Personality Correlates of Visual Attentional Processing

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A great deal of research into visual attention has used search tasks. A distinction has arisen between fast parallel search and slower, serial search. Parallel search can be used when a target differs from all of the distracters by a single feature, but a serial search strategy must be used if the target differs only by a combination of features. Individual differences in performance have received scarce attention. In the current study participants performed 2 visual search tasks, 1 suitable for parallel searching and the other unsuitable, which would therefore require a serial search strategy. Participants also completed the Temperament and Character Inventory, which is based on a neurochemical model of personality. Significant correlations were found between 'Novelty Seeking' and parallel search slopes and between 'Persistence' and the ratio of negative to positive serial search slopes.

Over the past two decades, research into visual attention has been strongly influenced by two paradigms, the visual search technique (Treisman & Gelade, 1980) and the cued orientation technique (Posner, 1980). Visual search has been a particularly attractive methodology because of the variety of measures that can be derived from the raw data. In particular, the linear relationships between set size and indices of processing time has permitted the testing of numerous hypotheses about the nature of the information processing under differing task conditions. In a typical visual search experiment, the participant is presented with an array of stimuli items on a monitor and must search for a particular target, making one response for detection or another for a failure to detect. By varying the total number of items in the array, data can be collected for different display sizes. Regression analysis can then be performed to estimate the amount of time needed to process a single item in the display (the slope value) as well as an estimate of the response time independent of search time (the intercept value). Of these two figures the slope values are usually considered to be of most interest and are used to develop theories of how search is performed for different configurations of target and non-target stimuli.

In their original experiment, Treisman and Gelade (1980) found that when the target and non-targets items differed by only a single feature (e.g. a green letter 'O' amongst red and blue 'O's) then slope values would be small. In other words, increasing display size has very little effect on how long people need to process it. Treisman and Gelade interpreted this as evidence that early visual attention processes operate in a parallel mode. This is known commonly as 'feature search', and is associated with the perceptual phenomenon of 'pop-out', with the target item appearing to emerge from the background. Conversely, if the target differs by more than one feature from the targets (e.g. a blue letter 'O' amongst red 'O's and blue 'T's) then the slope values are usually much higher. Increasing display size has a detrimental effect on how fast the display can be processed. Under these conditions, known as 'conjunctive search', attentional processes are thought to operate in a serial mode.

The serial processing hypothesis is supported by the pattern of results for true-positive (target present) and true-negative (target absent) responses. Across a series of trials, assuming serial search, a person will need to examine half of the items on average before finding the target, if one is present. However, in a target-absent display all the items must be examined before a decision can be reached. Theoretically, therefore, the slope of the true-negative responses should be about twice that of the slope for the true-positive responses. This 2 to1 ratio was confirmed by Treisman and Gelade. Other researchers have confirmed this general finding, but commented that the ratio is often slightly larger than 2 to1 (Zacks & Zacks, 1993). Treisman (1991) has also acknowledged this and suggests that some participants may recheck before responding in target-absent trials. This tendency is presumed to vary between individuals and may reflect underlying personality characteristics.

Precisely why apparently small changes in stimulus-background relationships should lead to such dramatic changes in mode of attention processing is not yet fully resolved, and not all researchers agree that the parallel-serial distinction is useful. However, attempts have been made to distinguish the physiological aspects of these two modes of attention. Corbeta, Shulman, Miezin and Peterson (1995) used PET scanning and found that conjunctive searching but not feature searching activated the superior parietal lobule, a finding subsequently confirmed by Goebel, et al. (1997) using fMRI. However, these studies did not reveal any areas that appeared to be specific for feature search, thus offering only a single dissociation between neuronal structure and mode of information processing. Another approach has been through the study of selected clinical groups. Studies of people with Parkinson's disease (PD) have found impairments in feature search, but not conjunctive search (Troscianko & Calvert, 1993; Lieb et al., 1999). Although a number of brain monoamine systems are disturbed in PD, the disease is most closely associated with hypofunction of the nigrostriatal dopamine (DA) system, as well as the mesolimbic and mesocortical systems. This suggests the hypothesis that feature search may be particularly susceptible to DA hypofunction, although the anatomical substrate is less certain.

