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Air Force recruits (N = 313) viewed a long series of briefly presented, 4-word arrays. After each array, subjects received one of the four words as a probe and were asked to indicate the array location in which that word had appeared. Subjects were encouraged to distribute their attention evenly across array locations in a divided-attention condition. Different arrays presented different mixtures of novel (never repeated) and familiar (often repeated) words. Somewhat surprisingly, when a single novel word appeared with three familiar words, attention appeared to be allocated preferentially to the novel word. Subjects were encouraged to focus most of their attention on a prespecified location in a focused-attention condition and on a prespecified word in a target-localization condition. Not surprisingly, attention appeared to allocated preferentially to the prespecified locations and target words in these conditions.

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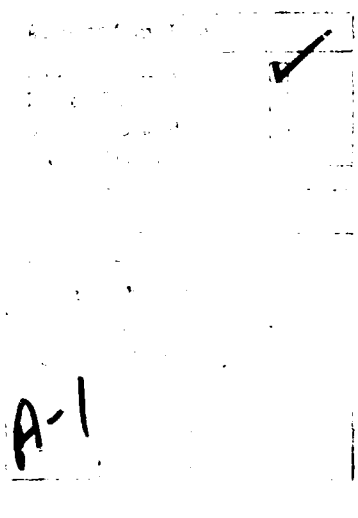

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INDIVIDUAL DIFFERENCES IN ATTENTION

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Abstract

Air Force recruits (N = 513) viewed a long series of briefly presented, 4-word arrays. After each array, subjects received one of the four words as a probe and were asked to indicate the array location in which that word had appeared. Subjects were encouraged to distribute their attention evenly across array locations in a divided-attention condition. Different arrays presented different mixtures of novel (never repeated) and familiar (often repeated) words. Somewhat surprisingly, when a single novel word appeared with three familiar words, attention appeared to be allocated preferentially to the novel word. Subjects were encouraged to focus most of their attention on a prespecified location in a focused-attention condition and on a prespecified word in a target-localization condition. Not surprisingly, attention appeared to allocated preferentially to the prespecified locations and target words in these conditions.

Subjects were classified into four attentional types based on measures of their ability to divide attention across four locations and to focus attention on a prespecified location. Most (72%) of the subjects were classified as either Divided Attenders (high divided, low focused) or Focused Attenders (high focused, low divided). These two types differed not only in terms of the measures by which they were defined but in terms of other measures as well. In particular, the general inclination to attend preferentially to novel words in a field of familiar words and to target words in a field of nontarget words was lowest for Divided Attenders and highest for Focused Attenders. It is suggested that these two attentional types are differentially suited to different tasks.

Introduction

This report summarizes the research carried out in collaboration with the Learning Abilities Measurement Program (LAMP) in the Air Force Human Resources Laboratory at Brooks Air Force Base, San Antonio, Texas. The purpose of the research was to explore individual differences in various attentional phenomena, especially the novel popout effect. Novel popout refers to the capturing of attention by a new, or novel, stimulus that appears in the company of old, or familiar, stimuli. This effect has been observed even when subjects cannot predict the spatial locations of the novel and familiar stimuli and when stimulus arrays are too brief (e.g., 100 ms) to allow eye movements. Thus, the effect appears to be based on a covert, automatic, and very rapid shifting to attention to the location of the novel stimulus in an array.

The present research sought to assess the generality of the novel popout effect, to test for complementary familiar and target popout effects, and to assess individual differences in these effects. In particular, the hypothesis was tested that these effects vary as a function of individual differences in two fundamental abilities: focused attention and divided attention.

Methodology

Subjects and Design

Subjects were 513 Air Force recruits who participated in the study as a part of their regular assignments. All subjects performed under five different attention conditions: three different divided-attention conditions, a focused-attention condition, and a target-localization condition. These conditions are described in detail below.

Apparatus

The experiment was controlled by TERAK 8510A microcomputers employing an RT-11 operating system. Up to 30 subjects were run at a time in individual cubicles. Each cubicle was furnished with a computer, TV monitor, keyboard, and instruction booklet.

