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Commentaries on Ruz & Lupiáñez (2002): *A review of Attentional Capture: On its automaticity and sensitivity to endogenous control*.

1. Filter or Disengagement?

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Ruz and Lupiáñez have provided a comprehensive review of the attentional capture research and we agree with their conclusion that attentional capture is automatic by default, but can be modulated by endogenous factors. One such endogenous factor is an attentional control setting, whereby top-down processes largely determine what type of visual events will capture attention. As noted by Ruz and Lupiáñez, there is considerable evidence both for attentional control settings and for the significant impact such settings have on various types of attentional tasks (although there is evidence that, in certain situations, bottom-up processes may largely determine behavior).

Of particular interest to us was the discussion on how attentional control settings operate. In their original work regarding the influence of task demands on attentional capture, Folk and Remington (e.g., Folk, Remington & Johnston, 1992; Folk, Remington & Wright, 1994) conceived the attentional control setting as a filter that allows attention to be captured at locations where a peripheral event (i.e., the cue) shares some critical feature with the task (i.e., the target). Thus, according to Folk and Remington, attention is not allocated to locations where the cue does not share some task relevant feature with the target (see also, Remington, Folk & McLean, 2001).

Recently, Theeuwes and colleagues suggested that attentional control settings are more likely to operate through the rapid disengagement of attention from a cued location (Theeuwes, Atchley & Kramer, 2000). Their

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hypothesis is that any salient cue will reflexively capture attention, but if the cue is not relevant to the task, the attentional control setting will rapidly disengage attention from the cued location and no cueing effect will be found at a short SOA. By manipulating cue-target SOAs, Theeuwes et al. argued that the rapid disengagement of attention occurs approximately 150 ms after the onset of the cue.

We believe there are three recent pieces of evidence from our lab that are more consistent with the rapid disengagement hypothesis of Theeuwes et al. (2000) than the filter hypothesis of Folk and Remington. First, our event-related potential (ERP) results indicated that stimulus-related differences do not become evident over primary visual areas until approximately 165-185 ms post-onset (Arnott, Pratt, Shore & Alain, 2001). During this time, smaller N1 amplitudes were observed when a distractor's features were not target-relevant as compared to when they were relevant. Because this ERP component is related to discrimination processes (Vogel & Luck, 2000), our N1 effects may reflect the relatively early disengagement of attention from a stimulus when it does not share target relevant features. Thus, although a person may be endogenously set to attend to a certain feature, it takes approximately 150 ms before the top-down modulation can override the stimulus-driven capture.

The second piece of evidence comes from the variation of the classic Folk and Remington paradigm (Folk et al., 1992) used by Pratt and McAuliffe (In Press). At the 150 ms SOA, as expected, they found that only uninformative cues that shared a target-relevant feature produced cueing effects. Interestingly, and unexpectedly, when the SOA was increased to 800 ms in order to examine inhibition of return (IOR) effects, IOR was found for onset cues *regardless* of the target defining feature (i.e., whether it was onset or color). In other words, the onset cues produced IOR with targets that were both consistent (onset) and inconsistent (color) with the attentional control setting. Assuming that IOR is produced only after attention has been allocated and then withdrawn from a peripheral location, the results from Pratt and McAuliffe suggest that the onset cues were attended to despite any particular attentional control setting. Overall, these results are consistent with the rapid disengagement hypothesis of Theeuwes et al., whereby salient onset cues are attended to and will therefore produce IOR at long SOAs, but may or may not show cueing effects at short SOAs depending on the attentional control setting.

Thirdly, we are currently testing the disengagement hypothesis by exploiting the phenomenon of attentional repulsion. Attentional repulsion refers to the perceived displacement of a Vernier stimulus in a direction that is opposite to a brief peripheral cue (Suzuki & Cavanagh, 1997). Because the repulsion effect is most evident at cue-target SOAs of less than 200 ms, it is an ideal phenomenon with which to test the disengagement hypothesis. In our study, we altered the attentional repulsion paradigm such that observers were encouraged to adopt an attentional set for a specific color (i.e., were only required to make the perceptual judgements when the Vernier stimuli were 'red'). Our cue display consisted of four simultaneously presented cues (one in each corner of the display) that preceded a Vernier stimuli (100 ms SOA).

Following our example, two of these cues, always diagonally opposite, were colored red. If attention was preferentially attracted to the cues sharing the target-relevant feature like the contingent-orienting hypothesis predicts, we expected to find Vernier judgements shifted in directions opposite to the red cues (i.e., attentional repulsion). Alternatively, if all onset cues initially attract attention as the disengagement hypothesis predicts, we would not expect to find the repulsion effect. In accordance with the disengagment hypothesis we did not find the repulsion effect, suggesting that attention had not yet been disengaged from those cues sharing the 'irrelevant' target features.

Although we have presented three recent pieces of evidence favoring the disengagement hypothesis of Theeuwes et al., it is important to note that there is also evidence favoring the filter hypothesis of Folk and Remington (e.g., Remington et al., 2001). Given the impact that attentional control settings have on the manner in which our attention is allocated in the visual field, it will be important for future research to determine exactly how attentional control settings operate.

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2. Can attention capture visual awareness?

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In their scholarly and useful review of the literature on attentional capture, Ruz & Lupiáñez conclude that attentional capture is largely automatic process, because it occurs "by default", in the absence of a specific strategic set, but can be endogenously modulated. In this commentary I will try to interpret evidence from brain-damaged patients with unilateral neglect as resulting from an asymmetry of functioning of processes related to attentional capture, and to propose an important role of these processes in visual awareness.

Left unilateral neglect is a neurological condition occurring after damage to the posterior part of the right hemisphere. Neglect patients live in a halved world, being unable to orient or respond to left-sided events. They bump into furniture on their left side, do not eat from the left part of the dish, and do not answer to people standing on their left. In contrast, they show a pathological, "magnetic" attraction toward right-sided objects. Their attention seems to be captured rapidly and compulsively by right-sided objects, even when these are irrelevant to the current task. For example, in clinical examination, when the examiner briefly moves the fingers of either or both hands in patients' visual fields in order to test for visual field defect, neglect patients often compulsively look at the hand on their right as soon as it appears in their visual field, before the actual administration of stimuli (Gainotti, D'Erme, & Bartolomeo, 1991). Another example comes from the line cancellation task, in which patients are presented with a sheet containing several lines and asked to draw over all of them with a pencil mark. Neglect patients often omit to cancel left-sided lines. In an ingenious variant of this task, neglect patients had to draw over lines or to erase them, and showed fewer omissions in the 'erase' than in the 'draw' condition (Mark, Kooistra, & Heilman, 1988). This pattern of results suggests that right-sided lines attracted patients' attention when they were crossed by a pencil mark, whereas rendering these lines invisible by erasing them obviously nullified this effect, thus decreasing neglect. In a Posner-type reaction time task, the mere appearance of the bilateral placeholder boxes was capable of further slowing patients' response latencies for left targets (as compared to a condition without boxes), as if the right-sided boxes attracted patients' attention before the actual targets appeared (D'Erme, Robertson, Bartolomeo, Daniele, & Gainotti, 1992). Taken together, these results strongly suggest that a crucial

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disorder in left neglect is a spatial asymmetry of processes involved in exogenous orienting of attention (Bartolomeo & Chokron, 2002). What can be the functional basis of this bias? A first hypothesis could be that left neglect stems from a disordered mental representation of the left half of space (see, e.g., Bisiach, 1993), such that left-sided objects have a lesser power to attract attention, perhaps as a result of being less perceptually salient than their right-sided counterparts. However, there seems to be no rigid boundary between left (neglected) and right (non-neglected) space in left neglect; rather, patients' performance seems to follow a left-to-right spatial gradient; even in the right, non-neglected space their performance is better for (relatively) right-sided items than for (relatively) left-sided items (Kinsbourne, 1993; Làdavas, Petronio, & Umiltà, 1990). Indeed, Marshall and Halligan (1989) reported that targets could be omitted in a shape cancellation task independently of their position with respect of the midsagittal plane, and concluded that 'right attentional capture' might be a better description of patients' performance than 'left neglect'.

Thus, one can imagine that in neglect a directional (rather than hemispatial) asymmetry of processes involved in attentional capture, with capture form right-sided events being easier and/or faster than capture form left-sided events, is at work. It is beyond the scope of this commentary to discuss the issue of whether this asymmetry results from an excessive facilitation for rightward orienting (see, e.g., Kinsbourne, 1993), or a deficit of leftward orienting (e.g., Heilman, Watson, & Valenstein, 1993; Riddoch & Humphreys, 1987), or both (see Bartolomeo & Chokron, 1999, for data and discussion relevant to this issue). What is of interest here is that an attentional bias primarily affecting exogenous orienting can lead to a dramatic lack of awareness for a huge portion of the patients' space. This is reminiscent of situations in which normal individuals show (less dramatic) forms of unawareness for perceptually salient stimuli, as in the "change blindness" experiments (recently reviewed by O'Regan & Noë, 2001), and suggests that processes underlying attentional capture, such as exogenous orienting of attention, are necessary for our phenomenal awareness of the visual world (Bartolomeo & Chokron, in press). It is an interesting possibility that research on attentional capture may eventually shed light on the mechanisms of visual awareness.

Ruz & Lupiáñez review evidence suggesting that attentional capture can be modulated by top-down processes, such as those related to the subjects' goals and strategies. Can neglect patients use these processes to compensate for their neglect? The answer seems to be yes, but has to be further qualified. First, it is well known that a number of patients clinically recover from neglect, either spontaneously or after rehabilitation. Evidence suggests that these patients in fact learn to compensate for an early right attentional capture with a later leftward orienting (Bartolomeo, 1997; Mattingley, Bradshaw, Bradshaw, & Nettleton, 1994), perhaps through the use of an active inhibition for right-sided items (Bartolomeo, 2000). Second, also patients with chronic neglect are able to exert some top-down control on their attentional orienting (Bartolomeo, Siéroff, Decaix, & Chokron, 2001; Duncan et al., 1999; Làdavas, Carletti, & Gori, 1994; Smania et al., 1998). Perhaps they can do so only in a narrow experimental set, and not in real life, because their endogenous orienting processes are too slow to cope with the ever-changing visual environment of everyday life (Bartolomeo et al., 2001). Thus, (relatively) preserved endogenous processes are apparently insufficient for a full awareness of the visual environment, if attentional capture is laterally biased. Further research on unilateral neglect, perhaps employing some of the clever experimental paradigms reviewed by Ruz & Lupiáñez, may shed further light on attentional capture and on its relationships with visual awareness.

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3. Modulability does not undermine the stimulus-driven nature of attentional capture

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In the following paragraphs, we will argue that although many studies reviewed by Ruz and Lupiáñez clearly show that a top-down modulation plays an important role in determining the location to which attention will be deployed, attentional capture is stimulus-driven in nature. We agree with the authors' claim that the endogenous component is much more relevant than was hypothesised by early works in the field, but we will discuss data showing that, under some critical conditions, it is possible to observe a purely stimulus-driven attentional deployment, that is attentional capture by an item characterised as being a salient singleton in a task-irrelevant feature dimension.

Criteria for defining a purely stimulus-driven attentional capture.

In our view (Turatto & Galfano, 2001; also see Yantis, 1993), the conditio sine qua non for defining a purely stimulus-driven attentional capture is that the investigated feature must be completely irrelevant to the task at hand. In order to rule out any top-down effects, there are two main criteria to be met:

1) The target defining attribute(s) must be clearly and totally independent of and dissociated from the feature dimension of the irrelevant singleton.

2) In a visual search paradigm with multiple-items displays, participants must perform the task at hand by means of a Feature Search Mode (FSM); that is, their attentional set must be restricted to the target defining attribute(s). As reported by Ruz and Lupiáñez, Bacon and Egeth (1994; also see Lamy & Tsal, 1999) proposed a distinction that has proved to be very useful in clarifying some apparently contradictory results emerged in the literature. Specifically, they showed that results from previous studies taken as evidence for stimulus-driven capture, were obtained under conditions where participants

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were allowed (e.g., Theeuwes, 1992) or even coerced (Pashler, 1988) to perform the experimental task by means of a Singleton Detection Mode (SDM), a 'search for the discrepant element, whatever it is' strategy. This strategy implies that participants have a broad attentional set that not only includes the target defining features, but also the singleton features. Under such conditions, any result showing that the presence of the singleton item affected performance cannot be said to show a purely stimulus-driven phenomenon, since the adoption of an SDM makes the singleton relevant somehow. One possibility to make an SDM ineffective and to force participants to adopt an FSM is to use a very inefficient visual search task (Wolfe, 1998) in which the target does not pop-out from the background, which means that all attentional resources must be focused on the target defining attributes. Reformulated in the perceptual load hypothesis (Lavie, 1995) framework, this criterion would state that a real stimulus-driven attentional capture might be said to occur under conditions of high perceptual load only.

