task, performing at a level beyond their skill. These subjects will either try hard (if conscientious or high in self-focused attention) or simply give up ("it's too hard for me!"). Thus, at the bottom end of the skill distribution, one cannot predict inattentional blindness; it can go either way. The same is true at the top end of the distribution: all these participants can perform the task, but if the difficulty is sufficiently lower than their skill, then (1) they may not see a need for engaging high levels of attention in the task or (2) if they are conscientious, they will likely focus a lot on the task, to make sure that they excel in accordance to their own standards. So, neither at the low nor high end of the skill distribution will skill alone predict inattentional blindness. Admittedly, our proposal remains to be tested, but we hope that it at least provides some guiding parameters for what considerations should be taken when one is trying to predict IB in a large group of people.

4.3. A Look Back at Visual Attention

We will not elaborate much on how visual attention works, except to emphasize some general properties that we believe guide how visual selection takes place. Our starting points are theories like Bundesen's theory of visual attention as well as Desimone and Duncan's biased competition theory. First, we propose that the visual system uses its "nodes" of specialization to select in parallel and across the visual field stimuli that are processed by those nodes. For instance, if the visual system has a level of specialization that focuses on processing motion, this node can be leveraged to select the presence of particular motions in the world (e.g. feature-based attention, Serences & Boynton, 2007). The same ought to be true for higher or lower nodes, so that one can select on the basis of orientations (V1), shapes (V4), colors (V1, V4a) but also alphanumeric characters (visual word form area, Nestor, Plaut, & Behrmann, 2012), and other objects of expertise (fusiform face area, like faces or cars, if one is a car expert, see McGugin, Gatenby, Gore, & Gauthier, 2012). In other words, one can easily set a filter to detect all faces in a scene. To the extent that those faces are sufficiently well represented at the neural level (i.e. this probably means there is no competition at the level of that nodes' receptive fields from nonpreferred stimuli), they will likely be selected in parallel. Thus, effortlessly, one can know where all the persons in a room are, and likely too, process in parallel properties of the group of selected faces (e.g. Chong & Treisman, 2003, 2005a,b; Haberman & Whitney, 2009).

Note that this "parallel" function of visual attention is both powerful and intuitive. We know that visual information about the entire scene flows in parallel throughout the visual system (i.e. is being analyzed by these different nodes), thus for example, the FFA is analyzing face-like inputs across the visual field all at once, or MT motion information across the visual field. What we are arguing is that attention leverages this massively parallel processing toward biasing a subset of elements in the scene. This allows for efficient selection (or adoption) of candidates across the visual field. Note, too, that there are natural limits to this parallel form of processing. For instance, in addition to competition for representation, cortical magnification will make it so that information farther from fixation will be represented with less fidelity than information at or near fixation, thereby imposing a constraint on the quality of input that is available to this parallel function of attention.

This initial form of parallel selection is a function of relevance (Bundesen, 1990; Fischer & Whitney, 2012). And it is evident in visual search, where observers are extremely efficient at massively rejecting in parallel large sets of items that are not relevant to the search task (Cunningham & Wolfe, 2012). Furthermore, to the extent that distractors are similar to each other and group well, observers can reject these in large groups, as well (e.g. Anderson, Vogel, & Awh, in press; Duncan & Humphreys, 1989). So, we can both put in place large "adoption" as well as large "rejection" filters to process information in parallel. The output of the "adoption" filter is the set of likely targets for the current task (i.e. *candidates*). Again, assuming that the items in the display can be accurately represented (i.e. no crowding), how fine the "adoption" filter will be in part determined by the ability of a particular "node" to process specific sets of features that discriminate targets from other stimuli in the set. The more diagnostic target features there are (relative to the specific vision node responsible for computing said features), the smaller the set of candidates or likely targets will be (i.e. the more effective the first sweep of selection will be). The less diagnostic the target features are, the larger the set of items is that will be selected in that initial sweep of selection.