Dopamine (DA) is a critical brain neurotransmitter, and is involved in many aspects of information processing, with its action manifest in behavior at all levels. There is the suggestion that DA status is also important in determining certain enduring behavioral and cognitive traits, or personality (Cloninger, 1987). Personality is often conceptualized as being partly specified by the cognitive processes of the individual (Pederson, Magaro, & Underwood, 1982). Such conceptualizations would suggest close associations between individual differences in personality and basic modes of information processing (e.g. those involved in visual attention), particularly when they rely upon the same neurochemical substrate. Despite this theoretical link, little research has been performed into the relationship between personality and visual attention.

Sen and Goel (1981) compared individuals who scored high on the trait characteristics of extraversion or introversion on a signal detection paradigm. They found that extroverts were more likely than introverts to miss peripherally located targets. While hinting at a possible difference in cognitive style, such results say little about the mode of information processing. Magaro, Smith and

Ashbrook (1983) employed a Neisser-type search task in subjects scoring high on a trait index of hysteria compared to normal controls. The task involved participants scanning a list of stimuli of varying length, searching for a pre-specified target. As in feature and conjunctive search paradigms, regression analysis was used to estimate the processing time per item of information. Magaro et al demonstrated that high-hysteria participants scanned each item more slowly than normal controls. The findings were interpreted within Neisser's explicitly serial model of attention, with no discussion of any alternative modes of processing, nor any underlying physiological basis for the personality trait being measured.

In the current investigation it was decided to examine aspects of normal personality believed to have neurochemical bases in respect to the two modes of attentional process described above, namely feature and conjunctive searching. Of particular interest, given the above discussion, was the relationship between mode of processing and aspects of personality believed to be influenced by the brain's DA systems. Cloninger's neurochemical model of personality offers one of the most explicit accounts, and provides the Temperament and Character Inventory (TCI) for its measurement (Cloninger, Dragan, Svrakic, Thomas, & Przybeck, 1993). This inventory comprises 4 factors assessing distinct suggested inherited temperament traits: Novelty Seeking (NS), Harm Avoidance (HA), Reward Dependence (RD) and Persistence (P). Cloninger has postulated that of the first 3 of these each is mediated mainly by the neurological tone of a single neurotransmitter: DA, Serotonin (5-HT) and Norepinephrine (NE) (see Table 1). The fourth factor, P, was originally a subscale of RD but was later separated on the basis of factor analysis. The chemical basis of P is unclear.

For the current study, NS was of particular interest, as it is supposedly related to brain DA levels, and so possibly to attentional processing. It was therefore hypothesized that processing speeds (as reflected by slope) on the feature and conjunctive search tasks will be related to individual NS scores. In particular, feature search would be more influenced as this is normally performed in a near perfect, parallel manner and so will be susceptible to alterations in processing style reflecting normal differences in the DA system. Finally as described above, the 2 to1 ratio of negative to positive conjunctive search slopes may also be influenced by individual differences relating more to the cognitive style (e.g. tendency to check) than to more basic differences in the speed or style of information processing. It was hypothesized that the ratios between slopes for true-positive and negative responses would be related to the persistence of the individuals, or the trait of 'P' on the TCI (see Table 1).

Table 1 Descriptions of the 4 temperament traits from the Temperament and Character Inventory of Cloninger, et al. 1993.

Novelty Seeking (NS): Dopamine
Described as a behavioral activation system. Represents a bias in the initiation of exploratory behavior, of impulsivity, of quick loss of temper and avoidance of frustration.

Harm Avoidance (HA): Serotonin
Described as a behavioral inhibition system. Represents a bias in the cessation of behavior, of shyness and fear of uncertainty.

Reward Dependence (RD): Norepinephrine
Described as a behavioral regulation system. Represents a bias of maintaining ongoing behaviors, of sentimentality, of social attachment and dependence on others.

Persistence (P): Unknown Perseverance of behavior despite frustration or fatigue.

Method

Design

A correlation design was used to estimate the relationship between experimentally derived results on visual attention tasks and personality scores. This design was chosen to allow observation of the contribution of personality to empirically derived measures of attentional function. A cut off level of $p < .05$ was taken as indicative of statistical significance in all calculations.

Participants

Participants ($N = 28$) between 21 and 38 years old (mean 27.5) took part in this study ($n = 17$ male and $n = 11$ female). All participants were unpaid volunteers and served in response to an advertisement. Throughout the study, all participants were treated in accordance with APA guidelines for the ethical treatment of human participants (1992a).

Materials and Apparatus

The visual search experiments were performed on a Dell laptop computer with a color 12.1" LCD display. Subjects sat approximately 2 feet from the display in a room with low level ambient lighting to permit good visibility. Responses were made via a button pad linked to a digital timing card in the PC (Amplicon PC214E). Input from the keys was sampled at the rate of 1000 Hz. The Temperament and Character Inventory of Cloninger et al., (1993) was used to assess personality and individual differences in NS, HA, RD and P.