In the next paragraph we report evidence from studies whose experimental conditions were as such as to fully conform to both the criteria discussed above.

The peril of relying on null results: Evidence that attentional capture is not always contingent.

Evidence have been discussed by Ruz and Lupiáñez that would confirm the view that not all visual properties are equally effective in capturing attention. We agree with this point as long as attentional capture is not considered as an 'all-or-none' phenomenon. We believe that the general distinction of visual features in static and dynamic (see, e.g., Folk, Remington, & Johnston, 1992) has both a theoretical and an empirical validity. In fact, many studies have shown that a task-irrelevant onset singleton is able to attract attention to its location (Yantis, 1998). As Ruz and Lupiáñez have pointed out, the fact that abrupt visual onsets receive a high attentional priority might rely on two different sub-properties characterising this kind of stimuli: an abrupt luminance change and/or a new object status (Yantis & Hillstrom, 1994). The relevant fact, in our opinion, is that whereas static discontinuities (stimuli that vary along space) such as those produced by the manipulation of colour, form, or luminance did not prove to capture attention automatically, dynamic discontinuities (stimuli that vary along both space and time) such as abrupt onsets do show a clear stimulus-driven attentional capture (e.g., Jonides & Yantis, 1988). This result by itself allows one to argue that employing the classic display-size method to assess the phenomenon, a stimulus-driven capture emerges only if the task irrelevant singletons are abrupt onsets. The observed lack of evidence for stimulus-driven attentional capture by static discontinuities, however, does not necessarily speak against the possibility that salient task-irrelevant singletons in the colour or shape feature dimensions grab attention involuntarily. What Jonides and Yantis' results say is simply that abrupt onsets receive a stronger bottom-up attentional priority (Yantis &

Johnson, 1990), clearly detectable by the display-size method. This, by itself, does not rule out the possibility that by using a more sensitive method, a stimulus-driven attentional capture might emerge even for stimuli characterised as being irrelevant static singletons. In fact, any claim based on a null result can say very little about the nature of the attentional capture phenomenon.

This idea has motivated many subsequent studies in pursuing stimulus-driven attentional capture by static discontinuities by employing different stimulus arrays from those used by Jonides and Yantis (e.g., Folk & Annett, 1994; Todd & Kramer, 1994; Yantis & Egeth, 1999), and, more importantly, different methodologies for assessing attentional capture (e.g., Gibson & Jiang, 1998). The null result relying on the lack of stimulus-driven attentional capture by static discontinuities was replicated in all the above cited studies. However, recent evidence has been reported that jeopardises the claim that static discontinuities are not able to grab attention in a purely bottom-up manner. Theeuwes and Burger (1998; also see Theeuwes, Atchley, & Kramer, 2000), using the method termed 'Identity Intrusion' based on the 'Additional singleton' paradigm (Simons, 2000), showed that, in a letter search task where participants were to decide which of two possible targets was present in a background of distractor letters, an irrelevant singleton colour distractor that was never the target affected performance producing a significant decrease in RTs when the singleton distractor identity was compatible with the target letter compared to when the singleton distractor identity was incompatible with it. This result was taken as evidence that the irrelevant colour singleton captured attention in a stimulus-driven manner. This interpretation accounts for the compatibility effect and is supported by two considerations. First, the colour singleton was never the target. Second, the letter search task proved to engage participants in an inefficient search (i.e., steep slopes in RTs plotted as a function of display size). Thus, both criteria indicated above for defining a stimulus-driven attentional capture are met. Moreover, the presence of a compatibility effect rules out the possibility that the results are accountable in terms of a filtering cost (Folk & Remington, 1998) rather than in terms of a spatial shift of attention.

In a more recent paper, we (Turatto & Galfano, 2000) have shown that a processing advantage for when the target appears at the singleton (an irrelevant unique item in colour, form, or luminance) location can be observed using a procedure we called the 'Distance method'. Our method adopts the logic of the 'Irrelevant feature search' paradigm (Simons, 2000), and has the advantage of requiring a single display size, with a fixed number of elements. In our study, participants were looking for the presence or absence of a vertical line segment (the target) embedded among variously tilted distractor segments. Line segments were presented inside shapes, whose features were manipulated to create the irrelevant singleton (also see Theeuwes, 1992). The target, when present, appeared at the singleton location in 1/n of target present trials (where n is display-size). Participants were more accurate in finding the target when it appeared inside the singleton element than when it appeared in the more accurate of the non singleton locations. As target defining attributes forming participants' attentional set concerned orientation (and not colour, shape, or luminance), we clearly met the first criterion for defining a stimulus-driven capture. The steep slopes observed in a similar search task with no singleton in which we varied display-size, ensured us that the task was very resource-demanding (i.e., a non-efficient search) thus allowing for reasonably ruling out the possibility that participants performed the task by means of an SDM. In another paper (Turatto & Galfano, 2001) where colour was the only investigated feature, we have replicated this finding with a T-L task (leading to a non efficient search: Wolfe, 1998) and RTs as the main dependent variable. Crucially, we have included a no-singleton condition mixed with singleton trials in the same block, and we have observed that participants were faster in finding the target when it was at the singleton location than the no-singleton condition. This result favours an interpretation in terms of spatial capture and definitely rules out the possibility of explaining the singleton-advantage pattern as a filtering cost (see Turatto & Galfano, 2001).

Ruz and Lupiáñez argue that our results may be interpreted as evidence of an attentional misguidance effect (see Todd & Kramer, 1994) rather than as evidence of stimulus-driven attentional capture. The attentional misguidance hypothesis applies to the 'Irrelevant feature search' paradigm and claims that participants may decide to start the search from the singleton location, which would act as a sort of landmark. In this view, any benefit shown by the singleton would be the consequence of the adoption of a specific search strategy, and therefore could be accounted for by invoking the involvement of a top-down component. We do not agree with this interpretation of our data on the basis of the fact that our experimental procedure fully met the criteria for defining a purely stimulus-driven attentional capture. Moreover, in a more recent paper (Turatto, Galfano, Gardini, & Mascetti, 2001), we have provided evidence that rules out this alternative explanation of our previous data. In fact, by comparing the sensitivity of the classic display-size method against that of our distance method, we obtained evidence for stimulus-driven attentional capture by colour in the distance method only, thus replicating the findings of Jonides and Yantis (1988). This result not only shows that the display-size method is less powerful than the distance method in detecting attentional capture, but also rules out any alternative account of our previous findings (Turatto & Galfano, 2000; 2001) in terms of attentional misguidance. In fact, as this hypothesis assumes that our participants strategically decided to begin the search from the salient item, one would have expected the attentional capture pattern to emerge in both the display-size method and the distance method. Because only the distance method was able to show evidence for such phenomenon, we can safely assume that the singleton was effectively not treated by participants as a landmark from which to start the visual search task. This means that no relevant top-down component affected the results, and that stimulus-driven control was therefore present in isolation.

In a rather different perspective from that of the typical paradigms used in the attentional capture literature, Stolz (1996) has tested the widely accepted implicit view that exogenous orienting represents an encapsulated system impervious to high-level cognitive influence. According to Posner (e.g., Posner & Petersen, 1990), there are three operations involved in orienting of attention: engage, move and disengage. In the terminology used by the spotlight metaphor, the engage operation would correspond to attentional capture. Stolz (1996, Experiments 2 and 5) used a variant of the classical spatial cueing paradigm where she had a word at the fixation location and a word acting as the non-informative cue for the target location. Participants were required to perform a discrimination task on the target. The crucial manipulation was that the cue was semantically related to the fixation word on half the trials and unrelated to it in the other half. Besides the classic validity effect, the results showed that the semantic relationship between the fixation word and the cue impaired performance in invalid trials only. This implies that the semantic status of the cue influenced its ability to hold attention at the cued location. The interference effect has been interpreted to take place at either the move or disengage stages and, crucially, not at the engage stage, as no effect of semantic relatedness was detected in valid trials. In sum, this pattern of results is consistent with the notion that, on valid trials, the cue captured attention and that attentional capture is impervious to high-level influences (see Pylyshyn, 1999 for a detailed discussion concerning the impenetrability of perceptual processes determining where attention will be deployed).

Evidence supporting this position also comes from the results of a study by Theeuwes et al. (2000; also see Theeuwes & Godijn, 2001), who were interested in investigating the time course of stimulus-driven and goal-directed processes in controlling visual attention. By varying the SOA between the onset of an irrelevant singleton and the onset of the target, these researchers showed that top-down control is able to suppress stimulus-driven capture only if participants are given enough time before target presentation (also see Kim & Cave, 1999; 2001). Specifically, their findings are consistent with the notion that top-down control does not operate at the level of early visual processing and does not literally override bottom-up capture, but works speeding up the operation of disengaging attention from the irrelevant singleton location instead. This interpretation would also disentangle the reason for why Folk et al. (1992) could not find evidence for stimulus-driven capture either by a colour or an abrupt onset singleton using the spatial cueing paradigm. In fact, in those experiments, the SOA between the onset of the irrelevant cue and the onset of the search display was 150 ms. As noted by Theeuwes et al. (2000), by the time the search array was presented in the Folk et al. study, participants may have been able to disengage spatial attention from the location of the cue and to move the attentional focus over the location of the target. This interpretation is also consistent with the finding of a stimulus-driven attentional capture in our previous studies (Turatto & Galfano, 2000; 2001; Turatto et al., 2001), where a 0-ms SOA between the onset of the irrelevant singleton and the onset of the target was employed. It is important to note that the study of Theeuwes et al. (2000; also see Kim & Cave, 1999) is susceptible of an SDM criticism. In fact, the procedure employed did not ensure that participants used an FSM to find the target, since the target always appeared inside a relevant shape singleton (as in Theeuwes, 1992). However, the modulation of attentional capture shown along the different SOAs, allows one to assume that the bottom-up activation produced by the 'irrelevant' colour singleton was stronger than the activation of the top-down component produced by the template matching process.

The importance of saliency in visual behaviour.

Further contributions attesting the relevance of saliency and bottom-up processes in human behaviour have been provided from other research fields, such as neurophysiology or psychophysics. For example, Constantinidis and Steinmetz (2001) recorded activity from single neurons in area 7a of the Posterior Parietal Cortex, known to play a crucial role in orienting of spatial attention and observed that, in a spatial multiple-stimulus display version of the match-to-sample task, responses to salient odd-coloured targets were enhanced. Clearly, this result does not represent evidence for a stimulus-driven capture by colour, as colour was the target defining attribute. However, the pattern emerged testifies the importance of saliency in controlling visual processing. The relevance of saliency has also emerged in a series of psychophysical studies conducted by Nothdurft (e.g., 1993; 2000a; 2000b). For example, Nothdurft (2000a) showed that performance in responding to a singleton target was significantly enhanced when the target was a singleton in two feature dimensions compared to when it was a singleton in only one feature. As in the case of the Constantinidis and Steinmetz (2001) study, this result is no way evidence for stimulus-driven capture, but shows that saliency per se relevantly affects visual performance. Evidence that bottom-up processes are important in visual processing has also been provided both in conjunction searches (Sobel & Cave, in press) and in the context of a recently discovered phenomenon strongly related to the attentional capture research field, that is Change Blindness (Simons, 2000). This latter effect refers to the observation that repeated changes between scenes often go unnoticed for a surprisingly long time (see, e.g., Turatto, Angrilli, Mazza, Umiltà, & Driver, 2002). In particular, Scholl (2000) has reported evidence that salient items, even when they are uncorrelated with the loci of change, show a dramatic decrease in change blindness. This pattern of results has been interpreted as evidence that the salient elements (late-onset items and colour singletons) captured attention in a stimulus-driven fashion therefore producing an attenuated change blindness effect.

