# AN ANALYSIS OF PRACTICE EFFECTS IN A CONTINUOUS VISUAL SEARCH TASK +

Eckart Scheerer

Psychologisches Institut der Ruhr-Universität,
Arbeitseinheit Kognitionspsychologie,
Postfach 10 21 48, 4630 Bochum 1,
W-Germany

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SUMMARY. A new experimental paradigm for the investigation of visual search processes is presented. In a continuous visual search task, the target accours several times in each search list, and a response is required to each occurence of the target. The analysis of the data is based on the regression of the interresponse intervals on the distance between successive target occurences. With a view to measure the size of the functional visual field and the efficiency of "skipping" strategies, the size of letter groups and the minimal distance between sucessive target occurences were varied. The rate parameter of the regression functions was used to infer the extent of the functional visual field; the efficiency of "skipping" was assessed on the basis of the intercept. A reliable expansion of the functional visual field during practice in the continuous search task could be demonstrated. Evidence for efficient "skipping" strategies was found at all stages of practice, subject to the constraint that there was a natural relationship between the size of letter groups and the minimal distance between target occurences.

## INTRODUCTION

The present report introduces a new research technique for visual search studies, which is applied to an analysis of practice effects in simple visual search tasks. In the "classical" visual search task (Neisser, 1963), the subject is presented with a search list consisting of a number of items (e.g., letter groups) which are arranged in a regular way (e.g., in columns) such that a consistent order of searching is encouraged. One of the items contains a previously specified target (target item); all other items are context items. The task of the subject is to detect the presence of the target, which may be taken from a memory list of potential targets. Typically, the time needed for the detection of the target is a linear function of the position of the target item in the search list. The rate parameter of the regression function is usually interpreted as search time per item

(Neisser, 1963), although strictly speaking it reflects the contribution of context processing to search time, while the intercept, in addition to motor response time, contains the time needed for processing the target item (Prinz, 1975).

In the classical search paradigm, the target item appears only once in each search list. This represents a special type of search activity, which may be termed discrete search. Many real-life search activities - such as proof-reading or industrial quality control - may be characterized as "continuous" tasks; i. e., the target occurs several times in each search field, and a response is required to each occurence of the target. If some regular order of search is enforced, a continuous search task can be analyzed in a way which is analogous to the usual analysis of discrete tasks. The interresponse interval between two successive target detections can be plotted as a function of the distance between two successive target occurences. In this way, for each trial a regression line can be found; the regression lines for discrete search tasks are always composites from a number of trials. Thus, in addition to its greater ecological validity, a continuous search task permits a more accurate estimation of search parameters. Moreover, we will show that one mechanism of practice in visual search can only be investigated by means of a continuous task.

One impressive property of the visual search process is its great susceptibility to practice, i. e., to a mere repetition of the search activity without any specific training. Most investigators have been impressed by Neisser, Novik and Lazar's (1963) finding that after practice the number of targets in a memory list ceases to have an effect on search time. As a result, most theories of the practice effect in visual search are concerned with changes in the access to, or the nature of, the memory representation of either target or context items (e. g., Prinz, 1975). But a very considerable practice effect is found even in the simplest case of search, where one highly overlearned target must be detected among a similarly overlearned set of context objects. In this case, the memory load is minimal, and it seems a little preposterous to assume that the system of letter features (which is constantly used in the daily activity of reading) should be further differentiated by some hours of practice in letter searching. Consequently, the locus of the practice effect in simple search tasks must be somewhere else than at the level of memory representations.

Another approach is to consider the search task in terms of the subject's capabilities for sensory information intake and control of eye movements. While engaging in a search task, the subject executes a sequence of fixations and saccades; during each fixation, a sample is taken from the search list. One way to increase search speed is to take a greater sample during each fixation, thus reducing the number of fixations needed to work through the search list. Any increase in sample size is equivalent to an increase in the spatial extent of the sample, which will be called the functional visual field. Thus, we whish to test the hypothesis that practice effects in simple visual search are mediated by an expansion of the functional visual field. In view of the fact that the minimum duration of a fixation is constant, it could be argued that there is scarcely another way to increase processing speed in tasks such as searching or reading. Marcel (1974) has shown that fast readers have a wider functional field than slow readers, but he explains this by a more efficient utilization of higher-order processing units. In the present study, the distribution of context objects is entirely random. Therefore, if an expansion of the functional visual field is found, it must be taken in purely spatial terms, without any recourse to a rearrangement of memory representations towards higher processing units. Besides an older report from a tachistoscopic experiment (Weber, 1942), so far there is no sound evidence for such a purely spatial effect of practice in visual skills.