What happens next? It depends on the task. In visual search, the task is to select the "one" target among the "selected few" possible candidates at various locations. To perform this operation, a comparison must be made between the candidates and the target template, and this comparison will be made in parallel in working memory and will be determined by the capacity of working memory (Anderson et al., in press). The larger the capacity is, the more of these comparisons can be made simultaneously. The smaller it is, the fewer of these comparisons can be made. So, in fact, the "serial" aspect of visual search observed in most experiments is actually the result of two massively parallel operations (see also Young & Hulleman, 2012). An initial sweep that determines candidates (i.e. a priori targets), that is likely of unlimited capacity (not counting visual acuity limitations or representational crowding). This initial sweep is followed by a second parallel sweep that compares candidates to the target template, also in parallel. However, this second sweep is capacity-limited (Anderson et al., in press; Pashler, 1987). For the current purposes, let us say that the maximum number of items is four. Search then will proceed in serial manner, in groups of four, inspecting the set of candidates, until a match is found (or until acuity and/or crowding require refixations to new locations in the search space). Note that the comparison process will also be limited by the precision of the target representations in memory as well as the confusability between candidates and target templates (e.g. Alvarez & Cavanagh, 2004; Awh, Barton, & Vogel, 2007). It is also likely that when the target is fixed, the comparison process will become more and more efficient over time (e.g. Carlisle, Arita, Pardo, & Woodman, 2011; Logan, 1988; Woodman & Arita, 2011).

From this overview, a second important function of attention can be determined: attention must act to decrease the noise in the representation of visual items (as proposed by biased competition theory), either covertly or overtly. That is, when items compete for representation, attention must act on each item individually to improve the representation of that item, at the momentary expense of surrounding items. Indeed, Scalf & Beck (2010) nicely demonstrated that attention to multiple items simultaneously does *not* result on improvements in representation of those items, if those are competing for representation because of their spatial arrangement. Eye movements, guided by attention, then work to solve this problem: by directly gazing at potential items of interest, the representation of those items is greatly improved. Alternatively, attention can be directed serially to each of the competing items to improve, one at a time, the representation of each of those items.

If the task is a Flanker task, the candidates selected by attention in parallel can actually be foils. That is, not only do candidates look like a target, congruent and incongruent flankers have links to potentiated responses (press right/left, for example). Thus, the Flanker Task is actually a task in which response selection processes must select which of the *already selected* foils they want to respond to. The problem comes from the fact that by virtue of having been selected in the first sweep, the foils are already activating potentiated responses, which is why the congruency between foils and target ends up producing a Flanker Effect. Studies in the Flanker Effect literature are, therefore, centered on the processes that allow for more *efficient suppression* of foil interference, or alternatively, better identification of the proper target among the foils (Lachter et al., 2004; Yigit-Elliott et al., 2011). And there are studies showing that the executive control system is actively trying to learn as much as it can from the task ecology to try to be as effective as possible in that regard (Max & Tsal, 2011, 2012). Yet, the critical message that should be remembered is that the presence itself of a Flanker Effect represents a specific sign of attentional success: the foil was successfully selected by our "adoption" filter as a candidate. The relative reduction (or elimination of a Flanker Effect when one was expected) reflects success of a different kind: success in the efficient suppression of foil interference. But note that the simple Flanker Effect can be modulated by both factors. In displays with "high perceptual load," a Flanker Effect may not be observed for two categorically different reasons: because the flanker was not selected as a candidate (perhaps because of crowding or competition for representation, which requires slow allocation of spatial attention to disambiguate visual representations) or because foil interference was entirely suppressed (perhaps because the executive system found ways to more efficiently suppress response-related foil processing).

5. CONCLUSIONS

A Flanker Effect experiment is an experiment that studies the response interference that is created by selected foils on target processing—what people may call a form of "distractor interference". Another example of distractor interference is seen in the color-word Stroop task, where foils are words that semantically activate the same response tokens as the colors of the ink in which the word is written (which is what determines the response). So, there are various forms of distractor interference effects, but, in general, it is important to recognize that the effects arise because the distractors are in fact "foils" of some sort (foils because of their visual similarity to the target as in the traditional flanker or their semantic overlap with the target information as in the classic Stroop). The attention system efficiently selects foils from a display (as it does with candidates). As we have argued before then, paradigms like the Flanker and Stroop cannot measure distractibility and cannot be used to study distractibility because the stimulus causing the interference was selected in the first place. Inspecting candidates and foils is a critical part of the task. It is what is intended from the start. Given that foils are present in the display, inspecting them is in an important way part of what the participant must do to successfully complete the task.