Finally, many computational models of visual attention make the clear prediction that a salient, although task-irrelevant singleton, would draw attention on its location (e.g., Cave, 1999; Cave & Wolfe, 1990; Itti & Koch, 2000; Koch & Ullman, 1985; Li, 2002; Niebur & Koch, 1998; Parkhurst, Law, & Niebur, 2002; Wolfe, 1994). The recent evidence showing purely stimulus-driven attentional capture give a critical empirical support to these models.

Conclusion

In sum, we do not put into question the fact that endogenous factors play a crucial role in determining attentional control. Our view is rather that, saliency is also relevant and if early studies were unable to show a purely stimulus-driven capture of attention by static discontinuities (i.e., discontinuities in feature dimensions whose ecological priority is less prominent than that of abrupt visual onsets, Yantis & Johnson, 1990), this does not mean that the bottom-up component plays no role in controlling the deployment of visual attention. In this commentary, based on previous proposals (e.g., Yantis, 1993; Bacon & Egeth, 1994), we have suggested some criteria to investigate stimulus-driven attentional control in isolation. As a matter of fact, evidence from our and other labs (e.g., Turatto & Galfano, 2000; 2001; Turatto et al., 2001; Kim & Cave, 2001; Scholl, 2000; Theeuwes & Burger, 1998) has appeared in the literature that shows that stimulus-driven attentional capture by static singletons does indeed take place. We emphasise that this growing evidence has been collected by carefully conforming to both the criteria discussed above.

The null effect reported by previous studies is attributable either to the low sensitivity of the employed experimental paradigms (e.g., Jonides & Yantis, 1988) or to the adoption of the inappropriate temporal parameters (e.g., Folk et al., 1992), whereas the debate concerning the earlier evidence for the phenomenon (see e.g., Bacon & Egeth, 1994; Lamy & Tsal, 1999; Pashler, 1988; Theeuwes, 1992) raised from the difficulty in studying the bottom-up component in isolation.

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4. The relationship between attentional capture and awareness

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The target article by Ruz and Lupiáñez (R&L) is a state of the art review on attentional capture. In this commentary we address the relationship between attentional capture and awareness. Although this issue was not addressed by R&L we feel it is an important issue that requires some elaboration. In everyday life we have the subjective impression that we are consciously aware of what captures our attention. However, the question may be asked whether events that capture attention always reach our awareness. This is an important issue, since awareness has been used in so-called inattentional blindness studies as an indicator of attentional capture. For example, in Mack and Rock (1998) participants were required to judge whether the horizontal or vertical arm of a cross was longest. On a single critical trial an additional object appeared simultaneously with the cross and after responding to the cross participants were asked whether they noticed anything that had not been present on the previous trials. Participants often failed to report the additional object even when it had a different color or when it moved during the trial. Findings from inattentional blindness studies are typically interpreted as evidence that unexpected salient events often do not capture our attention (e.g. Mack & Rock, 1998). However, this measure of attention is different from the measures that are typically used in attentional capture studies. As indicated by R&L attentional capture is typically inferred from response time differences between conditions with and without irrelevant distractors. When a task-irrelevant distractor increases the time to respond to a target it is assumed that it captured attention. R&L refer to two studies that show that objects that affect reaction times, indicative of attentional capture, do not necessarily reach awareness (McCormick, 1997; Danziger et al., 1998). Further evidence for a dissociation between attentional capture and awareness comes from the oculomotor capture paradigm (e.g. Theeuwes et al., 1998; 1999). In this paradigm participants are required to execute an eye movement to a uniquely colored target circle and to ignore the onset of a new circle. The results of Theeuwes et al. (1998; 1999) revealed that onsets not only captured attention, but also the eyes. Despite the fact that after the eye movement to the onset the eyes often had to move in a completely different direction to reach

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the target, participants were often not aware that the onset affected their eye movement behavior (see Mokler & Fischer, 1999 for similar results). Thus, not only are participants often unaware of the presence of unexpected salient objects (e.g. Mack & Rock, 1998), when they are informed about the salient event they are often not aware of the detrimental effects it has on their behavior.

Although awareness and attentional capture can be dissociated, objects that capture our attention often do reach our conscious awareness. It is important to develop an understanding of the relationship between attentional capture and awareness. Under what conditions does attentional capture lead to awareness? Even though R&L do not address this issue, it is important to develop a framework for understanding the relationship between attentional capture and awareness, since it would allow an integration of implicit measures of attentional capture (e.g. reaction time measures) and explicit measures (awareness) of attentional capture (e.g. Simons, 2000).

Most and Simons (2001) developed a preliminary framework for understanding attentional capture based on Neisser's (1967) concept of perceptual cycle. According to Neisser perception is a gradual process consisting of repeated cycles of visual exploration. When a salient object appears in the visual environment it may capture attention, or in terms of Most and Simons' model, it may lead to a transient shift of attention. Each transient shift of attention has the potential to alter the ongoing perceptual cycle, or alternatively, it may trigger a new perceptual cycle. When this occurs attention is sustained on the object ultimately resulting in conscious awareness. Whether objects enter the perceptual cycle depends on the strength of the signal (i.e. its salience) and its consistency with the adopted attentional set. Most and Simons further distinguished between implicit attentional capture and explicit attentional capture. Implicit attentional capture refers to the initial transient shift of attention, which may affect behavior, but does not necessarily lead to conscious awareness. Explicit attentional capture refers to the sustained attention that occurs when an object enters a perceptual cycle and leads to conscious awareness. In this framework the relationship between attention (and attentional capture) and awareness is clear. Awareness requires attention, but (implicit) attentional capture does not necessarily lead to awareness.

The distinction between transient and sustained shifts of attention is most likely related to the speed of attentional disengagement. When disengagement is relatively fast we may classify this as a the transient shift of attention that is not sustained. On the other hand when disengagement is relatively slow (for example, when the object that captured attention is similar to the target), the transient shift of attention is followed by sustained attention. Thus, when disengagement is fast it is likely that the object that captured attention will not reach awareness, but it may still affect behavior. When disengagement of attention is slow it is likely that the object does reach awareness.

The speed of disengagement may play an important role in explaining why there appears to be no evidence for capture in spatial cueing tasks as used by Folk et al. (1992) when the cue does not match the task-relevant properties of the target, while salient distractors in the additional singleton paradigm used by Theeuwes (e.g. 1991, 1994,1995) always appear to capture attention. As argued before (Theeuwes et al. 2000; Theeuwes & Godijn, 2001), in the spatial cueing paradigm there is a delay between the to be ignored cue and the search display. It is quite feasible that when the cue does not match the target, attention is captured by the cue, but the transient shift of attention is not followed by sustained attention and disengagement is fast. However, when the cue matches the target, a sustained shift will occur that does not result in fast disengagement of attention. Only in the latter condition (i.e., when the cue matches the target) it would seem that there is attentional capture, while in fact there is also attentional capture when the cue does not match the target; yet by the time the search display appears, attention has already been disengaged from the cue location and performance is not affected by the cue.

We believe that the study of attentional capture will benefit from a detailed examination of the relationships between attentional capture, speed of disengagement and conscious awareness. This will not only allow a better understanding of attentional processes, but it would provide a basis for integrating results from different tasks such as the additional singleton task (e.g. Theeuwes, 1994; 1995), the pre-cueing task (e.g. Folk et al., 1992) and the inattentional blindness task (e.g. Mack & Rock, 1998).

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5. On ecological requirements and possible mechanisms underlying attentional capture

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Ruz & Lupiáñez (2002) review an important part of the recent literature on attention which in my view expresses a paradigmatic shift. In the past, most attentional research was focused on stimulus driven attentional control, which corresponded to the general S-R orientation of Cognitive Psychology. Ulric Neisser (1967, p.4) in his influential book "Cognitive Psychology" stated that „....the term cognition refers to all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used". Thus, cognitive processes were considered as being determined mainly by the sensory input. In the last ten years, however, it became increasingly acknowledged that intentionally driven executive processes strongly influence stimulus processing. In attentional research this view is substantiated by the reviewed evidence that the impact of distracting stimuli is at least modulated if not determined by what the subject is voluntarily trying to attend (cf. also Pashler, Johnston, & Ruthruff, 2001). In the present comment I will speculate about ecological requirements and possible mechanisms that may underly this interplay between stimulus driven and voluntarily driven attentional capture.

1. Humans are multipurpose "devices". Accordingly, they are equipped with both a terribly flexible behavioral apparatus and sensory systems that are sensitive to millions of differences in external and internal states as well. However, there is a fundamental discrepancy between behavior and perception: Whereas at any given moment the behavioral output is usually restricted to one single act or one single task, the senses simultaneously provide information about countless states and their current changes. Thus, at any moment the senses provide much more information than needed in order to appropriately perform an ongoing action or to accomplish a current task. To deal with this problem, mechanisms have evolved that selectively facilitate the impact of only those stimuli on behavior that are currently behaviorally relevant.

On the other hand, to allow only stimuli that are currently relevant to influence behavior entails the risk to overlook imminent dangers or to miss more profitable options. Thus, any organism is well advised to remain

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sensitive for changes of the current situation despite concentrating on an ongoing action or task. For example, animals who ignore the appearance of a predator while feeding, would hardly survive and are unlikely to be found among our evolutionary ancestors. Thus, it is reasonable to assume that the evolved mechanisms are somehow able to manage a balance between facilitating the impact of currently relevant information in order to maintain an intention and continously monitoring the environment for potentially significant information on the other hand (Hoffmann, 1993; Goschke, 2002).

2. In vision currently relevant stimuli are selected by fixation, i.e. by directing the eyes so that the target stimulus falls in both eyes on the region with the greatest acuity, the fovea. But in order to do so, the "mind" has to know how exactly they eyes are to be moved. As this depends on the ever-changing locational relation of the head to the target, the necessary eye movements are almost never prespecified. Under these conditions it would be advantageous if a target would attract the gaze as soon as it appears in the visual field, so that a parafoveal target would automatically trigger eye movements that result in its fovealisation. For such a mechanism to work it is mandatory to assume that the visual effects of the target are in some way specified before the target is fixated. Otherwise it is impossible to see how targets could attract fixation. In other words, it is to be assumed that searching for a visual target includes anticipating its visual effects.

Intuition agrees with this consideration. If we look for our glasses, for a certain book, for the home keys, etc., we have a more or less vivid mental image of how the objects we are searching for looks like. Besides intuition, several theoretical conceptions also argued this way. For example Pillsbury (1908, cited after Pashler, 1999) stated: "Searching for anything consists ordinarily of nothing more than walking about the place where the object is supposed to be, with the idea of the object kept prominently in mind, and thereby standing ready to facilitate the entrance of the perception when it offers itself." Likewise Ach (1913, 1935) speculated that repeatedly performing a certain action leads to the formation of what he called "Bezugsvorstellung" (referential image), so that the intention to perform this particular act again goes along with anticipating the relevant initial stimulation to which the action has been successfully performed in the past. In the same context Lewin (1928) argued that task relevant objects obtain what he called "Aufforderungscharakter" (stimulative nature, cf. also the concept of 'affordances' coined by Gibson, 1979).

More recently, Duncan & Humphreys (1989) stated that visual search bases on "… matching input descriptions against an internal template of the information needed in current behavior" (p.444), whereby they considered a template as being "…an advance specification of the information sought." (p.446). Finally, Pashler (1999) mentioned in his insightful book on attention a finding that explicitely makes the point that an actually evoked mental image affects attention: Participants were requested first to form a vivid image of a concept like 'fish' or 'swimming pool'. Having done so, they started rapid sequential presentations of pictures in order to search for a digit interpolated among the pictures. If one of the pictures in the series met the precedingly evoked image it produced an "attentional blink" effect, i.e. detection of the digit was impaired if it was presented shortly after the critical picture. The finding suggests that participants "…adopted a set to detect whatever they had just formed an image of" (Pashler, 1999, p.249).