Procedure

Each condition was administered in at least one block of trials. A trial comprised four successive displays: warning, attention, probe, and feedback. In each display, an array of four cells appeared in the center of the screen. The array was arranged in the form of a horizontally elongated cross. The two horizontal cells shared a common border, and the two vertical cells were separated by the two horizontal cells. The array subtended approximately 1.90 degrees of visual angle vertically and 5.0 degrees horizontally when viewed from a distance of 60 cm. The center-to-center separation was 2.50 degrees between the two horizontal cells and 1.50 degrees between the two vertical cells. Stimuli were presented one to a cell and were center adjusted.

The stimuli in the warning displays were strings of three asterisks. A warning display appeared for 200 ms and was followed 600 ms later by an attention display. An attention display contained four words, one word per cell. Each word was exposed for 400 ms and then backward masked for 100 ms by a string of 9 "X"s. After a blank period of 500 ms, a probe display was presented. One of the words from the preceding attention display reappeared in all four cells along with a question mark. The subject's task was to indicate in which of the four cells of the attention display this word had appeared. A localization response was made by pressing the appropriate one of four keys on a numeric pad on the

keyboard. The spatial configuration of the keys corresponded to that of the four cells of the display. Following a subject's response, the probe display disappeared. After a blank interval of 500 ms a feedback display was presented in which the probe word appeared for 2 s in the correct cell. There was a 500 ms interval between the offset of this feedback display and the beginning of the next trial.

A 5-sec rest period was provided after every 30 trials. During this period, the subject's percentage of correct responses for the previous block of trials was computed and displayed on the screen. A warning tone sounded 2 s before the resumption of the trials. Altogether there were 700 trials, the nature and distribution of which are described below. In all conditions, subjects were encouraged to be as accurate as possible. Thus, both instructions and feedback emphasized accuracy over speed of responding.

Conditions

Divided attention. In the three divided-attention conditions, subjects were encouraged to distribute their attention equally across the four cells of the attention displays. To emphasize this, all four cells of the warning displays contained asterisks. The conditions differed only in terms of the composition of the attention displays in terms of novel and familiar words.

Only novel words were used in the all-novel condition. The probe word was selected randomly with the restriction that each cell be probed equally often. There were 128 all-novel trials altogether: a block of 60 all-novel practice trials, and two blocks of 34 experimental trials (all-novel 1 and all-novel 2). Each of the other two divided-attention conditions was administered in a single block of 136 trials. In the one-novel condition, each attention display consisted a different novel word and the same three familiar words. The assignment of words and probes to cells was random with the restrictions that the novel word and each of the three familiar words be represented equally in each cell and be probed for equally often (viz., 34 times). In the one-familiar condition, the same familiar word appeared in every attention display along with three novel words. With the restrictions that the familiar word and each cell be probed for 34 times, the assignment of words and probes to cells was random. Subjects were not preinformed that some words would be repeated and that different mixtures of novel and repeated words would be presented in different blocks of trials.

Focused attention. In this condition, subjects were encouraged to distribute their attention unevenly across the four cells of the attention displays. Only novel words were presented. The cell to which subjects were to devote most of their attention on a given trial was indicated in the warning display. Specifically, asterisks were presented only in the cell that was most likely to be probed on that trial. The cell indicated in the warning displays and the one actually probed matched on 70% of the trials (valid trials) and differed on the remaining trials (invalid trials). Across trials, both warning asterisks and probe words were equally distributed across the four cells. Outside of these constraints, the assignment of asterisks and probes to cells was random. Subjects were informed that the warning cues would be valid on 70% of the trials and were advised to direct most of their attention to the cued cell. The focused-attention condition was administered in a single block of 150 trials, the first 10 of which served as practice.

Target localization. In this condition, a predesignated target word appeared in the attention display on every trial and was probed on 70% of the trials. The nontarget words were novel, and one was probed on 30% of the trials. The assignment of words to cells varied randomly across trials with the restriction that both target words and nontarget words be represented approximately equally in all four cells both when they were probed and when they were not probed. Subjects were informed of the statistical structure of the trials and were encouraged to locate the target word on every trial and to allocate any residual attention to nontarget words. The target-localization condition was administered in a single block of 150 trials, the first 10 of which were devoted to practice.