We have reviewed a number of issues regarding various selective attention paradigms and more specifically, we have identified the problematic use of certain labels within this literature (Figure 7.4). We have proposed a new labeling system for qualifying "distractors" across various tasks, so as to minimize issues with the interpretation of results from these paradigms. Importantly, the labels themselves make it clear what the explanatory power and the explanatory domain are of a given stimulus and task set. One cannot and should not try to generalize results from one type of distractors to another set of distractors without proper evidence that such generalization is warranted. Conducting a Flanker Effect and concluding something about distraction is therefore problematic. Having defined this new set of labels is important because it allows investigators who are interested in using our paradigms to understand other aspects of cognition (such as cognitive problems in clinical populations) to know which tasks and stimuli are most appropriate for studying their phenomenon of

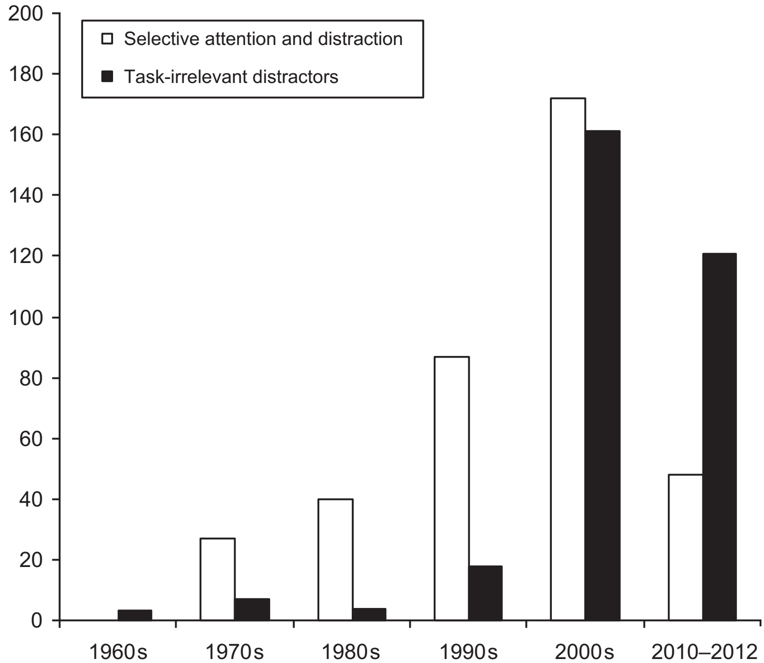

Figure 7.4 Citation counts each decade for two different searches in PsychInfo. In white are the citation counts for the keyword "distraction" in all fields within the specific subject "selective attention". In black are the citation counts for the search "task-irrelevant distractors" or "task-irrelevant distractor". This citation count simply illustrates the sudden explosion of articles using the terms "task-irrelevant distractors" in the last dozen years (2000–2012). The citation count for the conjunction selective attention and distraction is presented here as a baseline. This is instructive as it documents the research interest in understanding distraction, within the selective attention literature. That said, most selective attention paradigms are not appropriate for drawing conclusions about distraction, if they use candidates or foils as stimuli. With respect to the use of the term "task-irrelevant distractor," its rise in prominence in the literature is clearly worrisome as it is likely people are misusing and/or misunderstanding the meaning of the term: 75 of those papers (almost 40%) also include the word "distraction" as a descriptor of their paper.

interest. As an example, if one is interested in understanding distractibility in aging or in Alzheimer's disease, it would be simply inappropriate to use a Flanker or a Stroop task.

With respect to the critical difference between distractor interference and distractibility, one final comment is warranted. It is important to understand that distractor interference effects are all "within-task" effects. The subject never feels like he or she has "changed" what he/she is doing while performing a Flanker or a Stroop task. The instructions for the task are set and the participant feels in compliance throughout the trial. In terms of executive control, the goal structure to complete the task does not change, even when one is suffering from severe levels of distractor interference, as in the traditional Stroop task. A person trying to name the ink of a color word throughout the trial is struggling with completing one specific goal: naming the ink (not saying the word) of the colored word. That much is clear. A corollary to this is that no matter the type of task-relevant distractor, a task-relevant distractor can never alter the boundaries of the task space. In contrast, the study of distraction is itself a study of changes to the task space. Distraction is the taking possession of the mind by a stimulus or thought that the subject *never* intended to process in the first place. It is a thought or event that interferes with the "goal stack," therefore changes the task space. Participants are suddenly doing (or thinking about) something other than their stated intention. If prompted, participants can answer the question "are you currently doing the task you are supposed to be doing". If distracted, the answer to that question will be no (Giambra, 1989; McVay & Kane, 2009, 2012; Smallwood et al., 2003), because they can recognize that their goal stack has changed.