3. The readiness to perform an action or to accomplish a certain task seems to evoke anticipations (images, 'Bezugsvorstellungen', templates) of experientially relevant initial conditions. Stimuli that correspond to the anticipations presumably result in stronger activations than competing stimuli simply because the to be evoked representations are already partially activated in advance. If it is furthermore assumed that the relatively strongest activations automatically attract the gaze and by this attention, anticipations appear as a proper mechanism to selectively facilitate processing of relevant stimuli. Correspondingly, the efficiency of visual search should depend on the interplay between the quality and strength of current anticipations and the features of targets and distractors:

First, anticipations are task related, i.e. they are determined by the requirements of the given task. Accordingly, the attentional effects of the very same stimuli depend on the current task. For example, in an experiment by Kahneman, Treisman, & Burkell (1983) participants searched for a word in white letters among nonsense strings of colored letters. If the target word was merely to be detected it "popped out". But if the target word was to be read, search was serial. Hoffmann and Grosser (1985) manipulated target anticipations simply by naming the to be detected targets at different levels. Participants searched for target objects in displays with a varying number of pictured objects. The to be searched objects were among others indicated as being a member of a subordinate or a primary concept. For example, participants either searched for a birch or a tree in a display in which the only tree was a birch. Search was more efficient if participants searched for primary concepts than for more concrete categories (cf. also Hoffmann, Grosser, & Klein, 1987). In order to take an example from another domain, Durgin (2000) reported that in a Stroop task the interference caused by the incongruent color of a color word substantially increased if participants were required to move the cursor to a field of the designated color instead of naming the word as usually required.

In all these studies, the attentional effects of very the same stimuli were modulated by the requested task, which supports the general notion that the "functional defining attributes" (Duncan, 1985) by which the search was guided depend on task related anticipations. Participants who are ready to respond to a white string presumably anticipate (search for) merely a white string wheras participants who are ready to read the target word anticipate a word like stimulus. Likewise, searching for a tree evokes the image of a tree whereas searching for a birch evokes the more detailed image of a birch. And, participants who are ready to move a cursor to one of differently colored fields presumably keep in mind the images of these 'goal-colors'. If the to be detected target is the only (parafoveal) stimulus which meets the anticipation (as in the case of a white string or a tree), search is efficient and responses are fast. If, however, the target needs fixation in order to meet the anticipation (as in the case of a birch) or if distracting stimuli also meet the anticipation (as in the search for a word amongst letter strings or in the case of colored color words) serial search is needed and responses are delayed.

Second, within a given task set, the task related anticipations seem to adapt to the variety of the experienced targets. A recent finding of Kunde, Kiesel, & Hoffmann (submitted) may be taken to illustrate this point: Participants were requested to decide as fast as possible whether a presented digit is smaller or larger than 5. The presentation of the target digits was preceded by subliminal (masked) presentations of other digits. It is known that subliminal stimuli, despite not being consciously recognized, can nevertheless prime assigned responses, so that congruent primes accelerate and non-congruent primes decelerate the responses to the succeeding targets (e.g. Dell'Acqua, & Grainger, 1999; Klotz, & Neumann, 1999; Neumann, & Klotz, 1994; Wolff, & Rübeling, 1994). Kunde, et al. (submitted) extended these findings by showing that the congruency effect for particular primes depended on the range of the used targets. If, for example, participants exclusively responded to the targets 1, 4, 6, and 9, the primes 2 and 8 produced a congruency effect. If, however, only the digits 3,4, 6, and 7 were used as targets, the primes 2 and 8 remained without any influence on RTs. In other words, subliminal primes seem to affect response initiation only if they belong to the range of the expected targets (cf. also Damian, 2001). This and related findings suggest that participants learn to adapt their target expectations (anticipations) to the experienced range of targets (either 1 to 4 versus 6 to 9 or 3/4 versus 6/7) and that subliminal primes affect the initiation of the forthcoming responses only insofar as they meet the response related target anticipations.

Third, if targets are to be distinguished from distracting stimuli, as it is always the case in visual search, the task related anticipations seem to adapt not simply to the target set but rather to the most simple features that allow a reliable distinction of target and non-target displays. The "homogeneity coding" hypothesis by Duncan & Humphreys (1989) provides an illustrative example for such an adaptation. When participants repeatedly searched for a target letter among homogenous distractors, the targets not only "popped out" but responses to non-target displays were faster than to target displays. The authors accounted for this unusual finding by assuming that participants developed a readiness to respond to the global homogeneity of the non-target displays instead of responding to the local presence of a target. The "singleton search strategy" hypothesis by Bacon and Egeth (1994), mentioned in the review, is completely in line with this argumentation. In both hyotheses it is assumed that participants start to search for (to respond to) an unspecific feature although the specific target is known, presumably because it is less demanding as well as more efficient to rely on an unspecific feature of the whole display than to anticipate a concrete target (cf. also Egeth, Folk, Leber, Nakama, & Hendel, 2001).

In sum, the search for objects that allow current intentions to carry into execution is a permanent and ubiquitous challenge. The available evidence suggests that the basic mechanism to meet this challenge is the anticipation of the initial stimulations that experientially warrants success of the forthcoming actions (the attentional set). Anticipations shape and intensify the representations of those stimuli that meet what has been anticipated. As the gaze is automatically directed to the stimuli which are most strongly represented, attention is automatically attracted most likely by those stimuli the effects of which have been anticipated (contingent capture). Furthermore, the evidence suggests that for making the search as efficient and smooth as possible the task related anticipations (the attentional set) seems to adapt very flexibly to current task requirements, to the experienced targets, and to differences between targets and distractors as well.

4. As introductory mentioned, to attend exclusively to task relevant stimuli entails possibly fatal risks. Therefore animals like humans are equipped with what has been called the orienting reflex, i.e. an immediate orientation of all senses to intense stimuli or abrupt changes of the current situation (Pavlov, 1953/1916; Sokolov, 1963). However, the stimuli that release a reflexive orientation of attention are not fixed but rather are subject to learning. For example, if we spend our first night in a tent we are scared by any new unfamiliar noise. However, after a few nights we have already habituated and sleep undisturbed. Likewise, we adapt to a noisy site, to the traffic noise from a near highway, or to the noise of a party in the neighborhood. Thus, in the same way as task related attentional sets adaptively enhance the impact of just those stimuli that are currently appropriate, the impact of stimuli that repeatedly disturb us is adaptively reduced if they are behaviorally irrelevant. The same mechanism presumably works if in an experimental setting repeatedly presented distractors affect us increasingly less, even if they are salient like singletons or abrupt onsets. However, habituation of the orienting response is not to be expected if the distractors have features that are related to the simultaneously adapted attentional sets (contingent involuntary orienting). Furthermore, habituation should be delayed if not prevented if the distractors sufficiently often cue the target location because under such conditions it might be that the distractors become part of the attentional set as ocassionally helpful cues. That besides habituation distractors can also be voluntarily ignored seems to me to be unlikely. If the notion is correct that any content, we currently think off, works like a set to detect corresponding stimuli (cf. point 2) the attempt to actively ignore distractors should cause the opposite, just like the noise of the neighborhood party distracts us the more the more we voluntarily try to ignore it.

Conclusion

The preceding speculations about ecological requirements underlying attentional capture lead to the conclusion that attention does not base on separate mechanisms that work on incoming stimuli but rather on mechanisms that evolved in order to support an efficient control of purposeful goal oriented behavior. Thus, attention does not start to work with the intrusion of stimuli. Rather, attention starts with intentions and is substantiated by anticipations of intended stimulations before the corresponding stimuli appear. The only exception are stimuli that trigger a reflexive orienting response. But even the orienting response quickly becomes habituated or conditionalized according to behavioral experiences. Thus in my view, the present tentative conceptual analyses of attentional capture complements the profound review of experimental data provided by Ruz and Lupiáñez (2002) as it leads to the same conclusion: Attentional capture is primarily driven by endogenous processes, and it is driven by stimuli only by default.

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6. What grabs us: Comment on Ruz & Lupianez

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Ruz & Lupiáñez provide a broad, thorough overview of our present understanding of visual attentional capture, that is, of the tendency of visual events to attract our attention. They come to the conclusion that events commonly attract attention by virtue of their fit with our current task goals and task-related strategies, and the attentional selection criteria defined by them. Only in rare, exceptional cases will purely bottom-up attentional capture occur, such as when "no clear attentional set is established".

The picture Ruz & Lupiáñez draw fits nicely into the zeitgeist one can observe in cognitive psychology these days. Since the 1950s, when the interest in cognition was revived by information-processing approaches, human performance was often considered to be stimulus-driven (Hommel, Müsseler, Ascherleben & Prinz, in press). This legacy from the behavioristic tradition shines through in sometimes more, sometimes less obvious ways—the perhaps most famous example of the latter being Neisser's (1967) definition of cognitive psychology as the study of the "fate of the input". In recent years, however, cognitive processes that precede and, indeed, sometimes even produce, stimulation have attracted more and more interest. The emergence of attentional-set approaches discussed by Ruz & Lupiáñez are but one example, others are the study of task set in conflict tasks (e.g., Cohen, Braver & O'Reilly, 1998; Cohen, Dunbar & McClelland, 1990) and in task-switching performance (e.g., Allport, Styles & Hsieh, 1994; Meiran, 1996; Rogers & Monsell, 1995), demonstrations of the role of intentions in stimulus-response compatibility (e.g., Hommel, 1993), and investigations of the linguistic control of spatial attention (e.g., Logan, 1995; Spivey, Tyler, Eberhard & Tanenhaus, 2001) and of motor performance (e.g., Gentilucci, Benuzzi, Bertolani, Daprati & Gangitano, 2000).

As exemplified by Ruz & Lupiáñez' discussion, the picture emerging from these investigations is not simple. And it is certainly not well captured by the opposition of automatic versus intentional, or bottom-up versus top-down processes. Rather, it seems that goal states lead to the implementation of *conditionally automatic* (Bargh, 1992) cognitive processes that transform the processing system into something like a *cognitive reflex* machinery (Hommel,

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2000). Indeed, this is what Ruz & Lupiáñez conclude: Task-specific goals enable a set of automatically-running processes that under particular circumstances may process unwanted stimuli. From this perspective, research on attentional capture promises to extend our insights into the interaction of goals and the processes they affect. To do so more optimally, however, some challenges are to be met on both theoretical and empirical sides.

Theoretical challenges

A number of non-trivial theoretical problems remain to be addressed and solving them may well resolve at least some of the apparent empirical discrepancies Ruz & Lupiáñez identify. What we for instance do not yet really understand is, if attentional sets determine stimulus selection to a large degree, how do they do that? Logan and Gordon (2001) have claimed that an attentional set can be established by specifying or changing a single control parameter. If so, how is this parameter translated into a "set", on what types of stimulus codes ("physical", "phonological", or "semantic"; V1, V2, or "higher") does it operate? And what are the conditions under which a set is implemented? Is there just one level of sets (e.g., for color or for shape) or is there a hierarchy of sets with low-level, task-specific sets coexisting with higher-level, general goals (e.g., avoidance of life-threatening and unpleasant events, seeking events that make us happy and satisfy basic needs). I find this latter possibility very reasonable, but it would allow a set-theoretical post-hoc account of almost any demonstration of attentional capture one can think of without contributing anything to our insights on how attention works (see Gibson, 1941, for an early warning). The challenge to be met here is to specify in more detail exactly what an attentional set may be, how it may work, and on which conditions its implementation may depend.

On the other hand, the concept of "saliency" rests almost entirely on intuition and it is often used in a way that comes close to circularity. Everyone would agree that a single red circle among 20 green circles is somehow salient. But what if we increase the number of red circles to four, say. Is *red* still salient? Are the red *circles* salient? If we consider saliency as a continuous variable of which stimuli can possess more or less, what then is the relationship between saliency and attentional capture? Hard to believe it is linear. Indeed, the saliency concept is only clear in the extreme cases that are commonly investigated, so that post-hoc accounts in terms of "not enough" or "too much saliency" are always difficult to rule out. Unfortunately, it is these two concepts—attentional set and saliency—that represent the backbones of the two types of approaches to attentional capture. Hence, as long as they are as fuzzy as they are now it is not likely that the research based on them will reach some sort of final conclusion.