Condition order. Two sequential orders of conditions were prepared. Order A comprised all-novel practice, one novel, one familiar, all-novel 1, focused attention, target localization, and all-novel 2. Order B comprised all-novel practice, target localization, focused attention, all-novel 1, one familiar, one novel, and all-novel 2. Order A was administered to 277 subjects and Order B to 236 subjects. Subjects were not informed of the transitions between all-novel, one-novel, and one-familiar trials. Successive blocks of divided-attention trials were administered in one continuous sequence. However, subjects were informed of the transition from target localization to all-novel 2 in Order A and from focused attention to all-novel 1 in Order B. In addition, Subjects read written instructions prior to the all-novel practice, focused-attention, and target-localization trials. These instructions required that subjects interact with the computer in a way that moved them systematically through the important aspects of each condition.

Stimulus Material

The words were 2132 singular nouns, 3 to 8 letters in length, and ranging in frequency of occurrence from 6 to 492 per million. Of these words, 332 were used for the various practice trials, 20 were reserved for use as familiar and target words, and the rest were used as novel words on experimental trials. The assignment of the novel words to conditions, trials, and cells was performed randomly within the constraints noted above. The 20 reserved words were randomly divided into 5 subsets of 4 words each. Three of the words in each subset served as familiar words in the one-novel and one-familiar conditions and the fourth word served as the target word in the target-localization condition. One of the three familiar words in each subset was randomly selected to serve in both the one-novel condition and the one-familiar condition. Each subset was assigned to approximately 20% of the subjects. The two condition orders times the 5 subsets of reserved words yielded 10 stimulus sequences. Each sequence was recorded on three floppy disks, yielding 30 disks altogether. Each disk was assigned to one of the 30 subject cubicles, and subjects were assigned to cubicles on the basis of their order of entry into the laboratory.

Results

The overall effects of experimental manipulations are considered first, followed by an examination of individual differences in some of these effects. Because of the emphasis on accuracy over speed of localization, only the accuracy data, computed as percent correct responses to the probes, are summarized in this report. Suffice to say that accuracy and speed were highly correlated and that the trends in accuracy are not based on speed-accuracy tradeoffs.

Overall Effects

The data of primary interest are summarized in Table 1. Orders A and B yielded comparable overall accuracy, $F(1,511) < 1.00$. Moreover, the effect of probe type (i.e., novel vs familiar, valid vs invalid, and target vs nontarget) did not vary between orders except in the one-familiar condition. Therefore, with the exception of that condition, the analyses are summarized without regard to condition order. The all-novel condition provides a divided-attention baseline against which to evaluate the costs and benefits of different types of probe. Thus, in the analyses reported below, the two types of probe in a given condition are compared with one another and with the all-novel baseline. Since localization accuracy increased only slightly from the first (75.19%) to the second (76.41%) all-novel block, the data from these two blocks were pooled to yield a single estimate of baseline accuracy. Post-hoc comparisons between individual means were performed using the Newman-Keuls test. The level of significance was set a $p < .01$ for all statistical tests.

Table 1
Mean Percent Correct Localization of Probes as a Function of Attention Condition, Probe Type, and Condition Order

Condition	Probe Type	Order A	Order B
All Novel	Novel	75.71	76.02
Focused Attention	Valid	94.92	93.86
	Invalid	60.33	62.17
Target Localization	Target	81.76	85.85
	Nontarget	67.77	71.33
One Novel	Novel	32.24	80.62
	Familiar	74.32	73.22
One Familiar	Novel	76.30	75.33
	Familiar	74.73	77.64

In the focused-attention condition, localization accuracy was reliably above baseline for valid probes and below baseline for invalid probes, $F(2, 1022) = 1542.07$, $MSe = .0091$. Likewise, in the target-localization condition, localization accuracy was above baseline for targets and below baseline for nontargets, $F(2, 1022) = 333.06$, $MSe = .0078$. The advantage of valid cues over invalid cues and of targets over nontargets is well established in standard attention (e.g., target-detection) tasks. The present effects show that this advantage extends to a probe-localization task.