What is particularly pernicious about distraction is that we are not always aware that a change in the goal stack has occurred. That is troublesome. That is why understanding distraction is a matter of crucial importance to us as we try to understand problems like "distracted driving" or rumination in anxiety and depression. If we are not doing what we are meant to be doing and are not aware of it, that is a problem. The example that jumps to mind is distracted reading (Smilek, Carriere, & Cheyne, 2010). Often we realize we have been "reading" a book but have no idea of what it is that we just read, because our goal of reading was pushed down our goal stack to a lower priority than, for example, our preoccupation with Mom's dinner plans for thanksgiving. In the visual world, understanding sensory distractibility is also of crucial importance to understanding issues like performance at work or human response to alert and alarm systems. A number of interesting questions remain completely open and thus far are largely unanswered: What events in our intended task are capable of bringing us back to our main task? The death of the main character in our book? In the case of distracted driving, will the change of a traffic light to red bring us back from our cell phone conversation and into the driving task again? This issue of "competition for goal status" is fascinating and will likely be the source of much fruitful research in the years to come.

REFERENCES

Alexander, R. G., & Zelinsky, G. J. (2011). Visual similarity effects in categorical search. *Journal of Vision*, *11*(8).

Alvarez, G. A., & Cavanagh, P. (2004). The capacity of visual short term memory is set both by visual information load and by number of objects. *Psychological Science*, *15*, 106–111.

Anersdon, D. E., Vogel, E. K., & Awh, E. A common discrete resource for visual working memory and visual search. *Psychological Science*, in press.

Awh, E., Barton, B., & Vogel, E. K. (2007). Visual working memory represents a fixed number of items, regardless of complexity. *Psychological Science*, *18*(7), 622–628.

Beattie, G. W. (1978a). Floor apportionment and gaze in conversational dyads. *British Journal of Social and Clinical Psychology*, *17*(1), 1–9.

Beattie, G. W. (1978b). Sequential temporal patterns of speech and gaze in dialogue. *Semiotica*, *23*, 1–24.

Bichot, N., Rossi, A., & Desimone, R. (2005). Parallel and serial neural mechanisms for visual search in macaque area V4. *Science*, *308*(5721), 529–534.

Bongard, S. (1995). Mental effort during active and passive coping: a dual-task analysis. *Psychophysiology*, *32*(3), 242–248.

Bowman, H., & Wyble, B. (2007). The simultaneous type, serial token model of temporal attention and working memory. *Psychological Review*, *114*(1), 38–70.

Bundesen, C. (1990). A theory of visual attention. *Psychological Review*, *97*(4), 523–547.

Carlisle, N. B., Arita, J. T., Pardo, D., & Woodman, G. F. (2011). Attentional templates in visual working memory. *Journal of Neuroscience*, *31*(25), 9315–9322.

Cartwright-Finch, U., & Lavie, N. (2007). The role of perceptual load in inattentional blindness. *Cognition*, *102*(3), 1–20.

Carver, C. S., & Scheier, M. F. (2001). *On the self-regulation of behavior*. New York: Cambridge University Press.

Chong, S., & Treisman, A. (2003). Representation of statistical properties. *Vision Research*, *43*(4), 1–12.

Chong, S., & Treisman, A. (2005a). Attentional spread in the statistical processing of visual displays. *Perception & Psychophysics*, *67*(1), 1–13.

Chong, S., & Treisman, A. (2005b). Statistical processing: computing the average size in perceptual groups. *Vision Research*, *45*(7), 1–10.

Choo, H., & Franconeri, S. (2010). Objects with reduced visibility still contribute to size averaging. *Attention, Perception & Psychophysics*, *72*(1), 86–99.

Chun, M., & Potter, M. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(1), 109–127.

Cooper, J. M., Vladisavljevic, I., Medeiros-Ward, N., Martin, P. T., & Strayer, D. L. (2009). An investigation of driver distraction near the tipping point of traffic flow stability. *Human Factors*, *51*(2), 261–268.

Craston, P., Wyble, B., Chennu, S., & Bowman, H. (2009). The attentional blink reveals serial working memory encoding: evidence from virtual and human event-related potentials. *Journal of Cognitive Neuroscience*, *21*(3), 550–566.

Cunningham, C. A., & Wolfe, J. M. (2012). Extending "Hybrid" visual X memory search to very large memory sets and to category search. *Paper presented at the 53th Annual Meeting of the Psychonomic Society*.

Darlington, T., & Talbot, E. B. (1898). A study of certain methods of distracting the attention. III. Distraction by musical sounds; the effect of pitch upon attention. *American Journal of Psychology*, *9*(3), 332–345.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, *18*, 1–30.

