Defence Life Science Journal, Vol. 4, No. 3, July 2019, pp. 197-202, DOI : 10.14429/dlsj.4.13956

Review Paper

Target Detection: Its Relation with Individual and Target Features

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ABSTRACT

The phenomenon of target detection is studied. Explored its correlates using the technique of Narrative Overview. The phenomenon of target detection begins with the process of visual search. The saliency of the targets, acts as a factor to make the search efficient. The processing of the stimulus (using Bottom-Up and Top-Down approaches) is achieved by the engagement of personal characteristics of the individual like cognitive ability and perceptual speed. The role of these individual processes and their interaction with each other to help achieve target detection is the focus of the present study. The tests designed to measure these individual processes are also listed.

Keywords: Target detection; Sustained attention; Correlates; Visual search; Spatial orientation; Cognitive style; Perceptual speed.

1. INTRODUCTION

According to Cavanagh[1], an important aspect of vision is not what we see in the visual field but the processing of that information to make a unique percept based on internal sources and personal experiences, which will be a personalised representation of the stimulus for the individual. Attention is the mechanism that turns looking into seeing[2]. Our senses are constantly bombarded with a variety of information from our surrounding environment. An immense wealth of information in unlimited capacity reaches our visual sensory system, which is handled by our limited visual processing system. Attention helps in selectively processing the vast amount of data and bringing into focus only a portion of it, like a spotlight or a zoom lens, so that only a specific location and/or relevant information is attended to allocating greater resources to them. This processing of visual stimuli is achieved by employing one of the two approaches- bottom-up (B-U) or top-down (T-D). The bottom-up approach is involuntary, rapid and depends on the characteristics of the incumbent stimuli, requiring the least effort from the individual. The unique characteristics of the stimuli or its stark difference from the background and/or its surrounding objects 'draws attention' of the individual. On the other hand, the top-down approach requires effort from the individual and is comparatively slower. The top-down approach is employed when one intentionally engages in a search process to find something specific. In the T-D approach the individual has to 'pay attention' to the details of the object/s. The T-D approach is employed more often when thesearch process is goal directed and hence an important phenomenon in target detection. The features of the target, however, may make it necessary that the bottom-up approach be employed[3].

Human uses this phenomenon of target detection in a constant need to monitor the environment, detect, classify and locate specific events and track targets over a specific region[4,5,] both in the mundane civilian tasks and the complex military setup. To detect an object as a military vehicle, distinguishing the object as one of the friend (distractor) from that of the foe (target), identifying its potential threat and aiming for it, is very crucial. Target detection abilities are thus a necessity in analysts.

Target detection is, hence, studied as a subset of attentional abilities. It is a function of interplay of various other variables and cannot be measured as a singular process, thus it is important to study its correlates. A correlate is a variable that is related to another variable[6]. The purpose of this paper is to establish these correlates of target detection. It is necessary to identify these variables as target detection ability is pervasive in all walks of life and thus important to improve upon.

The seeds of the relationship between attentional processes, perception, and consciousness, were shown by Anne Treisman[7] in her 'feature integration theory' (FIT). Though this theory has received various criticisms[8], it is still a powerful interpretative framework to understand the critical involvement of spatial attention, object spatial coding and feature binding in visual conscious experience[9]. Treismanjustified the relevance of FIT in her later works on illusory conjunctions and the symptoms experienced by patients with simultanagnosia[10].

Carrasco[11], *et al.* used the test of target detection to study

Received : 11 January 2019, Revised : 12 April 2019
Accepted : 29 April 2019, Online published : 15 July 2019

the process of visual search. Their study addresses the issues of spatial resolution and target features as necessary in the process of visual search. Verghese[12] emphasises the importance of attentional abilities in identifying targets in a visual search paradigm. Tavassoli[13], *et al.* study the relevance of specific features of targets such as spatial frequency, orientation and saliency as necessary indicators of better target detection functions. The cognitive style of the individual have also proven to be effective performance variables in search tasks[14]. All these studies have measured various dimensions of psychological abilities and proven their importance in the search performance. However, no study has combined the observed effects to thereby determine their relationship. This paper reviews literature on various work in the field of target detection, visual search and visual attention and thereby explores the various psychological mechanisms that are collectively engaged in achieving the phenomenon of target detection. This paper aims to establish the studied variables as correlates of target detection. All the previous studies have been compiled and synthesised to reach a consensus on the correlates.

