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Notes and Comment

Directing attention in the visual field

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I shall be concerned here with the improvement in performance (speed or accuracy) that can result when a person knows in advance the precise spatial position that a stimulus will occupy, and so has an opportunity, in common language, to "direct attention" in advance to that position. I shall examine the implications of this phenomenon for one particular class of theories of visual attention.

In one interesting case, the stimulus, when it occurs, is presented in an otherwise "blank" field. Good examples come from a series of experiments by Eriksen and his colleagues (Eriksen & Hoffman, 1973, 1974; Hoffman, 1975). In the experiment of Eriksen and Hoffman (1974), a single letter was presented on the circumference of an imaginary circle centered on fixation. Reaction time (RT) to name this letter was the dependent variable. The important result, repeated in other experiments, was that RTs were shorter when the subject knew in advance the position of the letter than when this position was unknown until the letter itself arrived. Rather similar RT results have been reported by Posner and his colleagues (Posner, Nissen, & Ogden, 1978; Posner, Snyder, & Davidson, 1980), and accuracy of target detection has shown the same effect (Bashinski & Bacharach, 1980). Although there are published failures to observe the result (e.g., Grindley & Townsend, 1968), it seems generally quite robust.

In another case, the target is presented in a field of other similar stimuli. Again, its position may be known in advance. Alternatively, it may be indicated by a bar marker or similar cue, simultaneous with the stimulus field or presented just at its offset. Again, the response somehow indicates the target's identity, with RT (Eriksen & Hoffman, 1973) or accuracy (Butler, 1980a, 1980b; Shiffrin, McKay, & Shaffer, 1976) as the dependent measure. Again, the bulk of the evidence suggests better performance with target position known in advance, although Shiffrin et al. (1976) do suggest some exceptions.

What do these results tell us about the role of attention in perception? I shall show here that, for one particular class of theories, we may distinguish two logically separate questions about that role. Results on preknowledge of a target's position are relevant to one of these, but not to the other. In particular, they are not relevant to the question of how fully stimulus information (e.g., detailed form) is analyzed prior to attention, in the sense that it can already be of use to the system. The results are consistent with any arbitrary claim concerning the extent and detail of such analysis.

This is particularly interesting since the results are often cited in support of the position that attention can facilitate the very "early" stages of perceptual analysis (e.g., Bashinski & Bacharach, 1980; Hoffman, 1975; Keren & Skelton, 1976). Yet most "early selection" conceptions—conceptions of how attention might influence "early" perceptual processes—do impose some limit on the sorts of stimulus information that already preattentively can be of use to the system. The usual such view is that only a crude perceptual analysis precedes attention, leaving detailed information (e.g., concerning the exact form of a letter or word) as yet undetermined or unavailable (e.g., Hoffman, 1975). The contrast is with "late selection" views which impose no such limit on preattentive analysis (e.g., Duncan, 1980b). My argument here will be that results on preknowledge of a target's position may simply not be relevant to the evaluation of these opposing conceptions.

Figure 1 illustrates one theory of attention (Duncan,

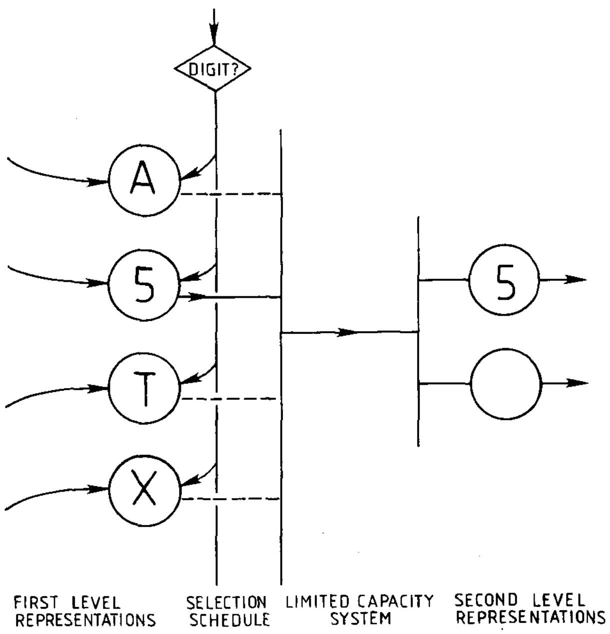

Figure 1. Two-level perceptual representation of four alphanumeric characters assumed present in the visual field. Though only form information is shown, the representation of each stimulus would include also information concerning position, color, size, and so on.