Deutsch, J., & Deutsch, D. (1963). Some theoretical considerations. *Psychological Review*, *70*, 80–90.
Di Lollo, V., Kawahara, J., Zuvic, S., & Visser, T. A. W. (2001). The preattentive emperor has no clothes: a dynamic redressing. *Journal of Experimental Psychology: General*, *130*(3), 479–492.
Di Lollo, V., Kawahara, J., Ghorashi, S., & Enns, J. (2005). The attentional blink: resource depletion or temporary loss of control? *Psychological Research*, *69*(3), 191–200.
Doherty-Sneddon, G., & Phelps, F. (2005). Gaze aversion: a response to cognitive or social difficulty? *Memory & Cognition*, *33*(4), 727–733.
Doherty-Sneddon, G., Bruce, V., Bonner, L., Longbotham, S., & Doyle, C. (2002). Development of gaze aversion as disengagement from visual information. *Developmental Psychology*, *38*(3), 438–445.
Driver, J., & Tipper, S. P. (1989). On the nonselectivity of 'selective' seeing: contrasts between interference and priming in selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *15*, 304–314.
Dulsky, S. G. (1932). Discussion: what is a distractor? *Psychological Review*, *39*(6), 590–592.
Duncan, J., & Humphreys, G. (1989). Visual search and stimulus similarity. *Psychological Review*, *96*(3), 433–458.
Duval, T., & Silvia, P. (2001). *Self-awareness & causal attribution: A dual systems theory*. Boston: Kluwer Academic.
Ehrlichman, H. (1981). From gaze aversion to eye-movement suppression: an investigation of the cognitive interference explanation of gaze patterns during conversation. *British Journal of Social Psychology*, *20*(4), 1–9.
Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a non-search task. *Perception & Psychophysics*, *16*, 143–149.
Estes, W. K., & Taylor, H. A. (1966). Visual detection in relation to display size and redundancy of critical elements. *Perception & Psychophysics*, *1*, 9–16.
Fecteau, J. (2007). Priming of pop-out depends upon the current goals of observers. *Journal of Vision*, *7*(6), 1.
Fischer, J. T., & Whitney, D. (2012). Distractor suppression: attention gates visual coding in the human pulvinar. *Nature Communications*.
Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(2), 317–329.
Folk, C. L., Leber, A. B., & Egeth, H. E. (2008). Top-down control settings and the attentional blink: evidence for nonspatial contingent capture. *Visual Cognition*, *16*(5), 616–642.
Fougnie, D., & Marois, R. (2007). Executive working memory load induces inattentional blindness. *Psychonomic Bulletin and Review*, *14*(1), 142–147.
Franconeri, S., Alvarez, G., & Enns, J. (2007). How many locations can be selected at once? *Journal of Experimental Psychology: Human Perception and Performance*, *33*(5), 1003–1012.
Gendolla, G. H., & Richter, M. (2010). Effort mobilization when the self is involved: some lessons from the cardiovascular system. *Review of General Psychology*, *14*(3), 212–226.
Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: a laboratory study. *Psychology and Aging*, *4*(2), 136–143.
Glenberg, A., Schroeder, J., & Robertson, D. (1998). Averting the gaze disengages the environment and facilitates remembering. *Memory & Cognition*, *26*(4), 651–658.
Goldman-Eisler, F. (1967). Sequential temporal patterns and cognitive processes in speech. *Language and Speech*, *10*(2), 122–132.
Grice, G. R., & Gwynne, J. W. (1987). Dependence of target redundancy effects on noise conditions and number of targets. *Perception & Psychophysics*, *42*, 29–36.
Grice, G. R., Canham, L., & Boroughs, J. M. (1984). Combination rule for redundant information in reaction time tasks with divided attention. *Perception & Psychophysics*, *35*, 451–463.

Haberman, J., & Whitney, D. (2009). Seeing the mean: ensemble coding for sets of faces. *Journal of Experimental Psychology: Human Perception & Performance*, *35*(3), 718–734.

Haberman, J., & Whitney, D. (2011). Efficient summary statistical representation when change localization fails. *Psychonomic Bulletin and Review*, *18*(5), 855–859.

Helton, W., & Russell, P. N. (2012). Brief mental breaks and content-free cues may not keep you focused. *Experimental Brain Research*, *219*(1), 37–46.

Hillyard, S. A., & Münte, T. F. (1984). Selective attention to color and location: An analysis with event-related brain potentials. *Perception and Psychophysics*, *36*, 185–198.

Hollingworth, A., Matsukura, M., & Luck, S. J. Visual working memory modulates rapid eye movements to simple onset targets. *Psychological Science*, in press.

Itti, L., & Koch, C. (2001). Computational modelling of visual attention. *Nature Reviews Neuroscience*, *2*(3), 194–203.

Jaensch, E. R. (1929). *Grundformen menschlichen Seins*. Berlin: Otto Elsner.