Empirical Challenges

Apart from these theoretical issues there are also some more empirical weaknesses Ruz & Lupiáñez' overview can be taken to point at. Although being motivated by the rather general question of whether and how endogenous and exogenous sources of attentional control interact the majority of actual empirical research focuses on a single aspect of this question: *under what circumstances is searching for a feature singleton affected by the presence of another, irrelevant singleton*. This empirical self-restriction brings with it a whole bunch of theoretical limitations, which in several ways confine our insights into attentional control to situations that are not really, or at least not fully, representative for the everyday use of attentional capabilities.

First, although there are certainly situations in which people scan their environment for the occurrence of one particular feature, many other circumstances are likely to require the search for feature conjunctions—just think of looking for a friend of yours in a crowd, going shopping, or searching for a textbook suited for your introductory class. As the research on attentional capture focuses almost exclusively on feature search tasks (with the few exceptions Ruz & Lupiáñez discuss in their section on salience), there is not much we know about whether and when irrelevant singletons distract our attention under conjunction search. In view of the limited evidence for true capture in singleton-search tasks and the entire absence of capture in the few studies on conjunction search, there is some reason to worry about the relevance of attentional capture for understanding the nature of human attention.

Second, whether attentional capture can count as strictly automatic or not, it seems clear that events attract our attention the more the more salient they are. However, in capture research the saliency of a given stimulus is (implicitly) defined with respect to the other, currently available stimuli only. True, it is intuitively obvious that one or a few oddballs may attract attention merely by being different, but objects and events may be odd for other reasons than possessing a feature that other, simultaneously presented stimuli do not. A number of examples for that stem from Berlyne's extensive work on the effects of novelty and oddity on visual attention (e.g., Berlyne, 1960), which is widely ignored by the capture literature. For instance, stimuli are fixated more likely and longer the more irregular their shape, the more, and the more heterogeneous, their elements and, in the case of pictures, the more they distort the object they depict (Berlyne, 1958). Expectations are also important, as suggested by the observation that stimuli are identified more easily if they appear in a new color (Berlyne & Ditkofsky, 1976). These and other findings demonstrate that events can grab our visual attention by virtue of their particular visual structure alone—independent of their oddity with respect to other, competing attentional targets—and they do so to the degree that they surprise us, hence, if they violate our expectations. These kinds of effects are of obvious importance for a whole range of everyday situations, whether we talk of advertisement, fashion, art, or safety in car driving, so that one would expect research on attentional capture to address them in one or the other way.

Third, a somewhat related issue, attentional capture is commonly investigated without any consideration of the history of both target and distractor stimuli. Given the broad and solid evidence that the degree to which stimuli capture attention varies with their novelty (Cowan, 1997; Sokolov, 1963), it is surprising to see that studies on capture use singletons or other distractors over and over again, and commonly do not even assess possible habituation effects. Lorch and colleagues have investigated the impact of habituation to picture distractors in a speeded classification task (Lorch, Anderson & Well, 1984; Lorch & Horn, 1986), and they did find some reduction of interference after a few pre-exposure trials already. Thus, it is not unreasonable to assume that at least part of the capture effect can be eliminated by some practice and/or by using predictable distractors.

Finally, it is interesting to note that attentional capture is almost exclusively measured in terms of distraction, that is, as interference with ongoing information processing. As most methods such an approach has its strengths and weaknesses. *If* stimuli can be demonstrated to distract attention even if they are entirely irrelevant to the task at hand (which to determine the discussion about attentional sets has shown to be difficult, however), then we indeed have very good reasons to believe that capture is truly automatic. But this is a rather strong test and it does not tell us a lot about what grabs our attention if we are not currently busy with a demanding reaction-time task. Again, some consideration of Berlyne's (1960) approach to curiosity may provide some guidance to overcome this limitation.

To sum up, Ruz & Lupiáñez sketch a research field in progress: Approaches are in the process of overcoming the (probably too simplistic) binary questions that seem to be typical for the initial steps of most research (Newell, 1973) and move towards a more integrative view. To the degree that this process is completed we can expect interesting contributions to more general questions of how human behavior integrates bottom-up processing and top-down control, hence, how performance can be intentional and adaptive at the same time.

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7. Attentional capture: Biological relevance, multisensory stimulation, and consciousness.

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The authors Ruz and Lupiáñez are to be commended for a thorough overview of many of the key studies in the attention capture literature. In the present commentary we would like to suggest three lines along which future attention capture research might be broadened: (1) the role played by biologically relevant stimuli; (2) the role played by multisensory stimulation, and (c) the role played by consciousness.

Attention capture research has focused almost exclusively on the interplay between primitive features of visual stimuli, such as shape (circle, square, diamond, etc), color (red, green, blue, etc), and luminance (abrupt onset, abrupt offset, ramped onset, etc). And as the excellent review by Ruz and Lupiáñez has established, the conditions under which primitive features of this sort can capture visuospatial attention are quickly becoming well understood. However, there is also a new and growing body of research which suggests that reflexive orienting of visuospatial attention may also turn on the extent to which a stimulus is, or is not, biologically relevant (Langton, Watt, & Bruce, 2000). For instance, Kingstone and Friesen (1998), Langton and Bruce (1999), Driver et al. (1999) have each shown that presenting a picture of a face that has the eyes and/or the head turned to the left or right will produce a shift in spatial attention to the gazed-at location -- even when participants are instructed to ignore the gaze cue and are informed that the cue does not predict where a visual target will appear. These findings, coupled with the observation that the effect can emerge as soon as 100 ms after cue onset, demonstrate that the effect is reflexive in nature. Importantly, this orienting produced by a biologically relevant stimulus has several unique characteristics that differentiate it from non-biologically relevant stimuli. First, eye direction produces a shift in attention <u>away</u> from the location of the cue itself (i.e., the eyes) and a shift in attention toward the location that is being gazed-at. This contrasts with the standard attentional capture finding whereby attention is drawn <u>towards</u> the capturing stimulus. Second, the beneficial effect that gaze direction has on response latency lasts longer than anything that is observed normally with a peripheral non-informative cue. Namely, response time (RT) to a target can be facilitated with cue-target intervals of

1000 ms or more when the attentional cue is directed gaze, but facilitation does not normally extend beyond cue-target intervals of 200-300 ms when attention is drawn, say, to an abrupt peripheral onset. Finally, shifting attention reflexively to a gazed-at location has failed to produce any evidence that it results later in an inhibitory effect emerging at the gazed-at location. In other words, unlike primitive stimulus features normally studied by attention capture researchers, gaze direction does not appear to result in the inhibition of return phenomenon. Indeed recent work by Friesen & Kingstone (submitted) suggests that facilitation by gaze direction, and inhibition of return, are dissociable effects that can co-occur. In sum, these findings suggest that reflexive orienting or spatial attention in response to biologically relevant stimuli may represent a new and unique form of attentional capture. Whether this form of orienting is amenable to endogenous modulation in a manner similar to capture by simple features is a subject of future research.

As the authors correctly note at the outset of their paper, a multitude of stimuli reach our senses at any given moment. However, this rich stimulation is by nature not constrained to one single sensory modality, but rather it is composed of a constellation of stimuli reaching different senses. There is a growing appreciation among researchers that attentional selection is best understood within a multisensory framework, superceding those of merely visuospatial attention (see Driver & Spence, 1998, for a review). Indeed, attentional capture across stimulus modalities in the form of reflexive shifts of attention have sometimes been proposed as an account for multisensory integration phenomena in the spatial domain such as the ventriloquist illusion whereby an auditory stimulus is mislocalized toward a concurrent visual event. Here, a reflexive shift of spatial attention in one modality is thought to capture spatial attention in a different modality (see Caclin et al., 2002; Macaluso, Frith & Driver, 2000; McDonald, Teder-Sälejärvi, & Ward, 2001; and Macaluso, Frith, & Driver, 2001, for a recent discussion). Importantly, this type of capture between sensory modalities appears to generalize to a number of modality combinations (i.e., touch and vision, touch and audition) and across the spatial and the temporal domains (Caclin et al., 2002; Soto-Faraco et al., in press). The conclusions reached by Ruz and Lupiañez´s review raise many interesting questions for future research on attentional capture across stimulus modalities. For example, whether a sensory modality can by itself serve as a "capturing" dimension, and whether a sensory channel can be established as a filter thereby permitting endogenous processes to modulate capture. Opening the field of attentional capture to a multisensory framework will undoubtedly improve our understanding human information processing in real world environments.

Finally, an intriguing question that Ruz and Lupiáñez touch on concerns the link between attentional capture and that of conscious awareness. For the most part attentional capture research has sought to determine the boundary conditions under which different types of primitive features do (or do not) capture attention and what role (if any) attentional goals play in capture. In most studies attentional capture is inferred from an increase in RT to respond to a task relevant target as a function of the presence of one or more unique distractors in the display. One seemingly important question that has yet to be resolved concerns the degree to which attentional capture by unique distractors co-occurs with awareness of the attentional capturing stimuli. We would conjecture that many researchers implicitly assume that once a stimulus captures attention, the stimulus is consciously perceived. This however could be incorrect and may exaggerate the putative link between attentional orienting and awareness. It may be possible that stimuli that use attentional resources do not always reach awareness. Several recent studies support this view. First, in a study of patients with visuospatial neglect, Danziger, Kingstone and Rafal (1998) found that visuospatial attention is drawn to the location of a cue for which there is no visual awareness. In this experiment target detection was facilitated for targets that appeared at a cued location despite the fact that subjects were not aware of the cues (see also Kentridge et al. (1999) for further evidence of dissociations between attention and awareness in patient populations). In a study with healthy subjects McCormick (1997) found further evidence for spatial orienting without awareness, whereby visually degraded cues, of which subjects were not aware, affected orienting behavior to a subsequent target. In three experiments targets typically appeared at the location opposite that of the cued location. An interaction effect was observed. When subjects were not aware of the cue, RTs were faster when the target appeared at the cued location than at the likely target location. In contrast, when subjects were aware of the cue, target detection was faster when the target appeared at the likely target location than at the cued location. This study shows that while cues that are not consciously perceived capture attention reflexively, they do not affect endogenous shifts of attention. Finally, and possibly of most relevance for the attentional capture literature, Theeuwes et al. (1998), and Kramer et al. (2000) have shown that the eyes can be drawn toward the location of an abrupt onset before landing on a target elsewhere, and yet participants appear to have no conscious awareness of moving their eyes to a distractor by mistake. Taken together, these studies indicate that attentional orienting to a stimulus need not always co-occur with awareness of the attentionally grabbing stimulus.

In summary, the attentional capture research has made many significant steps forward recently, as the review by Ruz and Lupiáñez has clearly demonstrated. In the future there lie ahead many important and exciting lines of research for investigation.

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8. Endogenous inhibitory control of selection: Evidence from preview search.

by Melina A Kunar, Jason J Braithwaite, Glyn W Humphreys*

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The review of attentional capture research by Ruz & Lupianez provides a useful summary of a complex and hotly debated research area. It is clear from the literature that new objects are important for visual selection, and that these items can enjoy a special status. As Ruz & Lupianez point out, the likelihood that new objects capture attention can be mediated by the intentional set of the observer; attentional capture is most effective when participants are set to prioritise the new stimuli. Most usually, the intentional set of observers is conceptualised in terms of a positive bias towards new items. For example, pre-activation of a system for detecting transient onsets may help bias selection towards new events. In addition to this, however, attentional prioritisation for new stimuli may be enhanced by a negative bias against old items. Such a negative bias has not been considered by Ruz & Lupianez, but it may provide an important role in optimising selection. Here we briefly review evidence for negative bias effects helping to prioritise selection of the 'new'.

Watson and Humphreys (1997) first argued for the role of a negative bias in selecting new objects in a modified standard colour form conjunction search task (e.g. Treisman & Gelade, 1980). Watson and Humphreys (1997) decomposed the presentation of items across two displays, segregated by a 1-second preview interval. They found that in the preview condition, search was as efficient as when only the new items appeared alone (in a single feature baseline condition) and it was considerably more efficient than in a conjunction baseline, when both sets of distractors were presented simultaneously. They proposed that the search advantage in the preview condition occurred in part because old items were actively inhibited (a process they termed 'visual marking'). This inhibition was thought to depend on an intentional, resource-limited mechanism.