The Experimental Tasks

Two experimental tasks were performed by each participant in counterbalanced order. The feature search and conjunctive search tasks were identical but for the target stimuli. In the feature search task the target was either any green letter or a letter 'X', while in the conjunctive search task it was a blue 'O'. A target was present on half of the trials. For each trial the participant pressed one button for 'target present' and another for 'target absent'. The total number of distracters was varied pseudorandomly such that the total number of elements on the screen was either 1, 5, 15 or 30. The distracters were made up of roughly equal numbers of blue 'T's and Red 'O's. The elements were displayed semi-randomly across the central area of the screen, and not in a regular grid. Elements never overlapped. For each experiment there were 20 practice trials followed by 160 data trials. These were comprised of 20 trials of each of the 4 display sizes and the 2 display types (target-present or target-absent). Errors were recorded but not used for response time analysis and randomly replaced later in the experiment so that the total number of data points was not reduced. Any trial that followed an error trial was also excluded from the analysis in order to control for post-error slowing.

Procedure

Participants were instructed to search for any green letter or any 'X' in the feature search task and for a blue 'O' in the conjunctive search task. Two fingers of the dominant hand were used to respond via the response keys, one for target present and the other for target absent. They were further instructed to respond as quickly as possible, but without making a large number of errors. They received auditory feedback whenever an error was made. After completion of the two experimental tasks participants completed the Temperament and Character Inventory. The entire test session lasted approximately one hour.

Results

Median response times were calculated for each of the 8 conditions in each experiment (see Figure 1).

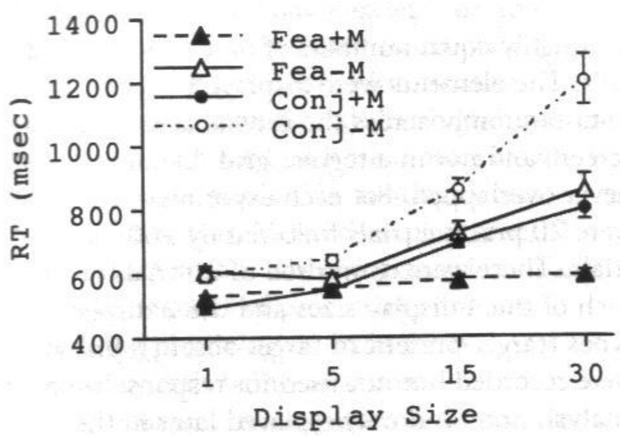

Figure 1 Group means of median response times for positive (+) and negative (-) responses in the feature and conjunctive search tasks.

Individual medians were then used to calculate the regression slope and intercept values for the 4 task types (feature search positive and negative responses and conjunctive search positive and negative responses). For the conjunctive search task only, each participants negative response slope was divided by the positive response slope to give a ratio. Negative slope data from the feature search task is of less theoretical interest and is not reported in this study. Scores from the TCI were extracted using standard scoring procedures.

The mean number of false positive and false negative responses were calculated and are shown in Table 2. Although the error rates were relatively low in each condition, the average number of errors made by each participant was 4.93 in the feature search and 8.43 in the conjunctive search tasks. This raises the issue of some participants 'trading off' of speed for accuracy (see Table 2).

Table 2 Mean number of false positive and false negative errors in the feature and conjunctive search tasks by display size and total.

	False Positive Display Size			
Task	1	5	15	30
Feature	.714	.607	.393	.357
Total	2.071			
Conjunctive	.250	.607	1.750	3.180
Total	5.787			

	False Negative Display Size			
Task	1	5	15	30
Feature	.750	.571	.643	.893
Total	2.857			
Conjunctive	1.000	.357	.321	.964
Total	2.642			

Group slope data for the conjunctive and feature search tasks are shown in table 3 and are consistent with the findings of previous studies. The slope values for the feature search task were low with a mean of 2.14 msec per item. Such a low figure is typical of feature search tasks and indicates that targets were perceived as 'popping-out' of the display. The mean slope value for conjunctive search tasks was higher at 10.78 msec per item. Such a value is consistent with a more serial mode of processing. The ratio of negative to positive search slopes was also approximately as expected. The observed ratio was 1.85 to1, close to the 2 to1 figure taken as an indication of a serial search strategy (see Table 3).