Kastner, S., O'Connor, D. H., Fukui, M. M., Fehd, H. M., Herwig, U., & Pinsk, M. A. (2004). Functional imaging of the human lateral geniculate nucleus and pulvinar. *Journal of Neurophysiology*, *91*(1), 438–448.

Kim, S., Kim, M., & Chun, M. (2005). Concurrent working memory load can reduce distraction. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(45), 16524–16529.

Kirchner, H., & Thorpe, S. (2006). Ultra-rapid object detection with saccadic eye movements: visual processing speed revisited. *Vision Research*, *46*(11), 1762–1776.

Lachter, J., Forster, K. I., & Ruthruff, E. (2004). Forty years after Broadbent: still no identification without attention. *Psychological Review*, *111*, 880–913.

Lang, P., Bradley, M., & Cuthbert, B. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual.* Technical Report A-8, Gainesville, FL: University of Florida.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*(3), 339–354.

Lavie, N. (2010). Attention, distraction, and cognitive control under load. *Current Directions in Psychological Science*, *19*(3), 143–148.

Lin, J., Franconeri, S., & Enns, J. (2008). Objects on a collision path with the observer demand attention. *Psychological Science*, *19*(7), 686–692.

Lleras, A., & Buetti, S. (2012a). Ocular capture by abrupt onsets is severely reduced during mental arithmetic: evidence against cognitive load theory. *Paper Presented at the 53rd Annual Meeting of the Psychonomic Society*.

Lleras, A., & Buetti, S. (2012b). Where do the eyes go when you think? Away from visually salient information. *Paper presented at the 12th Annual Meeting of the Vision Sciences Society*, Naples, Florida. 12(9), 1261, http://dx.doi.org/10.1167/12.9.1261.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*, 492–527.

Macdonald, J., & Lavie, N. (2008). Load induced blindness. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(5), 1078–1091.

Macdonald, J., & Lavie, N. (2011). Visual perceptual load induces inattentional deafness. *Attention, Perception & Psychophysics*, *73*(6), 1780–1789.

Mack, A., & Rock, I. (1998). *Inattentional blindness*. Cambridge, MA: MIT Press.

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory & Cognition*, *22*(6), 657–672.

Maljkovic, V., & Nakayama, K. (1996). Priming of pop-out: II. The role of position. *Perception & Psychophysics*, *58*(7), 977–991.

Max, R., & Tsal, Y. (2011). Efficient selection is modulated by target-distractor discriminability and not by perceptual load. *Poster presented at the 52nd Annual Meeting of the Psychonomic Society*, Seattle, WA, November 4, 2011.

Max, R., & Tsal, Y. (2012). Exact temporal locus of visual distraction. *Poster presented at the 53rd Object Perception Attention and Memory Workshop*, Minneapolis, MN, November 15, 2012.

McGugin, R. W., Gatenby, J. C., Gore, J. C., & Gauthier, I. (2012). High-resolution imaging of expertise reveals reliable object selectivity in the FFA related to perceptual performance. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(42), 17063–17068.

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning Memory and Cognition*, *35*(1), 196–204.

McVay, J. C., & Kane, M. J. (2012). Drifting from slow to "D'oh!": working memory capacity and mind wandering predict extreme reaction times and executive control errors. *Journal of Experimental Psychology: Learning Memory and Cognition*, *38*(3), 525–549.

Miller, J. (1982). Divided attention: evidence for coactivation with redundant signals. *Cognitive Psychology*, *14*, 247–279.

Miller, J. (1987). Priming is not necessary for selective-attention failures: semantic effects of unattended, unprimed letters. *Perception & Psychophysics*, *41*, 419–434.

Moore, C., & Egeth, H. (1997). Perception without attention: evidence of grouping under conditions of inattention. *Journal of Experimental Psychology: Human Perception and Performance*, *23*(2), 339–352.

Moore, C., Grosjean, M., & Lleras, A. (2003). Using inattentional blindness as an operational definition of unattended: the case of surface completion. *Visual Cognition*, *10*, 299–318.

Moore, C., Lleras, A., Grosjean, M., & Marrara, M. (2004). Using inattentional blindness as an operational definition of unattended: a response-end effect. *Visual Cognition*, *11*, 705–719.

Mordkoff, J. T., & Halterman, R. (2008). Feature integration without visual attention: evidence from the correlated flankers task. *Psychonomic Bulletin and Review*, *15*, 385–389.

Mordkoff, J. T., & Yantis, S. (1991). An interactive race model of divided attention. *Journal of Experimental Psychology: Human Perception and Performance*, *17*(2), 520–538.