Direct evidence for intentional inhibitory effects comes from studies using probe dot detection. Watson and Humphreys (2000) found that probe dots were difficult to detect when presented at the locations of old items. Interestingly, probe detection was only impaired at old locations when observers were engaged in search for new targets on a minority of trials; it did

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not occur when probe detection was the primary task (Watson & Humphreys, 2000). This suggests that the effect is linked to an attentional-set against old items in the search task, and not simply due to the temporal parameters of the displays. Furthermore, the efficient selection of new targets is reduced when observers perform a demanding secondary task during the preview interval, when only the old items are present (Humphreys, Watson & Joliceur, in press; Olivers and Humphreys, in press; Watson & Humphreys, 1997). Indeed, when a secondary task is introduced (presumably removing inhibition), probe detection at the location of old items actually improves (Olivers & Humphreys, in press).

The origin of this "preview effect" has itself been debated, matching the arguments about endogenous and exogenous control of selection of new objects. For example, in contrast to the top-down inhibitory account proposed by Watson and Humphreys (1997), Donk and Theeuwes (2001) have recently argued that the preview benefit is due to exogenous attentional capture by the new stimuli. Donk and Theeuwes (2001) failed to observe a preview benefit when new items were isoluminant with the background. They proposed that new onsets are fundamental to the benefit, and inferred that this reflects the potency of these signals for an exogeneously – controlled selection system. However, these findings may also simply mean that, in order for old items to be inhibited, they must have been registered in some representational map sensitive to dynamic change.

The onset capture account holds that the old items are entirely irrelevant to the preview benefit. However studies using a top-up procedure counter this. Kunar et al. (in press) employed these preview conditions. In the standard preview condition (700 ms preview), old items were presented for 700 ms before the search set appeared. Search here was more efficient than in a conjunction baseline replicating Watson and Humphreys (1997). In a second preview condition the old items appeared on the screen for just 150 ms before the search set. With such a brief preview, performance was no more efficient than the conjunction baseline. The lack of benefit may be due to the short time allowed to build – up inhibition, or to insufficient time to separate the onsets of the old items from those of the new. In the third "top-up" condition, preview items appeared for 450 ms, disappeared for 250 ms and then re-appeared in their original positions 150 ms prior to the search set. Previous work shows that, if the preview items disappear and then re-appear with the onset of the search set, then any preview benefit is lost (Watson & Humphreys, Experiment 6, 1997). Despite this, a preview benefit emerged in the "top-up" condition. This result is difficult to explain in terms of attentional capture. If a 250ms offset is sufficient to have old items compete as new objects in one case (without the "top-up" preview), then this should also have occurred in the "top-up" condition. Instead, it seems that the short "top-up" of the preview, before the new items was sufficient to recruit the prior memory for the old stimuli and this helps them to be ignored in subsequent search. Rather than being due to exogenous attentional capture by new onsets, the coding (and inhibition) of stimuli as old distractors seems important.

Other evidence against an onset capture account comes from studies that manipulate the colours of the stimuli across old and new displays. As Ruz & Lupianez note, evidence for attentional capture come from experiments on singleton interference; where visual search is disturbed by a salient distractor that differs in its features from the target. Olivers and Humphreys (submitted) report that singleton interference within search displays is strongly modulated by old previews. For instance, a singleton colour in a search display is much less effective when it shares its colour with preview items. Again, the old items influence performance in a manner consistent with an inhibitory (in this case inhibition may be carried over to affect targets sharing inhibited features), and contrary to an attentional capture view.

Braithwaite, Humphreys and Hodsoll (submitted a) have similarly shown that carry-over effects from old to new items influence search to the new items. Previous studies of search have demonstrated that targets in a 'majority' colour in a display are more difficult to find than target's in a 'minority' colour (e.g. Bacon & Egeth, 1997; Egeth, Virizi, & Garbart, 1984; Kaptein, Theeuwes & van der Heijden, 1995; Moore & Egeth, 1998; Poisson & Wilkinson, 1992). This result has been attributed to participants using the ratio of colours in a new display to guide search. However, this bias to a new minority colour can be reversed if these minority items match the colour of previews (Braithwaite et al., submitted a; Braithwaite Humphreys and Hodsoll, submitted b). Here it seems that inhibitory colour carry-over is more influential than search guided by the colour properties of the new. Collectively these studies suggest that, rather than simply prioritising onsets, participants can adopt an inhibitory-set for old items. The inhibitory-set for old items operates on the basis of colour (grouping) as well as location, and it provides a means of endogenous control of selection

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9. Attentional capture and cognitive control.

by Eduardo Madrid*

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Advertisers have been flashing images on TV commercials for a long time, not quite knowing why, relying on the intuition that this kind of ever-changing stuff will catch the attention of potential buyers. Now cognitive psychologists have a good deal of data and knowledge about how human attention is captured and the target article by Ruz and Lupiáñez (R&L) is an excellent review of this research effort. From the R&L review it seems that commercial-makers will never succeed in producing the ultimate spot, the one that absolutely nobody will be able to ignore, as the conclusion of the target article is that the individual immediate goals can override the effect of stimulus-driven attentional capture. In this comment we will consider how the automaticity of attentional capture could survive even in front of this conclusion. Attentional capture will be considered in the wider context of the control of cognitive processes.

Attentional capture, as a mechanism of selective attention, is regarded as basic to the construction of focal awareness (Posner & Raichle, 1994). It has been assumed that we are aware of stimuli that are within our focus of attention and unaware of stimuli that are outside the current focus of attention (Cowan, 1995; Klatzky, 1984; Mandler, 1975; Miller, 1962; Posner & Boies, 1971). In that sense the question about what conditions external stimulation has to meet in order to attract the focus of our attention can be rephrased in terms of awareness: Exist any value or feature that will give to stimuli showing it direct access to our awareness?. The research effort reviewed by R&L addresses extensively this question and points out that discontinuities both in the temporal (transients, abrupt onsets, new objects) and spatial domains ("singletons", saliency) are likely to reflexively attract attention and to automatically trigger awareness of then. Most importantly, this seems to be the case provided that the observer attention is not engaged in anything else; if he/she is engaged, what attracts attention depends on the current task structure and on the goal the subject is trying to achieve. In other words, it seems that it is the relationship of stimuli properties and target finding properties the critical factor for attentional capture to occur and not any absolute property of the stimuli.

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Folk and its coworkers (Folk, Remington, & Johnston, 1992) proposed a theory of cognitive control where reflexive control of attention is analogous to the functioning of a thermostat. In an air conditioning machine, once the pretended temperature is settled up (i.e., the task settings are generated) the thermostat will have the "control" and will start up the engine (attention will be captured) if the temperature departs from the aimed value. It can be said that the thermostat has some "automatic control" on the performance of the cooling system. In the case of human performance the cognitive goal will determine the processing settings in advance (off-line); once those settings are in place, the appearance of stimuli matching relevant values in some dimensions will capture attention with no additional involvement of cognitive control processes[2], in that sense, mechanism for attentional capture have some degree of "automatic control".

Folk and his co-workers (Folk et al., 1992) model postulates goal setting processes and performing processes as two functionally differentiated kind of processes. This view stand against one in which the control of performance or attention is a by-product of other processes as priming (Johnston & Dark, 1986) or competitive neural interactions (Desimone & Duncan, 1995). Both views (control processes as a causal force or "attentional effects" as by-products) have been considered incompatible, however, like in some other issues in attention research, this kind of dichotomization can turn out to be, as it was in the early-late selection debate, not fair with the flexibility that the human processor is able to exhibit. The rather long history in the research of those dichotomies could be due, at least in part, to the limited sensitivity of pure performance measures (reaction time and accuracy) to resolve then. Reaction time measures are well suited to study the processes involved on a single trial. However, behavioral measures could be less than optimal if we are interested in processes that –like control processes- develop mostly outside of the interval between the stimulus and the response. Control processes are likely to be on by the beginning of the session, when the observer is trying to figure out what is expected from him/her. Additionally, on the practice trials it is likely that the processing resources needed to deal with the task are settled on in the right sequence, contrasting the task instructions with the actual stimulation. Furthermore, during single specific trials, e.g., like those were the observer do wrong and realize it, control processes are likely to be active as well, and to remain so during the inter trial interval, what can lead to worse performance for the next few trials. There are many other situations where control processes could get active, in any case those are situations where the behavioral measures are somehow limited in their sensitivity to those control processes. Some techniques of the cognitive neuroscience (ERPs and functional neuroimaging in particular) have almost obliterated those limitations. The acquisition of continuous and direct data from the brain of the observer as he/she performs a

[2] The question of who will set up the cognitive "thermostat" arise, the quick-and-dirty answer is –of course- the homunculus inside. We will not enter this debate here (see (Monsell & Driver, 2000).

cognitive task has proven to be extremely useful both, in getting insight about the functional architecture of the mind and in getting a better understanding of the organization and interaction of neural processes. From the cognitive neuroscience arena, a distinction has arose between neural networks that are the source of attentional signals and neural networks where attentional effects express themselves (Corbetta, 2000; LaBerge, 1995) . This distinction, in some extent, parallels the one proposed by Folk et al. (1992) in the "thermostat" model mentioned above. Cognitive goals are conveyed by the instructions given. Instructions must be decoded, stored and funneled to the processing system. The activity of the instructions-to-goal "translator" will result in an attentional template in order to perform the task, that will include directions at the trial time-scale as well as at larger time-scales. Once that this multidimensional attentional template is settled up, the processing system can proceed in an automatic way, and attentional capture by distracters sharing dimensional values with targets will automatically occur as a by-product of what task the system is trying to perform. We humans have the capability to –within milliseconds- generate a new specific arrangement of neural machinery on demand, recruited and coordinated in order to perform a task. What the R&L review suggest is that what an stimulus is going to trigger depends very much on what are we trying to do or perceive. The interaction between the control mechanisms and the processing mechanisms that results in human behavior is receiving nowadays extra attention. At the stimulus to response (S-R) translation end, similar conclusions to the reported by R&L are drawn: automatic processes of S-R translation are modulated by the intentions or goals of the acting person (Hommel, 2000). The specification of the interaction, at different levels, of goal-generating and control processes with the processes implementing the treatment of the information is perhaps the next challenge, and the review of R&L is a very useful tool for researchers heading this direction.

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10. Commentary on Ruz and Lupiáñez's "A review of attention capture: On its automaticity and sensitivity to endogenous control"

by Bruce Milliken*

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One of the main themes of the review by Ruz and Lupiáñez is that attention capture can be modulated by endogenous processes. That attention capture can involve more than just a reflexive orienting response toward salient events has led to a rich variety of visual search and cueing procedures to measure properties of attention capture, as pointed out in the review. However, the notion that endogenous processes can contribute to attention capture may have equally interesting, although less obvious, implications for other research domains.

A fundamental implication of attention capture may be that the cognitive system makes use of the difference between a predicted and actual occurrence. Presumably, we orient to sudden loud noises because they produce representations that differ markedly from prediction. Now, introducing the notion that endogenous processes can modulate attention capture implies that we can be more or less sensitive to this difference between predicted and observed events. This appears to be the essence of Bacon and Egeth's (1994) distinction between being or not being in discrepancy detection mode. What implications might a discrepancy detection mode have beyond the conventionally defined attention capture domain? Consider a task in which a prime (or cue) is followed by a probe (or target), and the prime and probe are either related or unrelated. Of course, related probes are usually responded to more quickly than unrelated probes (i.e., repetition priming). However, if participants can engage in a discrepancy detection mode, then the discrepancy between an unrelated prime and probe pair could conceivably produce an effect opposite to repetition priming. That is, to the extent that discrepant probes can attract attention, one might expect performance for unrelated probes to be more efficient than for related probes.

This possibility is noteworthy because when such effects are observed (e.g., negative priming, inhibition of return, repetition blindness), they are often attributed to inhibition processes. The logic underlying this type of attribution is that inhibition of the internal representation of a prime (or cue) will subsequently show up as slowed performance for a related probe (or target). However, if attention can be captured by discrepancy, and if this attention capture can produce particularly efficienct performance for unrelated trials, then there may be no need to posit an inhibition process that slows

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responses for related trials. In effect, to explain "inhibitory" priming and cueing phenomena, one may not need more than the mechanism that produces attention capture.

The notion that attention capture is subject to endogenous control would then be an important tool to explain why "inhibitory" priming effects are often sensitive to task demands.