We first begin with the process of achieving target detection, then explain the characteristics of the target that help in achieving target detection, and finally explore the characteristics in an individual that makes one a better performer in the target detection task. This will help us determine that if an individual's performance is better on these variables, his/her performance in target detection tasks will also be better.

2. METHODOLOGY

This review paper employs the method of narrative overview in order to study the various articles that have been published in the area of target detection, visual search, attention and cognitive abilities. Narrative overviews are comprehensive narrative syntheses of previously published information[15]. In this the author reports his findings in a condensed format that typically summarises the contents of each article that has been reviewed thus presenting pieces of information into one readable format. Search was performed with the key words 'target detection' 'attention and target detection' 'visual search and target detection' 'target detection and cognitive abilities' 'target detection and cognitive style' 'target detection and perceptual speed' 'target detection and military psychology' in the Google Scholar search engine. Articles were shortlisted on the basis of relevance to the study. Manual search was then performed using the reference section of the selected articles. Target detection studies in other fields such as medicine and technology were excluded, only those related to cognitive sciences and psychology were included.

3. THE PROCESS OF TARGET DETECTION

3.1 Visual Search

Visual search is the process of looking for a specific target that varies in one or more dimensions from its surrounding distractors[8].

According to Verghese[8],the ease of search depends chiefly on how distinguishable the target of search is from the background. A target that stands out from its background in stark contrast is easier to locate than the one that blends in it, as used in the technique of camouflaging used in the uniforms and vehicles of the military. They are made in such a way that they can blend into the background of trees/dust/snow of the ground, thus making it difficult for the enemy to spot them.

3.1.1 Theories of Visual Search and their relation to Target Detection

The efficiency of visual search is dependent on how different the target is from the distractor and how similar the distractors are in their features. In accordance with the popular Feature Integration Theory, proposed by Triesman[7], perceiving individual features of an object is automatic and requires little mental effort- thus carrying out a pre-attentive processing, whereas, putting together pieces of information to form complex or coherent object requires greater mental capacity. However, Joseph[16], *et al.* that it is unlikely for attention to be employed only in the latter, complex conjunction search, and claimed that the pre-attentive features also employ attentional systems, thus making attention indispensable in the search performance.

Recent studies in visual search rely on the signal detection theory (SDT) to explain the detection and discrimination in search paradigms undermining the role of the limited (attentive processing) and unlimited capacity (pre-attentive processing) of attentional systems as assumed by the FIT[8].The SDT, unlike the FIT, enumerates the psychophysical mechanisms of attentional systems. Specific neurons are cued implicitly or explicitly to the target objects or locations, which then are triggered by the presence or absence of the target, employing attention in the process of visual search[17-18]. Verghese[8] further theorised that attention could improve the search phenomenon.

3.1.2 Visual Search and Attention

Attention works by enhancing response strength to the target or excluding the response to the distractor. On a neural level, attention improves performance by sharpening the target-specific neuron filter, so that the 'signal' is enhanced and the 'noise' is suppressed[19,20]. Attention in general improves performance toward the relevant stimuli and excludes irrelevant stimuli. In the spatial context, attending to a specific increases the gain of neurons tuned to that location, thereby enhancing the search performance in that location, while excluding the response of neurons tuned to other locations[8]. Thus, attention is employed to enhance the responses to the target and restrict the faculties of attention towards the distractors. Hence, attention combines the mechanisms of signal enhancement, external noise reduction and decisional factors to improve the task of visual search. Attention is an inevitable feature in the process of visual search; however, the amount and kind of attention employed at various stages of the search process might be different and is yet to be explored.

3.1.3 Tests of Visual Search

The cancellation test (letter/symbol) is used to test visual search. For example the cancellation task of the WAIS asks the test taker to scan either a structured or an unstructured arrangement of visual stimuli and mark targeted images within a specified time limit and taps visual selective attention and related abilities[21]. It assesses visuospatial attention and helps evaluate clinical deficits in visual scanning of patterns and spatial neglect problems. It also helps understand visuospatial attentional bias and visual exploratory performance during the target-search process. Computerised versions of this test have helped evaluate visual attention more sensitively than the traditional paper-pencil tests. This test also helps in understanding the efficiency of attentional shifts and visuospatial strategies employed in the phenomenon of target detection.

Other important processes that affect the search performance are local spatial frequency and orientation of the objects. We will now discuss the role of spatial orientations in the phenomenon of target detection.