The major focus of the study was on the possible emergence of a novel-popout effect. As can be seen in Table 1, localization accuracy was higher for novel words in one-novel displays than for either familiar words in those displays or novel words in all-novel displays, $F(2, 1022) = 159.01$, $MSe = .0050$. Thus, attention appears to have been diverted from the familiar words and captured by the single novel words in one-novel

displays. The one-novel, target-localization, and focused-attention conditions all appear to have yielded a differential distribution of attention between "figure" (i.e., novel, target, and cued) and "ground" (i.e., familiar, nontarget, and noncued) stimuli. A benefit in localization accuracy was observed for the figure in each case, and a cost was observed for the ground.

The data are less clear and consistent with respect to the one-familiar condition. The effect of probe type depended on condition order, $F(2, 1022) = 10.46$, $MSe = .0045$. As Table 1 reveals, localization accuracy was below baseline for the familiar word and above baseline for novel words in Order A, but just the reverse was obtained in Order B. That is, the single familiar word in one-familiar displays appeared to repel attention in Order A but capture it in Order B. The basis of this interaction may be that the one-familiar condition was immediately preceded by the one-novel condition in Order A but not in Order B. Thus, in Order A, perceptual satiation may have built up for the familiar word across the one-novel trials and carried over to the one-familiar trials. In Order B, the familiar word in the one-familiar condition had not been presented in prior conditions, so it may have both benefitted from figure-ground (familiar-novel) discontinuity and not suffered from accumulated perceptual satiation. Because of the possible carryover effects in Order A, further analyses of the one-familiar condition were confined to Order B and, thus, to the "familiar popout" effect. However, it remains for future research to assess more fully the factors that control attention when familiar stimuli are in the minority.

Supplementary analyses were conducted to assess the stability and generality of the effect of primary interest, namely, the novel popout effect. Novel words in the one-novel condition were more localizable than familiar words regardless of the particular cells of the display in which the words appeared. That is, when each of the four cells was examined separately, the accuracy with which a probe word was localized was higher for novel words than for familiar words. In addition, the effect was found to occur for each of the five sets of familiar words used in the study. Thus, the effect appears to be a robust one that generalizes across display locations and items as well as condition orders.

Individual Differences

The next series of analyses was designed to assess individual differences in the above effects. Performance in the all-novel and focused-attention conditions was used to classify subjects into four "attentional types". Subjects were classified as high or low in divided attention depending on whether they were above or below the median level of accuracy in the all-novel condition. Likewise, subjects were classified as high or low in focused attention depending on whether they were above or below the median in terms of degree of focused attention. Degree of focused attention was indexed in terms of the extent to which localization accuracy was higher for valid probes than for invalid probes. Subjects were classified as divided attenders if they were high in divided attention but low in focused attention, as focused attenders if they were high in focused attention but low in divided attention, as flexible attenders if they were high on both measures, and as nonattenders if they were low on both measures. The representation in the subject population was 35% for divided attenders, 37% for focused attenders, 13% for flexible attenders, and 15% for nonattenders.

Table 2 compares the four attentional types in terms of mean localization accuracy in the different conditions. In the all-novel condition, localization accuracy was substantially higher for divided and flexible attenders than it was for nonattenders and focused attenders, $F(3,509) = 259.75$, $MSe = .0063$. This result is a necessary consequence of the fact that all-novel accuracy was used to distinguish between nonattenders and focused attenders on the one hand and divided attenders and flexible attenders on the other hand. Not surprisingly, this difference between attentional types tended to carry through the remaining conditions, $F(3, 509) > 96.00$, $MSe < .0210$ in all conditions. However, in the analyses of these conditions, it is the main effect of neither attentional type nor probe type (summarized above) that is of interest. Rather, it is the possible interaction of attentional type with probe type. This interaction would indicate individual differences in the distribution of attention in a given condition.