Of course, this argument requires an extension of the processes that cause attention capture at a location in space to dimensions other than spatial location. Attempts to push in this direction may or may not meet with success, but given the possible gains in parsimony it seems a worthwhile step to take. If some success is met, it would suggest that attention capture at a location in space is a particular manifestation of a general attentional principle, whereby resources are allocated in response to processing discrepancies.

11. Commentary on Ruz and Lupiáñez's "A review of attention capture: On its automaticity and sensitivity to endogenous control"

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In their valuable review Ruz and Lupiañez note that neurological patients with the syndrome of hemispatial neglect offer a special opportunity to investigate the capture of unattended stimuli. Individuals with this syndrome, which typically involves the right parietal lobe, may be unaware of objects and events in the visual field contralateral to the lesion, even though sensory visual pathways are intact. A common observation in bedside tests is that of extinction: patients can report the presence of a contralesional item presented alone, but fail to report its presence when it appears together with a competing ipsilesional item. That is, the competing ipsilesional stimulus causes the contralesional item to be extinguished from awareness.

A simple clinical observation has shown, however, that features of unattended stimuli in the contralesional field are, nevertheless processed outside of awareness: namely, that there is less extinction when two competing objects are different, than when they are the same (Rafal, 1994). In a sense, when there are two different items present, both are 'singletons'; and this may be viewed as an example of singleton 'popout'. Baylis, Driver, & Rafal, (1993) extended this clinical observation to demonstrate that this singleton popout is contingent upon attentional control settings. They showed that the similarity of features determined whether the contralesional object was extinguished only if the features were relevant to the task. On each trial coloured letters appeared either unilaterally or bilaterally and the patients were asked to report what they saw. In one condition patients were asked to name only the letter(s) (X or E), and in another to report only the color(s) (red or green) that they saw. Extinction occurred more frequently when the bilateral stimuli were the same on the attribute to be reported than when they were different on this attribute, and more frequently than when the stimuli were the same on the irrelevant attribute. In blocks that required letter naming, extinction was not ameliorated if the stimuli were of different colours; and *vice versa* for the color report blocks. These results demonstrate not only that information about shape and color of neglected objects is encoded, but also that access of this information to conscious awareness is contingent upon task goals.

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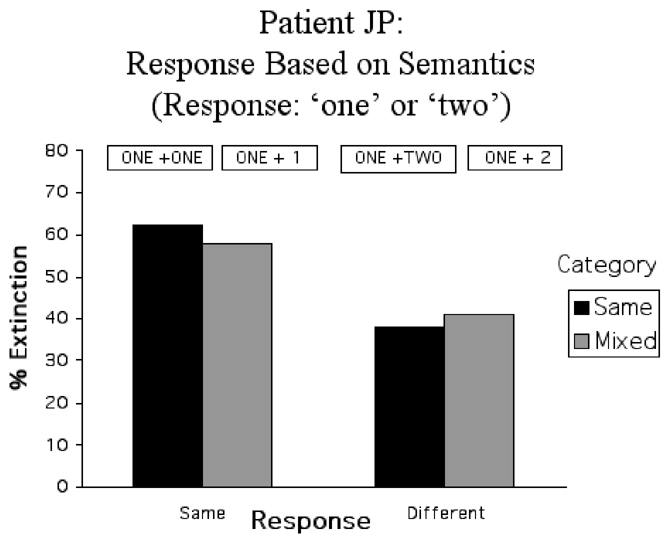
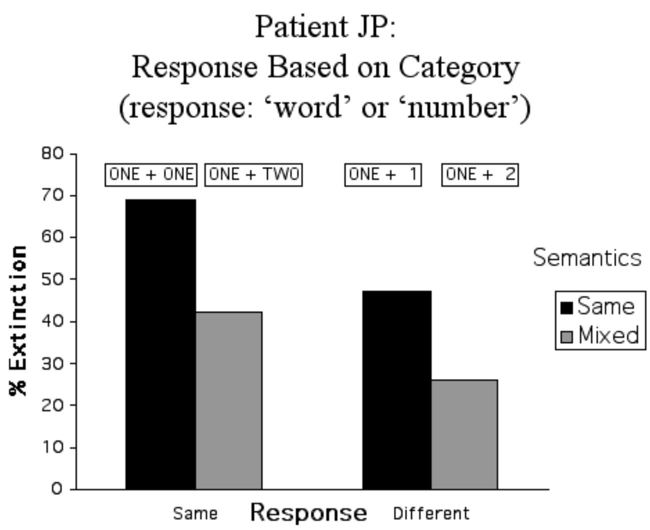
In this earlier study, the patients' responses were determined solely on the basis of simple visual features (color or shape). Competition for awareness could therefore be due either to competition among objects sharing the relevant visual feature, or between objects sharing the same implications for response. The former could be implemented on the basis of competitive feature selection early in the visual pathway, while the latter implies preserved early visual processing and biased selection at a later level of semantics and/or response.

Some recent work in a single patient suggests that access to consciousness is gated at the level of processing at which the meaning of the stimulus is used to determine action. Patient JP was tested in a task requiring a response based on the semantics of the items, while visual similarity between concurrently presented items was manipulated. The stimuli were the words “ONE” and “TWO” and the numerals “1” and “2” that appeared, randomly, in the left field, the right field or both fields. She was asked to read the item(s) and to report what was present in each visual field by responding “one” (indicating either the word "ONE" or the digit "1"), “two” (the word "TWO" or the digit "2"), or “nothing”. The responses here were, thus, contingent upon the semantic meaning of the stimulus (i.e. what it denotes in terms of numerosity), and independent of its visual features or category (i.e. whether a word or digit).

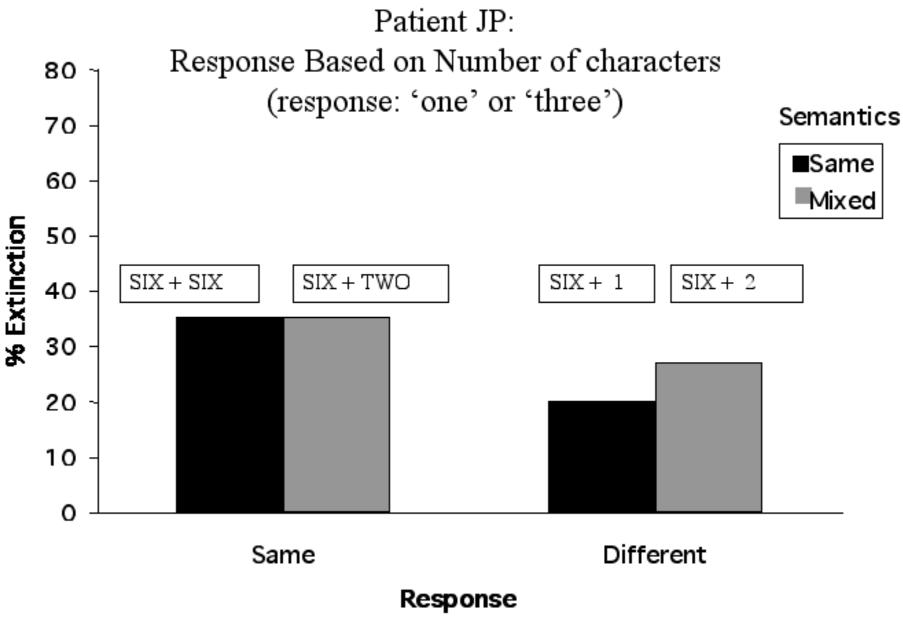
If selection is determined solely by allocation of attention to perceptual features, then perceptual similarity should modulate the degree of extinction. If selection is determined solely by the allocation of attention to the semantic meaning required for response selection, then visual similarity between the competing items should not influence extinction. Figure 1A shows that there was more extinction when the items shared the same meaning and required the same response, than when they required different responses c^2 (1) = 6.35, p = 0.02. This was the case whether they were from the same category and visually identical (e.g. ONE + ONE) or were from different categories and visually dissimilar (e.g. ONE + 1).

In a second experiment the task was changed and she was asked to report the category of each item (“word” or” digit”). In contrast to the first experiment, in this experiment items from the same category required the same response. Figure 1B shows that in this experiment there was, in contrast to the first experiment, an effect of category (c^2(1) = 9.03, p = .0027). That is, pairs of items that required the same response showed more extinction than those requiring different responses, regardless of perceptual or semantic similarity. Note, however, that there was also an independent effect of semantics (c^2(1) = 5.55, p < .02). We can provisionally conclude that attentional selection gates access to awareness at both the level of semantics and the level of response selection. However, we cannot conclude that attentional selection at the level of semantics is automatic and obligatory since, in this experiment, semantics could be used in determining the correct response, e.g. patients might read the stimuli as a step in determining their category.


Patient JP:
Response Based on Semantics
(Response: 'one' or 'two')
ONE +ONE
ONE + 1
ONE +TWO
ONE + 2
% Extinction
80
70
60
50
40
30
20
10
0
Same
Response
Different
Category
Same
Mixed


Patient JP:
Response Based on Category
(response: 'word' or 'number')
ONE + ONE
ONE + TWO
ONE + 1
ONE + 2
% Extinction
80
70
60
50
40
30
20
10
0
Same
Response
Different
Semantics
Same
Mixed

JP was tested in a third experiment in which not only were semantics irrelevant to the task, but she was also explicitly required to ignore semantics to perform it successfully: to report the number of characters present in each field. Thus, the correct response was “One” for digits and “Three” for words; and response selection did not require any access to semantics. The items for this experiment were 2, TWO, 6 and SIX. Note that, with this stimulus set, not only is the semantic meaning of the items irrelevant to selecting the correct response, but simple reading of the items would compete with generation of a correct response, since neither “Two” nor “Six” was a correct response. The task, then, not only makes semantic analysis of the stimuli irrelevant, but JP needed to inhibit reading of the items in order to prevent them from competing with the correct response. This is essentially a Stroop-like situation in which word/numeral reading is always incompatible with the correct response, and inhibition of word reading would provide the optimal strategy for task performance. Figure 1C shows, as was the case in the second experiment, that items sharing the same response (ONE + ONE) showed more extinction than did pairs sharing the same semantics but requiring a different response (ONE + 1) $c^2(1) = 6.14$, $p=0.013$. Moreover, in this experiment, semantic similarity had no effect: that is, there was as much extinction between (1 + 1) as (1 + 6) ; or (ONE + ONE) as (ONE + SIX).



The current preliminary observations in patient JP provide further evidence that that attetional capture is contingent attentional control settings and suggest that attention can grant or deny access to the gates of consciousness at a stage of processing at which the meaning of the visual stimulus is utilised in selecting it for action.

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12. A Review that should Capture your Attention: Commentary on Ruz & Lupianez

by Jurjen van der Helden and Harold Bekkering*

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The paper of Maria Ruz and Juan Lupianez on attentional capture is excellent for at least three reasons. First, they succeeded in describing very clearly the results of almost two decades of research after attentional capture (AC) even when produced in complicated paradigms. Second, their timing of a thorough and critical review on the role of automaticity and endogenous control in AC is accurate as more and more models incorporate endogenous modulations on low-level information processing levels. Finally, the insights provided in this review on attentional capture are also very meaningful for other paradigms used to study the processes of visual attention.

Relevance for other attentional paradigms: Attentional Blink

We would like to begin where Ruz & Lupianez finished their review, namely the observation that several theories recently state that early low-level information processing stages of visual perception can be governed by the very endogenous control settings. There is accumulating evidence for the view that humans are able to transfer a relevant stimulus modality from the top to the bottom into the earliest processing levels in such a way that these relevant endogenous settings capture attention and that irrelevant singleton stimulus modalities do no longer capture attention 'automatically'. For instance, Visser, Bischof, & DiLollo (1999) came to a similar conclusion on basis of a review of the data of the 'Attention Blink' (AB) phenomenon. AB emerges when subjects have to report a second target within 200 to 500 ms. after a first target in a stream of stimuli. That is, under these circumstances subjects fail to report the second target in ca 80 % of the cases. Interestingly, when the second target is presented within 200 ms. this failure is sometimes absent. This Lag-1 Sparing, as Visser et al called it, was absent when target 1 and 2 differed in a) location or b) stimulus modality (for example, color and movement). This led them to conclude that a low-level processing stage can be set by endogenous control that opens a door for further processing in a later stage. This ‘door’ shuts immediately for stimuli presented elsewhere or in another modality, but remains open for still 200 ms. more when on the same location another target emerges in the same modality.