4. FEATURES OF TARGET

4.1 Spatial Orientation

Spatial Orientation is the ability to imagine how a stimulus would appear from another perspective[22]. It requires an individual to imagine oneself in a position and view the stimulus from that perspective. French[23] defined it as the ability to remain unconfused by the varying orientations in which a spatial pattern may be presented.

Tavassoli[9], *et. al.*, claim that spatial frequency and orientation are important features in visual processing and can guide visual attention. A principal characteristic of the cells in the visual cortex is to tune in for orientation. The attentional capacities employed differ for targets with standard orientations (for example vertical lines), as compared to those with deviant orientations (tilted lines). The unique characteristics of the target in the latter make it 'pop-out' of the display, thereby enhancing the responses to the target. Thus, spatial orientation of the target plays an important role in the target detection performance.

The difference in the orientations of the target and the distractors predicts the probability of errors in the search task[8]. An inverse relationship is established, showing that, lesser the difference in the orientation of the target and the distractor, greater the probability of errors. Increased distractor heterogeneity, degrades the performance of the observer in target detection. Hence target detection becomes a function of discriminability[8]. It can be manipulated by priming the observer to a location or a feature of the target. It employs the enhancement and exclusion responses in combination, thereby increasing the discriminability, which results in the effective response towards the detected target and suppression of response toward the distractor.

4.2 Spatial Uncertainty and Use of Cues

To aid the individual in recognizing the spatial orientation of the target in laboratory tasks, experimenters use a cue (in the direction of target, away from the target or randomly dispersed on the screen), which precedes the presentation of the target. Precuing helps manipulate spatial attention. Thereby the individual is focusing on the point and (imaginarily) positioning oneself in a particular direction of reference to the target which is about to appear so that its orientation can be determined. Spatial uncertainty is, therefore, inversely related to performance, as it becomes a cause of noise that can be confused with the target signal.

4.3 Target Eccentricity and Target Detection

The position of the target in the field of vision also has a remarkable effect on the phenomenon of target detection. Performance on the search task deteriorates as target presents itself further and further at the peripheral locations[7]. The sensitivity of the visual system to spatial frequency decreases with eccentricity, as a large portion of the cortex is involved in the processing of incumbent stimulus from the central part of the visual field than the periphery. Target processing is enhanced at the fovea and the features of the target are variedly processed depending on the area of retina that receives the signal. Also, the search performance deteriorates in detection, localisation and identification tasks as the target appears farther from the center and displays eccentricities[7]. However, the details of the above are not within the scope of this study.

4.4 Tests of Spatial Orientation

The mental rotation test and paper folding test are used to test spatial orientation.

5. INDIVIDUAL CHARACTERISTICS

5.1 Cognitive Style

To identify a target, it is important for the individual to perceive the environment, assess the existing information, organise it and interpret it before finally making a decision to act upon it; this process is dependent on the cognitive style of the individual. Studies conducted in the field of attention have further determined the role of cognitive style as an effective performance variable in the search tasks[8]. Field dependent-independent (FDI) is a construct of cognitive style that is widely studied. It interacts with the attentional capacities of the individual, playing a major role in the phenomenon of target detection. In their study, Guisande[10], *et. al.*, measured specific aspects of attentional functioning in relation to cognitive style of the individual. They observed various characteristics of the field independent individual that makes them better performers of target detection tasks.

- The individual with field independent (FI) cognitive style approaches the partial aspects of the environment, thereby performing efficient parallel processing of information to spot the target
- The FI individual has the same degree of attentional capacities as the individual with field dependent (FD) cognitive style; however, the FI individual has an effective process control and efficiently allocates attentional resources to the task, discriminates relevant stimuli from the irrelevant and thus performs a successful target detection. On the other hand, the FD individual, in contrast has a different approach that is helpful in other tasks.
- The FD individual has a global approach toward the environment and thus faces difficulty in extracting information from a masked context; they find it difficult to inhibit the irrelevant stimulus while focusing on the relevant stimulus, thus making them perform poorer in

target detection. This also depicts their reduced capacity of sustained attention.

- They have reduced efficiency in using attentional resources, which makes it difficult for them to attend to target cues. The difficulty rises when the distractors are salient or very closely related to the target.