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1980b) of the general sort I shall be considering. I shall return shortly to the case of identifying a target with or without preknowledge of its position; for the moment, Figure 1 simply assumes present in the visual field an array of four alphanumeric characters, A5TX. Two levels of perceptual representation are distinguished. At the "first level," processing is parallel: representations of the four characters are formed simultaneously and (lateral masking apart) without mutual interference. In fact, Duncan (1980b) suggested that a great deal of information about each character is already usefully represented at this level, including form as well as "simpler" stimulus characteristics such as position, size, color, and so on; but, for present purposes, this is not important. What is important is that no information at the first level can yet serve as the basis for a perceptual report. Phenomenally, nothing has yet reached awareness. To allow a report (or to reach awareness), a stimulus representation must be chosen ("selection schedule") from those present at the first level and passed through a "limited capacity system" to the "second level." Phenomenally, this would correspond to directing attention to the stimulus. Importantly, the limited capacity system cannot, without loss of performance, pass more than one stimulus at a time. It provides the major limit on our ability to identify (divide attention between) several stimuli at once.

It is worth making explicit that we should expect the potential to employ a large number of different selection schedules in choosing a stimulus for passage from the first level to the second. Figure 1 shows what might happen if a person is looking for a digit target among letter nontargets. Each first level representation is interviewed to see whether or not it is the representation of a digit (assuming such information to be available at this level): only the "5" passes on. But, equally, a person might wish to report only the stimulus in a given spatial location, or in a given color, or adjacent to a bar-marker also present in the display, and so on. In each case, a different property of first level stimulus representations would be interviewed to determine passage into the limited-capacity system.

It is important that for present purposes this theory serves only as an example of a broad class of theories sharing certain crucial common features. These include the distinction between a first, parallel level of stimulus analysis and a second, limited-capacity process, and the important claim that information at the first level cannot yet be reported, so that even though a certain stimulus characteristic (e.g., form) may for some purposes be usefully represented at this level, it cannot be reported until the stimulus has attracted the limited-capacity process also. Theories of this general sort have been described by many authors (e.g., Allport, 1977; Johnston & McClelland, 1980; LaBerge, 1973; Posner, 1978). Although they differ among themselves over the degree of useful information represented at the first level and over the precise function of the limited capacity system, for present purposes such disagreements are immaterial.

We are now in a position to distinguish two quite different questions. The first concerns the sorts of information usefully represented at the first level, that is, prior to attention. This question invites two well-known experimental approaches. Can attention (on the theory: entry into the limited capacity system) be directed on the basis of a given stimulus property? If so, then this property must be usefully represented prior to attention. It was this criterion, for example, that led Duncan (1980b) to suggest that alphanumeric class is often thus represented. Alternatively, can some other use be made of the given stimulus property, even for stimuli never attended? Again, claims and counterclaims about the preattentive availability of form information, based on the use of unattended words as "primes" on a simultaneous task, are highly familiar (e.g., Allport, 1977; Bradshaw, 1974; Inhoff & Rayner, 1980).

The second question concerns the relative efficiency of different selection schedules. We have said that first level processing is parallel across objects simultaneously present in the visual field; but this does not imply either that different object properties—position, color, size, alphanumeric class, and so on—are all derived with equal speed or accuracy, or that all are equally effective in guiding access to the limited capacity system (guiding attention). Indeed, it is obvious on general grounds that this will not be so. Selection schedules will vary in efficiency. The speed with which a given stimulus representation is passed into the limited capacity system, or the chance of its passing in at all with a short exposure duration, will depend on the property used to choose this particular representation for passage. As an example, we find, if we ask subjects to report as many letters as possible from a briefly presented array, that more are reported if selection is to be based on position ("Report letters from the top row") than if it is to be based on color ("Report red letters"), and so on (von Wright, 1968, 1972). For the moment, we may leave open the explanation of such differences, and simply note that they can be expected to occur.

Let us return, then, with these two separate sorts of question in mind, to the case of a single stimulus (e.g., a letter) presented in an otherwise "blank" field, with or without preknowledge of position. To allow a report, a representation of the target must be passed from the first level to the second. A few moments' thought shows that, even though the target is the only "stimulus" the experimenter presents, still there remains the problem of selecting the correct information for passage into the limited-capacity system. It would, after all, be possible to pass, instead of the target, a representation of some other, empty part of the stimulus field. Phenomenally, this would correspond to directing attention to that empty part of the field—surely a possible experience. The stimulus representation entering the limited-capacity system might at that moment be that of an area of white tachistoscope card; but it is, after all, only a convention that we choose to call this "blank." Even here, then, some selection schedule is needed to ensure that the correct information passes from the first level to the second.