Table 2
Comparison of Attentional Types in terms of Percent Correct Localization of Probes for the Different Attention Conditions and Probe Types

		Attentional Type*			
Condition	Probe	Nonattenders	Focused	Divided	Flexible
All Novel	Novel	64.40	65.30	87.08	82.82
Focused Attention	Valid	89.52	94.24	95.77	96.39
	Invalid	67.27	46.59	76.40	55.67
Target Localization	Target	80.75	78.07	89.96	85.90
	Nontarget	67.42	53.21	81.47	71.47
One Novel	Novel	78.43	72.47	89.38	83.79
	Familiar	70.23	63.95	83.36	74.61
One Familiar (Order B)	Novel	70.43	66.29	86.39	73.19
	Familiar	75.32	69.43	86.92	79.56

*The representation in the subject population (N = 513) was 15% for nonattenders, 37% for focused attenders, 35% for divided attenders, and 13% for flexible attenders.

In the focused-attention condition, the advantage of valid probes over invalid probes was greater for focused attenders and flexible attenders than for nonattenders and divided attenders, $F(3, 509) = 338.47$. This finding also is a necessary consequence of the way the four attentional types were defined. That is, subjects were classified as focused attenders and flexible attenders if they were above the median in terms of the advantage of valid over invalid probes. The important question is whether focused attenders and flexible attenders evidenced more selective attention in the other conditions as well. Interestingly, this was not always the case.

In the target-localization task, the advantage of targets over nontargets was greatest for focused attenders, least for divided attenders, and in between these extremes for nonattenders and flexible

attenders, $F(3, 509) = 26.65$, $MSe = .0034$. In the one-novel condition, the novel popout effect tended to be smaller for divided attenders than for the other attentional types. In the one-familiar condition of Order B, the familiar popout effect was most evident for nonattenders and essentially nil for divided attenders. This interaction between attentional type and probe type was reliable in the one-novel condition, $F(3, 509) = 3.40$, and approached reliability in the one-familiar condition, $F(3, 509) = 2.44$.

In general, divided attenders displayed a reluctance, or reduced ability, to selectively process the word arrays in all conditions. Consequently, localization accuracy for divided attenders was quite stable, remaining close to baseline (i.e., all-novel accuray) in all conditions and for all probe types. Other attentional types were more apt to process the arrays selectively when there was a basis for doing so. For nonattenders and, to a lesser extent, focused attenders, this selective processing yielded a net benefit (i.e., improvement above baseline); but for flexible attenders, who were defined by a relatively high baseline, this selective processing tended to be more costly than beneficial.

Discussion

In general, subjects selectively processed cued and noncued locations, target and nontarget words, and novel and familiar words. Relative to the all-novel baseline, all forms of selective attention entailed both enhanced accuracy for selected items and inhibited accuracy for nonselected items. The selectivity indicated in the one-novel condition defined the novel popout effect. Its occurrence in the present probe-localization task indicates that a novel figure in a familiar ground draws attention to its location and not just to its content or identity. That is, subjects tended to see not only what the novel stimulus was but where it was as well. The emergence of a complementary familiar popout effect in the one-familiar condition in Order B indicates that what pops out may be based more on what is in the minority, novel or familiar, than on a general tendency for attention to be repeled by familiar stimuli and captured by novel stimuli.

Importantly, there were clear-cut individual differences in all forms of selective processing. In particular, selective processing was consistently lower for divided attenders than for the other three attentional types. Moreover, although selective processing proved more beneficial than costly for some subjects, especially nonattenders, it proved more costly than beneficial for other subjects, especially flexible attenders. Pooled over all conditions and probe types, localization accuracy was highest for divided attenders (37.10%), lowest for focused attenders (70.15%), and in between for flexible attenders (30.91%) and nonattenders (74.50%).

