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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

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 everchanging 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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