5.1.1 Performance of FI and FD Individuals in Different Tests

The performance of both FI and FD individuals, of same age, with matched IQ, perform equally well in the Digit Forward Test, which marks that the storage capacity and the resistance to distraction is similar in both groups. However, there is a significant difference in the Digits Backward Test, Digit Symbol Test and the Visual Search and Attention Test, where the FI individual perform better than the FD individuals. This finding reveals that the specific attentional functioning of verbal working memory, focus, shift and maintaining of attention and vigilance or sustained attention (as measured by the above tests, respectively) is better in FI individuals than FD individuals are. Hence, cognitive style determines the use of attentional capacities, thereby exerting control over the phenomenon of target detection. The embedded figure test is used to measure cognitive style.

5.2 Perceptual Speed and Neural Pathways of Processing

French defines perceptual speed as the task of finding a memorised figure from a group or pattern of distracting material, including the ability to compare items and/or locating a unique item in a group of identical items[8]. The individual's speed in discriminating, making comparisons, recognizing predetermined yet novel configurations and classifying configurations into categories all form subsets within the factor of perceptual speed[8]. As we have discussed above target detection is a function of discriminability. The speed with which this discriminability is achieved is perceptual speed. The ability of object classification is considered a very fast process among which faces are recognised faster than any other object and they are not effected by inverting the target[24].

Kirchner & Thorpe[25], in their study on how perceptual speed can be influenced by the semantic content of the scene report important findings. For example, it is easier to spot an animal in its natural setting. Even when participants have no prior information about targets to look for, the accuracy and speed in response is very high when the target is in its natural setting[26]. The neural basis for the rapid detection of targets within the natural settings are also studied[8]. The authors claim the involvement of the ventral visual pathway that is said to be responsible for object recognition, the frontal eye fields (FEF) and the lateral intraparietal sulcus (LIP). The FEF is said to be engaged in target discrimination and very early processing (40-80 ms after stimulus display). This is, however, only the initial wave of processing which is sufficient to evoke a behavioral response i.e., in response to the target detected; after which a series of complex events occur which are helpful in segmenting the scene, selecting the part of the image where target is located and generating conscious perception. We can note here that the later processing helps in specific feature analysis, and thus the more similar the target is to the distractor the later it is perceived. Perceptual speed and accuracy are improved by spatial covert attention.

5.2.1 Tests of Perceptual Speed

Symbol modalities test, Finding 'A' test, go/no-go tasks and n-back tasks are used to measure processing speed.

6. CONCLUSION

In order to successfully detect a target, an individual has to intentionally allocate his/her attentional resources that guide the focus of attention to select relevant information to process. The process of bringing into focus a specific field is dependent upon the individual's cognitive style- if he or she perceives the whole or parts of the whole. The features and complexities of the target along with its position in the visual field play important role in performing an efficient search task. These properties of the visual stimulus such as orientation and eccentricity, along with its variation from the distractor/s acts as a guiding representation to the deployment of attention[27]. Finer details of the target object are easily noted when attention is directed in the target location than away from it, improving the search performance.

Visual search is performed by employing attention, perceptual speed, and based on cognitive style of the individual. It is affected by the saliency of targets. Attention, thus, seems to play a vital role in the processes of visual search, target discrimination and perception. Cognitive style, in turn, exerts a control on the attentional processes being employed. Spatial attention and specific features of the target affect perceptual speed. The test stimuli used for measuring cognitive style is affected by spatial orientation. Hence, there is a complex interplay between these processes of visual search, attention, spatial orientation, perceptual speed and cognitive style that ultimately lead to effective target detection.

Variables in the phenomenon of target detection have been discussed under two subheads, that of the individual and that of the target. Along with brief exploration of the psychological and related biological factors of the individual, the variables of the target that affect the individual are also explained. The limitation of this study is the fact that this is an exploratory study of literature which has identified the variables involved in target detection but it still needs to be confirmed how all these theoretical variables interact with each other and how much they contribute, individually to the phenomenon of target detection. After establishing relationships between variables identified above, structural equation modelling is a suitable choice to see how these variables fit and would help analyse their interaction.

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She has contributed in conceptualisation of the paper, the reviewing of the drafts and added from her field expertise as contribution to the present paper.

Mr. Syed Yaseen is a post graduate from University of Hyderabad and was working on the relationship between gender and military. He has worked in the field on how gender and sex affect various facets of a soldier and has contributed on how studies across the military are dwelling on these relationships and what are the shortcomings of the review on this aspect which were then incorporated in the article.
His contributions include the reviewing of the paper and suggesting research methods to be incorporated in the reviewing of the paper.