Mordkoff, J. T. (1996). Selective attention and internal constraints: there is more to the flanker effect than biased contingencies. In A. F. Kramer, M. G. H. Coles & G. Logan (Eds.), *Converging operations in the study of visual selective attention* (pp. 483–502). Washington, DC: APA.

Most, S., Simons, J., Scholl, B., Jimenez, R., Clifford, E., & Chabris, C. (2001). How not to be seen: the contribution of similarity and selective ignoring to sustained inattentional blindness. *Psychological Science*, *12*(1), 9–17.

Most, S., Scholl, B. J., Clifford, E. R., & Simons, D. J. (2005). What you see is what you set: sustained inattentional blindness and the capture of awareness. *Psychological Review*, *112*(1), 217–242.

Navalpakkam, V., & Itti, L. (2007). Search goal tunes visual features optimally. *Neuron*, *53*(4), 605–617.

Neider, M., & Zelinsky, G. (2011). Cutting through the clutter: searching for targets in evolving complex scenes. *Journal of Vision*, *11*(14).

Neisser, U., & Becklen, R. (1975). Selective looking: attending to visually specified events. *Cognitive Psychology*, 7(4), 480–494.

Neisser, U. (1979). The control of information pickup in selective looking. In A. D. Pick (Ed.), *Perception and its development: A tribute to Eleanor J. Gibson* (pp. 201–219). Hillsdale, NJ: Lawrence Erlbaum.

Nestor, A., Plaut, D., & Behrmann, M. (2012). Orthographic form processing—a multivariate investigation of its neural basis. *Cerebral Cortex*, Cereb. Cortex firxt published online June 12, 2012, http://doi.10.1093/cercor/bhs158.

Norman, D. A. (1968). Towards a theory of memory and attention. *Psychological Review*, *75*, 522–536.

O'Connor, D., Fukui, M., Pinsk, M., & Kastner, S. (2002). Attention modulates responses in the human lateral geniculate nucleus. *Nature Neuroscience*, *5*(11), 1203–1209.

Pashler, H. (1987). Detecting conjunctions of color and form: reassessing the serial search hypothesis. *Perception & Psychophysics*, *41*(3), 191–201.

Peters, R., Iyer, A., Itti, L., & Koch, C. (2005). Components of bottom-up gaze allocation in natural images. *Vision Research*, *45*(18), 1–20.

Purcell, B., Heitz, R., Cohen, J., Schall, J., Logan, G., & Palmeri, T. (2010). Neurally constrained modeling of perceptual decision making. *Psychological Review*, *117*(4), 1113–1143.

Raab, D. H. (1962). Statistical facilitation of simple reaction times. *Transactions of the New York Academy of Sciences*, *24*, 574–590.

Raymond, J., Shapiro, K., & Arnell, K. (1992). Temporary suppression of visual processing in an RSVP task: an attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, *18*(3), 849–860.

Rensink, R. (2000). Seeing, sensing, and scrutinizing. *Vision Research*, *40*(10–12), 1–19.

Scalf, P. E., & Beck, D. M. (2010). Competition in visual cortex impedes attention to multiple items. *Journal of Neuroscience*, *30*(1), 161–169.

Schall, J., Purcell, B., Heitz, R., Logan, G., & Palmeri, T. (2011). Neural mechanisms of saccade target selection: gated accumulator model of the visual-motor cascade. *European Journal of Neuroscience*, *33*(11), 1991–2002.

Serences, J., & Boynton, G. (2007). Feature-based attentional modulations in the absence of direct visual stimulation. *Neuron*, *55*(2), 1–12.

Shapiro, K., Caldwell, J., & Sorensen, R. (1997). Personal names and the attentional blink: a visual "cocktail party" effect. *Journal of Experimental Psychology: Human Perception and Performance*, *23*(2), 504–514.

Shiffrin, R. M., & Gardner, G. T. (1972). Visual processing capacity and attentional control. *Journal of Experimental Psychology*, *93*(1), 72–82.

Silvia, P., McCord, D., & Gendolla, G. (2010). Self-focused attention, performance expectancies, and the intensity of effort: do people try harder for harder goals? *Motivation and Emotion*, *34*, 363–370.

Silvia, P., Jones, H., Kelly, C., & Zibaie, A. (2011). Trait self-focused attention, task difficulty, and effort-related cardiovascular reactivity. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *79*(3), 1–6.

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

Simon, J., Acosta, E., Mewaldt, S., & Speidel, C. (1976). The effect of an irrelevant directional cue on choice reaction time: duration of the phenomenon and its relation to stages of processing. *Perception & Psychophysics*, *19*, 1–7.