Interpreted in this way, we see that the comparison of performance with and without advance knowledge of target position in fact reflects a question about the comparative efficiency of two different selection schedules. When the target letter arrives, it (as opposed to some other empty part of the field) may, in one case, be chosen for passage into the limited-capacity system on the basis of advance knowledge of its spatial position. (It may be suitable to think of attention being "pointed" in advance at that position.) In the other case, the different parts of the visual field in which a stimulus might have appeared must each be interviewed to see which, in fact, contains a letter rather than white background, and the target must be chosen for passage (attention directed) on this basis.

It is, in my view, a very interesting result that one of these selection schedules is better than the other. It must be important that selection is especially effective when based on advance knowledge of position. But two points are worth making clear. Absolutely no *prediction* could have been made from the theory as it stands, since the relative efficiency of different selection schedules is, as yet, purely an empirical matter. And the result is simply not relevant to the other sort of question arising within this theoretical context, the question of what sorts of information are usefully available at all at the first level, or prior to attention. It is, for example, perfectly consistent with the claim that complete and detailed form (or any other) information is thus available.

Much the same applies to the case of a target stimulus presented in a field of other similar stimuli, with target position either (1) known in advance or (2) indicated by a bar marker or similar cue, simultaneous with the stimulus field or presented just at its offset (Butler, 1980a, 1980b; Eriksen & Hoffman, 1973; Shiffrin et al., 1976). Again, we are concerned with a comparison of two different selection schedules or processes. In the one case, the target, when it arrives, can be selected for passage into the limited-capacity system on the basis of advance knowledge of its spatial position. In the other case, after presentation of the stimulus field, first-level representations must be interviewed to locate the bar marker (or similar cue) and to show which item in the field it indicates, a process which, of course, cannot begin until the marker itself arrives. Again, these are simply different sorts of process, and we have no reason to expect equal (or unequal) performance in the two cases. Again, it is a most interesting result that preknowledge of position affords a better selection cue than adjacency to a simultaneous bar marker; but, again, it is not a result relevant to the question of what sort of perceptual representation precedes attention.

A contrast may be worthwhile between these results and a rather different set reported by Shiffrin and his colleagues (Shiffrin & Gardner, 1972; Shiffrin, Gardner, & Allmeyer, 1973). In the typical experiment, the task is to detect a target (e.g., the letter T) presented at one of the four corners of a square. Other corners contain nontarget material (e.g., the letter O). In one condition, only two corners are to be considered at a time (the subject knows in advance that, at this time, the target will not occur in either of the other corners), while in the other condition all four corners are to be considered at once. Although there is reason to doubt the generality of the result (Duncan, 1980a, 1980b), it is interesting that, in a sequence of experiments, Shiffrin and his colleagues found no difference in performance between these two conditions. This has been taken to conflict with the results described earlier, since here no improvement in performance resulted from increased certainty concerning the (momentary) position of the target.

On the present theoretical position, we may note that in neither condition of the Shiffrin experiments could a target have been chosen for entry into the limited-capacity system simply on the basis of advance knowledge of its spatial position, since in neither condition was this position known exactly. Instead, the contrast was between two alternative and four alternative positions. In both cases, it would have been necessary to interview first-level stimulus representations in search of the specified target property, for example, target T vs. nontarget O, only passing into the limited-capacity system a representation with this property. It would be a mistake to say that in the two conditions selection schedules were identical. We would assume that in one case four stimulus representations at a time were to be interviewed in search of the target property, while in the other case only two were thus to be interviewed, representations of material at the remaining corners being rejected on the basis of advance knowledge that these positions were irrelevant. Still, given the similarity of the two selection schedules, similar performance in the two conditions may not have been surprising (though, again, it could not have been firmly *predicted*).

An important point must be emphasized. On this sort of theoretical position, our two experimental questions must be kept carefully apart. Experiments on the comparison of selection schedules can give fascinating results: it must be important that advance knowledge of position affords such an excellent (perhaps the best) selection cue. But they cannot on their own cast light on the question of what stimulus information is usefully represented at all at the first level, or prior to attention.

The special feature of the present position is the explicit assumption that preattentive perceptual representations, however detailed and complete, are not yet available for report. For report, a stimulus must attract also the further, limited-capacity process (attention). I have shown that if this is so, a new interpretation attaches to the improvement in performance that can follow advance knowledge of a target's position. In contrast with most conceptions of an "early" perceptual role for attention (Bashinski & Bacharach, 1980; Hoffman, 1975; Keren & Skelton, 1976), no necessary limit attaches to the completeness or accuracy of preattentive perceptual analysis, in the sense that there is no necessary limit to the completeness or accuracy of perceptual information already preattentively of use to the system. If such a limit is, in fact, to be found, it cannot be by experiments on the improvement of performance by advance knowledge of target position. These, instead, raise a different question: Why is it that advance knowledge of position affords such an excellent cue for attentional selection?

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