Since the best and the worst performers defined the bulk (72%) of the subject population, it may be of some value to examine these subjects in some detail. Although focused attenders were relatively inaccurate in most conditions, they may be better suited than other subjects to tasks that place a heavy premium on focused attention, that is, on the ability to both attend to some environmental locations and ignore others. These subjects were as proficient as any subjects in terms of their ability to attend to cued locations and were clearly superior in terms of their ability to ignore noncued locations. This ability to ignore certain

locations may be beneficial when the stimuli that arise from those locations are always irrelevant and potentially distractive. Divided attenders may be poorly suited to such tasks because of their apparent inability to ignore irrelevant locations and, consequently, their vulnerability to distraction. On the other hand, divided attenders may be better suited than other subjects to tasks that require either complete division of attention or only partial focusing of attention. By definition, divided attenders were superior to most other subjects in performance of the all-novel task, which encourgages complete division of attention. However, in the focused-attention task, not only were divided attenders as proficient as any subjects in the processing of cued locations, but they were clearly more proficient in the simultaneous processing of noncued locations.

The four attentional types differed not only in terms of measures of divided attention and focused attention by which they were defined but in terms of other indices as well, including target, novel, and familiar popout effects and the costs and benefits of selective attention. Thus, divided attention and focused attention appear to be fundamentally different and partially orthogonal dimensions of attention and sources of individual differences. The observed differences between the two most common attentional types, divided and focused attenders, are sufficiently marked and potentially important as to call for further investigation. Attentional type may prove to be of high diagnostic utility in attempts to optimize the match between individuals and job requirements.

Summary

Five hundred thirteen Air Force recruits performed a sequence of five attention tasks. In all tasks, subjects viewed an array of four words, next received one of the words as a probe, and then indicated their best guess as to the array location in which that word had appeared. The four-word arrays were exposed for only 400 ms before being backward masked. In the "all-novel" task, the four words were always novel in that none had appeared before in the experiment. This task afforded a divided-attention baseline with which to compare accuracy of probe localization in the other tasks. In the "one-novel" task, one novel word appeared with three familiar words. The same three familiar words appeared in every array. In the "one-familiar" task, one of the three familiar words appeared in every array along with three novel words. In the focused-attention task, subjects were precued before each array as to the location that was most likely to be probed on that trial. The cues correctly specified the location of the probe word 70% of the time. In the target-localization task, a particular target word appeared in every array and was the word probed for 70% of the time.

Accuracy of localization was higher for the target word than for nontarget words in the target-localization task, higher for cued words than for noncued words in the focused-attention task, and higher for novel words than for familiar words in the one-novel task. In all of these cases, localization accuracy was above the divided-attention baseline for the more accurately localized type of probe and below baseline for the less accurately localized type. Thus, attention appears to have been allocated to, or captured by, target words, cued words, and novel words. The difference in localization accuracy between novel and familiar words in the one-familiar task was relatively small and unstable.

The direction of attention to novel words in the one-novel task is called novel popout, and the direction of attention to target words in the target-localization task is called target popout. In order to assess individual differences in the magnitude of these popout effects, subjects were subdivided into four attentional types on the basis of whether they were above or below the median in terms of divided-attention (i.e., localization accuracy in the all-novel task) and focused-attention (i.e., the difference in localization accuracy between cued and noncued words). "Divided attenders" were high in divided attention but low in focused attention, "focused attenders" were high in focused attention but low in divided attention, "nonattenders" were low on both measures, and "flexible attenders" were high on both measures. Divided attenders and focused attenders comprised the bulk (72%) of the subject population. The novel and target popout effects were relatively small for divided attenders and large for focused attenders. In general, divided attenders more accurate overall and evidenced less selective processing than other attentional types, especially focused attenders. Divided attenders should be best suited to tasks that require vigilance to all stimuli and locations, even those that normally are irrelevant and call for no response. By contrast, focused attenders should be uniquely qualified for tasks that place a high premium on the ability to ignore certain stimuli and locations.

Publication Plans

I expect to submit for publication a manuscript that summarizes several related studies, one of which is the study described in this report. In addition, the data of this study have been made available to investigators in Project LAMP (specifically, Dr. Woltz). They plan to use these data, along with additional data that they collected from the same subjects, to investigate in more detail individual differences in information processing.