Simons, D., & Chabris, C. (1999). Gorillas in our midst: sustained inattentional blindness for dynamic events. *Perception*, *28*(9), 1059–1074.

Simons, D., & Jensen, M. (2009). The effects of individual differences and task difficulty on inattentional blindness. *Psychonomic Bulletin and Review*, *16*(2), 398–403.

Simons, D., & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin and Review*, *5*, 644–649.

Smallwood, J., Obonsawin, M., & Heim, D. (2003). Task unrelated thought: the role of distributed processing. *Consciousness and Cognition*, *12*(2), 169–189.

Smilek, D., Carriere, J. S.A., & Cheyne, J. A. (2010). Out of mind, out of sight: eye blinking as indicator and embodiment of mind wandering. *Psychological Science*, *21*(6), 786–789.

Smith, T., Ruiz, J., & Uchino, B. (2000). Vigilance, active coping, and cardiovascular reactivity during social interaction in young men. *Health psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, *19*(4), 382–392.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied*.

Strayer, D. L., & Drews, F. (2007). Cell-phone induced inattention blindness. *Current Directions in Psychological Science*, *16*, 128–131.

Strayer, D. L., Watson, J. M., & Drews, F. A. (2011). Cognitive distraction while multitasking in the automobile. In B. Ross (Ed.), *The psychology of learning and motivation* (Vol. 54, pp. 29–58). Burlington: Academic Press.

Stroop, J. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662.

Temple, J., Warm, J., Dember, W., Jones, K., LaGrange, C., & Matthews, G. (2000). The effects of signal salience and caffeine on performance, workload, and stress in an abbreviated vigilance task. *Human Factors*, *42*(2), 183–194.

Tinker, M. A. (1925). Intelligence in an intelligence test with an auditory distractor. *American Journal of Psychology*, *36*(3), 467–468.

Torralbo, A., & Beck, D. (2008). Perceptual-load-induced selection as a result of local competitive interactions in visual cortex. *Psychological Science*, *19*(10), 1045–1050.

Townsend, J. T. (1972). Some results concerning the identifiability of parallel and serial processes. *British Journal of Mathematical and Statistical Psychology*, *25*, 168–199.

Trautwein, U., Lüdtke, O., Roberts, B., Schnyder, I., & Niggli, A. (2009). Different forces, same consequence: conscientiousness and competence beliefs are independent predictors of academic effort and achievement. *Journal of Personality and Social Psychology*, *97*(6), 1115–1128.

Treisman, A., & Geffen, G. (1967). Selective attention: perception or response? *Quarterly Journal of Experimental Psychology*, *19*(1), 1–17.

Treisman, A., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97–136.

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

Tseng, Y. C., Glaser, J. I., Caddigan, E., & Lleras, A. *Attentional decision making in pop-out visual search*, Submitted for publication.

von Mühlenen, A., & Lleras, A. (2007). No-onset looming motion guides spatial attention. *Journal of Experimental Psychology: Human Perception and Performance*, *33*, 1297–1310.

Wan, X., & Lleras, A. (2010). The effect of feature discriminability on the inter-trial inhibition of focused attention. *Visual Cognition*, *18*, 920–944.

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: prioritizing selection for new objects by top-down attention inhibition of old objects. *Psychological Review*, *104*, 90–122.

Wenger, M. J., & Townsend, J. T. (2000). Basic tools for attention and general processing capacity in perception and cognition. *Journal of General Psychology: Visual Attention*, *127*(1), 67–99.

Wolfe, J., Alvarez, G., Rosenholtz, R., Kuzmova, Y., & Sherman, A. (2011). Visual search for arbitrary objects in real scenes. *Attention, Perception & Psychophysics*, *73*(6), 1650–1671.

Wolfe, J., Vo, M., Evans, K., & Greene, M. (2011). Visual search in scenes involves selective and nonselective pathways. *Trends in Cognitive Sciences*, *15*(2), 77–84.

Wolfe, J. (1994). Guided search 2.0: a revised model of visual search. *Psychonomic Bulletin and Review*, *1*(2), 202–238.

Woodman, G. F., & Arita, J. T. (2011). Direct electrophysiological measurement of attentional templates in visual working memory. *Psychological Science*, *22*(2), 212–215.

Yantis, S., & Egeth, H. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(3), 661–676.

Yigit-Elliott, S., Palmer, J., & Moore, C. M. (2011). Distinguishing blocking from attenuation in visual selective attention. *Psychological Science*, *22*(6), 771–780.

Young, A. H., & Hulleman, J. (2012). Eye movements reveal how task difficulty moulds visual search. *Journal of Experimental Psychology: Human Perception and Performance.*