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Back to Attentional Capture

In the paradigm of Folk et al. (1992) paradigm, to recapitulate, two consecutive frames in which the first was irrelevant and the second contained a target (see Fig 3. in Ruz & Lupianez). The first frame contained an irrelevant singleton. In some blocks these singletons occupied the same location as the targets (valid trails), in other blocks they were presented on different locations (invalid trails). The second frame contained a target either overlapping or non-overlapping the dimension of the singleton. The invalid condition (singletons and targets were presented on different locations) singletons with no dimensional overlap with the target did not induce RT-costs. However, this would be expected if all singletons capture attention automatically. Theeuwes, Atchley, & Kramer (2000) used Theeuwes' (1991a, 1992) Visual Search paradigm. Subjects had to ignore a color singleton distractor presented at different stimulus onset asynchronies (SOA's) prior to the search display in which they had to search for a shape singleton target. When presented simultaneously the irrelevant color singleton disrupted search performance, indicating an involuntary orienting reaction. This effect was eliminated when the SOA was 150 ms. or longer. They concluded singletons do initially capture attention and soon after attention is disengaged from that location. Apparently, Theeuwes et al. 's study shows that a singleton attracts attention for a short time (for 150 ms.) even when the singleton and target do not overlap dimensionally. This is different in the case that the subject has to report the first stimulus too. That is, the study of Visser et al., described above, did show that there is no Lag-1 Sparing when target 1 and 2 differ in stimulus dimension. In addition, the Folk and Remington (1998) study shows that a spatial capture paradigm is more sensitive for attentional control settings than is the visual search paradigm of Theeuwes (1991a, 1992) (p. 26). Attentional capture effects on the target are only measured when a target appears in the same location and in the same modality as the preceding singleton. Similarly, Lag-1 Sparing is only seen when the first and the second target overlap in location and stimulus dimension.

ERP's

There are some basic problems with solving the debate of AC with using RT-measures only. In fact, Folk and Remington (1998) on the one hand state that RT-effects 'should not invariably lead to an attentional orienting interpretation' (p. 23) while Theeuwes, Atchley, and Kramer (2001) on the other hand state that 'a null reaction time effect does not necessarily rule out that a singleton has captured attention' (p. 26). In other words, reaction time is not the most powerful tool to determine whether the automaticity in attentional capture is a hard-wired bottom-up effect in its origin or that its 'defaults' can be overcome by endogenous settings. An alternative promising method is to measure the event related potential (ERP) during visual processing in time. For example, Arnott et al. (2001) used the Folk et al (1992) paradigm and showed that the N100 components was modulated by stimuli sharing task-relevant attributes only, and singletons that showed capture effects in RT evoked a negative modulation before presentation of the target compared to singletons that did not show capture effects in RT. This finding indicates that at least in the Folk et al. (1992) paradigm the 'task set modulates processing of cues at early stages of sensory processing' (p. 19). Other ERP data not directly testing the hypotheses discussed here can be useful too. Luck and Hillyard (1994) carried out an ERP study that focused on pop-out stimuli (singletons) in visual search, very similar to the Theeuwes' paradigm.). They showed in four experiments that certain ERP components were enhanced when subjects were presented with displays with pop-outs (contralateral P1 and the anterior N2), these did not reflect a fully automatic pop-out detection processes. They showed, however, that specific components were enhanced when the pop out happened to be the target. This indicates that pop-out induce no (early) component modulation on it self per se (which would be expected when pop-outs were processed in separate, hard-wired routes), rather, these components are modulated according to the relevancy of the pop-outs. This finding mirrors the contingent involuntary orienting hypothesis. ERP data in both paradigms (i.e. Spatial Cuing and Visual Search) tend to subscribe the notion that singletons are not processed in hard-wired highway to attention and these findings can play a decisive role in this theoretical discussion. Thus, the combination of behavioral studies in terms of RT and the use of brain-imaging methods with a high temporal resolution like ERP and MEG seems to be a promising way to resolve some long-standing issues in the attentional literature so far. Of course, in these combined research approach, experimenters should still be well aware of the dangers that have also haunted classical RT-research. For instance, 'the research method chosen to explore attentional capture can have consequences for the inferences that are drawn' as Ruz and Lupianez legitimately finish their review (p.27).

Conclusion

As more and more models on visual attention currently state, we are inclined towards a view that automaticity can be governed by endogenous control. This and other insights as derived from the now overwhelming amount of literature on Attentional Capture can and should facilitate the research on other attentional phenomena as Attentional Blink. In addition, experimental research on Attentional Capture can and has to be inspired by new research methods and existing models of visual attention. Furthermore, we suggest that psychophysiological methods like ERP can calibrate the interpretations of the fragile RT-effects. To conclude, not only because of its importance for overviewing the literature on AC, but also for the insights it provides about the processes of visual attention in general, the review of Ruz and Lupianez is one which should capture your attention (but not fully automatically).

Additional Literature

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13. Attentional Capture and its manifestation on performance: New perspectives in the study of the Attentional Capture phenomena.

Reply by Ruz & Lupiáñez

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The nature and characteristics of the interaction between top-down and bottom-up processing in the cognitive system is a theoretical question currently guiding research in diverse fields of Cognitive Psychology. The growing literature in the field of Attentional Capture (AC), reviewed in this article and extended in the commentaries, is a paradigmatic example of this interest.

As such, AC is an empirical effect in which RT to detect a stimulus is modified by the presence of a singleton, i.e., a stimulus unique in some dimension. The theory behind this effect assumes that it reflects the spatial orienting of attention to the location occupied by the singleton. When this singleton is irrelevant to the task and it is not used by any means to perform the search, the capture is said to be automatic, that is, uncontaminated by top-down strategies.

Evidence now seems to give a role for both exogenous and endogenous factors in AC effects. Both static and dynamic singletons are able to generate AC in paradigms such as the Identity Intrusion (Theeuwes and Burger, 1998) or the Distance Method (Turatto & Galfano, 2000), which are situations that meet the conditions for the capture to be considered 'purely automatic' (see Galfano & Turatto's commentary). On the other hand, research methods such as the Precueing Paradigm (Folk, Remington, & Johnston, 1992) show that endogenous factors are able to modulate AC effects to a great extent. These and other data lead to the idea that AC might be automatic by default, but that it is also sensitive to endogenous control, which is a conclusion supported by most of the commentaries.

One important issue to be solved is how endogenous attention modulates AC. Accordingly, a main debate among researchers in the field concerns at which processing level top-down factors do operate (see Arnott & Pratt's commentary). Whereas some authors argue that attentional sets act as a filter (Folk & Remington, 1998) that enable attention to focalize only on items congruent with the current task set, others contend that the top-down modulation operates by speeding up the disengagement of attention from stimuli not matching the set (Theeuwes, Atchley & Kramer, 2000). The former notion corresponds to the contingent allocation of attention hypothesis, where all AC effects are modulated by top down factors; whereas the latter stresses the automaticity of AC in its very beginning. As noted above, there is evidence favouring both positions but using rather different research paradigms. One prototypic example of this divergence of results between paradigms is the data from Turatto, Galfano, Gardini, and Mascetti (2001).

This authors showed that exactly the same visual search was indicative of AC when RT was examined by means of the display size method, whereas an inspection using the display size indicated no AC at all.

These results could indicate that some methods are more sensitive than others for measuring AC. Importantly, however, it could also be the case that the different methods are tapping rather different processes related to AC. Some of them may be more sensitive to perceptual competition processes that take place at an early point of attentional deployment (Desimone & Duncan, 1995), whereas others may reflect the operation of an exogenous attention orienting mechanism separated from perceptual processors (Posner & Petersen, 1990). The fact that they are all named AC effects does not necessarily mean that they all reflect the operation of the same underlying processes. Indeed, it may be the case that AC effects found with different research paradigms are tapping different underlying attention-related phenomena. Thus, it is important to distinguish between AC as an empirical effect, and the theoretical explanation offered for this effect.

On the other hand, as some authors have implicitly done (Folk & Remington, 1998; Theeuwes et al., 2000), it might also be theoretically relevant to differentiate between the actual capture of attention and the manifestation of this capture on performance (i.e., the AC effect). For example, if attention is captured in a specific location but then it is disengaged before the target appears, this capture will not manifest on behaviour. Furthermore, even after attention has been disengaged, the previous capture of attention can manifest itself on performance in either a positive or negative way, leading, in the latter case, to phenomena like Inhibition of Return (Milliken) or inhibitory visual marking (Kunar, Braithwaite & Humphreys).

What these examples show is that the processes involved in the capture of attention itself can be rather different from those responsible for the effects that the captured attention has on behaviour by the time the target appears. However, perhaps the dissociation is difficult to make with behavioural methods, because a single response measure is taken (RT/error rate to the target), which supposedly reflects the joint effects of different processes at different moments (capture of attention and its manifestation). In this sense, future research will benefit from new brain recording technologies (Arnott & Pratt; Madrid; van der Helden & Bekkering), which allow continuous recording of different dependent measures in the absence of open behaviour.

Some of the commentaries made to the target article touched on several of the above referred topics. One of the main concerns was related to what an attentional control setting is and how it operates (Arnott & Pratt; Galfano & Turatto). Kunar et al. proposed that the ability some features, such as new objects, appear to have in capturing attention might be complemented by an attentional marking mechanism, which they conceive as the inhibition of old objects to capture attention. Milliken suggests, however, that this kind of inhibitory processes leading to a lack of attentional capture by old objects might rather be considered as a lost of novelty, without the concept of inhibition being needed.

Hoffman, on the other hand, elaborated the possibility that attentional control settings operate by the generation of a template matching the searched for features, i.e., an anticipation, which in turn would select those features for further processing. It would be interesting to investigate whether *this anticipation* modulates the capture of attention or its manifestation on performance. One possibility is that new or salient stimuli capture attention (i.e., trigger a call for attention) in a bottom-up manner. However, only those stimuli *anticipated* by the control setting will lead to the manifestation of the attentional capture, by allowing them to access consciousness (Rafal).

Rafal, and also Bartolomeo, showed how useful can hemispatial neglect be for deepening our understanding of several topics in AC, such as the level of representation at which the attentional control settings operate. Other commentaries stressed the possible links between the AC and the Attentional Blink phenomenon (van der Helden & Bekkering) or noted the general principles that may underlie both the AC and other effects, such as Negative Priming and Inhibition of Return, i.e., the allocation of resources to processing discrepancies (Milliken).

Some authors drew links between AC and other research problems such as consciousness (Godijn & Theeuwes; Kingstone, Danziger, Langton & Soto-Faraco; Madrid). Godijn & Theeuwes, for example, made the interesting suggestion that those forms of AC either leading or not to conscious awareness may be related to an either slow or fast disengagement of attention from the stimuli, respectively. Thus, the capture of attention may have different manifestations on behaviour depending on the speed of disengagement. Indeed, that AC either leads or not to consciousness might be just one example of those differential manifestations. As stated above, AC might lead to opposite effects, depending on different variables.

Finally, several commentaries discussed different challenges the growing field of AC must confront (Hommel; Hoffman; Kingstone et al.; Madrid; Milliken; van der Helden & Bekkering). Apart from the hard task of operationally specifying some ill-defined terms, such as saliency, broadening the scope of the AC research seems to be one of the main needs in the field. Some of the future lines may include the relevance of habituation processes and oddity in orienting attentional resources, AC between sensory modalities, the special status biologically relevant stimuli may have in capturing attention and the specification of the links between AC and conscious awareness. Moreover, this future research will for sure benefit from the inclusion of brain imaging techniques to the field (Arnott & Pratt; Madrid; van der Helden & Bekkering). This new facilities would allow, among other things, to study to what extent all the AC effects reviewed in the article are actually tapping exactly the same attentional effects or rather different, but related, phenomena. The distinction between the attentional capture and its manifestation on performance, together with the consideration of processes related to disengaging of attention, might also be helpful to further increase our understanding of the AC phenomena and their modulation by endogenous control.

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