Table 3 Mean true positive slope and intercept values (and SD) for the feature and conjunction search tasks and true negative slope (msec per item), intercept and ratio of negative to positive slopes for the conjunctive search task.

Search Type	Feature	Conjunctive
True Positive		
Intercept	538.30 (75.24)	493.04 (71.04)
True Negative		
Intercept	-	549.04(73.26)
True Positive		
Slope	2.14 (1.94)	10.78 (5.06)
True Negative		
Slope	-	19.98 (13.75)
Ratio Positive to Negative Slope		1.85 (0.87)

Table 4 Partial correlation values and p values (two tailed tests) between personality traits and positive visual search slopes and with negative to positive conjunctive search slope ratios.

	Search		
	Feature	Conjunctive	Ratio
Trait			
NS	.407	.270	.092
ps	.044*	.17	.65
HA	.161	.083	.193
ps	.44	.68	.34
RD	.303	.205	.150
ps	.14	.30	.46
P	-.036	-.037	.456
ps	.86	.85	.017*

In order to assess the contribution of individual differences to the performance in the experimental tasks, correlations were performed with the TCI data. The 3 experimental dependent variables (feature and conjunctive search slopes for true positive responses, and the conjunctive negative to positive slope ratios) were compared with the 4 personality scores derived from the TCI (NS, HA, RD, P). In order to control for the effects of errors and the possible confound of participants 'trading off' speed with accuracy, partial correlations were performed with the number of false negative errors in the relevant experimental task as a factor. The correlation coefficients and associated p values are shown in table 4, where it can be seen that 2 correlations reached significance at the .05 level. The positive slope values in the feature search task correlated with NS ($r = .407$, $p < .05$) indicating that participants scoring high on novelty seeking showed higher slope values and therefore less 'pop out'. The negative to positive conjunctive search slope values correlated with P ($r = .456$, $p < .05$), indicating that individuals high on P tended to have higher ratio values (see Table 4).

Discussion

The basic findings from the conjunctive and feature search tasks are consistent with previous published studies and validate the version of the task used here. The primary aim of the present study was to investigate how individual differences may be associated with performance. It was hypothesized that the DA-dependent trait of novelty seeking would be associated with the parallel processing mode of the feature search task, but not the more serial mode of the conjunctive search task. This prediction was confirmed, supporting a possible role for DA-related process in certain types of information processing. However, the direction of the association was counter to prediction. Rather than high NS being associated with lower slopes and more parallel processing, high NS (and presumably DA tone) was associated with higher (i.e. less parallel) slopes. This finding appears to be inconsistent with the reports of increased slopes in the hypodopaminergic condition of PD.

An implication of this finding is that the proposed association between dopamine and visual attention is complicated when a personality measure of dopaminergic tone is used, and further research clearly needs to be done on the three-way relationship between cognitive processing/behavior, personality and their underlying neurochemical substrates.

The other significant finding in this study is that the negative to positive slope ratios in the conjunctive search were associated with the trait of P. An increase in the ratio implies that the participants were more likely to recheck after completing their first visual scan of a display that did not contain a target. The positive correlation of the ratios with P indicates that individuals scoring high on P were therefore more likely to recheck the display. This is as predicted. However, the lack of any proposed neurobiological substrate for P, reduces the theoretical significance of this result.

The commonly reported 2 to1 ratio of search slopes was initially sighted as support for the serial nature of conjunctive search performance (Treisman & Gelade, 1980). However, the current finding indicates that this relationship is in fact much less strict and varies between individuals, as shown by the association with the trait of P. The favored explanation for this is that participants scoring high on P will have normal positive search slopes, but take longer to make a response under conditions of the target being absent because they recheck the display before responding. However, an alternative explanation may relate to delays in initiating a response to the absence of a stimulus. In this regard, parallels can therefore be drawn between willed or internally driven action and stimulus driven action. Any action which involves responding in the absence of a target will necessarily involve to some degree a willed component (see e.g. Frith, Friston, Liddle, & Frackowiak, 1991), and greater involvement of prefrontal cortical regions. In contrast, responding to a stimulus can be considered a more 'automatic' mode of responding, with a more direct mapping of stimulus onto a motor response. Such a possibility requires further investigation in the context of visual search tasks. However, it may also be a worthwhile area of study in other experimental paradigms that involve some form of categorization of stimuli. This might also include the study of how the processes underlying willed action relate to individual differences in the personality traits such as that measured by the P-scale on the TCI.

Author Notes

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