Turning to the control of eye movement, we meet another possibility for the improvement of search speed, for which we propose to use the generic term, optimization of search activity. In an optimal search process, any redundancy with respect to the information in each sample is eliminated. For instance, a search process would be optimal if the locus of each fixation were selected in such a way that there would be no overlap whatsoever with the previous sample. If the size of the functional visual field and the average duration of a fixation is known, the search rates can be used for an estimation of the extent to which this type of optimization has occurred. In the present study, eye-movement records were not taken; instead, another form of optimization was investigated by means of a continuous task. In such a task, a minimal distance between two sucessive occurences of the target can be defined. An optimal search process would skip the context objects lying within this minimal distance. Thus, we propose the second hypothesis that in practiced searching irrelevant context objects are skipped. Neisser and Stoper (1965) have studied a "skipping" strategy be means of a discrete task. However, in such a task a special signal for "skipping" must be given, which may account for Neisser and Stoper's failure to find an efficient skipping strategy. In a continuous task, the "skipping" signal is identical with the target signal itself; therefore, a skipping strategy may reveal itself without being impeded by the necessity to look for a special skipping signal.

How are "size of the functional field" and "skipping of context objects" related to the parameters of the regression function in a continuous search task? It is easy to show that the former must be reflected in the rate paramter, and the latter in the intercept, of the regression function. Let us first assume that each sample of letters is processed at a constant speed, irrespective of the number of letters in the sample. Then the search speed for individual letters must be a reciprocal function of the number of letters in each sample. In other words, an expansion of the functional visual field will result in a reduction of the search rate for individual letters. Secondly, let us assume that n letters out of the N letters lying between two successive occurences of the target are "skipped", that is, are not processed at all. This is equivalent to saying that the X-axis of the regression function is shifted by n units to the left, which results in a reduction of the intercept on the Y-axis. That is, the more context letters are skipped, the lower should be the intercept parameter of the regression function, and if a considerable number of context letters is skipped, negative intercept values are to be expected. As will be noted, this analysis rests on the assumption that motor response time and the time needed to locate and identify the target make a constant contribution to the intercept parameter. There is no way to validate this assumption as far as motor response time is concerned; but an attempt will be made to scrutinize the intercept values for a potential contribution of target processing time.

The size of the functional visual field can be determined be varying the size of the letter groups which make up a search list. It is reasonable to assume that a search strategy minimizing overlaps between successive samples is favored if the size of the letter groups matches the size of the functional visual field. On the basis of this assumption, it can be expected that the search rates will form a U-function of the group size. The minimum of this function can then be used for inferring the size of the functional visual field. This allows us to convert our first hypothesis into the following prediction: During practice, the minimum of the function relating search rate to letter group size will shift from small groups to large groups.

In order to assess the efficiency of skipping redundant context letters, the minimal distance between two successive occurences of the target letter must be manipulated. In an attempt to sample a wide variety of skipping rules, the following "minimal distance" conditions were employed. In the first condition, there was a minimal distance of 1 letter between two sucessive target occurences; in the second condition, the minimal distance coincided with the group size; and in the third condition, a minimal distance of 12 was defined. In the first and third conditions, the minimal distance did not depend on the group size; consequently, the intercept parameter should be the same for the various group sizes. However, compared to the first condition there should be a much smaller intercept value in the third condition, where a "skipping" of letters is possible. In the second condition, the intercept value should be smaller the larger the group size. With respect to practice, no specific predictions are made; a general decline of the intercept value for all condition is expected. In summary, we predict that the intercept value should be an accurate reflection of the minimum-distance properties of the distribution of target letters, while the rate parameter should be sensitive to the size of the letter groups across all minimal-distance conditions.

## METHOD

### Subjects and Design

15 subjects (psychology students fulfilling course requirements and some staff members of the Psychology Department) participated in the experiment. The subjects were equally distributed among the three "minimal distance" conditions: Condition 1 - minimal distance = 1; Condition 2 - minimal distance = group size; Condition 3 - minimal distance = 12. "Group size" was an intraindividual factor varying on seven levels: 1, 2, 3, 4, 6, 8 and 12.

### Stimulus materials

A total of 315 search lists (105 for each minimal distance condition and within these 15 for each group size condition) and some practice lists were generated by means of a computer program and produced in the form of computer printouts. Standard

24 x 36 mm slides with black letters on white background were prepared from the computer printouts. Each search list contained 480 capital letters which were arranged in 10 rows of 48 letters each. All letters of the alphabet (except "X" and "I") appeared in a random order, with the restriction dictated by the appropriate minimal distance condition; besides this, there was no further constraint or deviation from randomness with respect to the distance between two sucessive occurences of a letter. In all group size condition, each row of the search list occupied an horizontal extent of 96 letter spaces on the computer printout. To achieve this, a blank space corresponding to the group size was inserted after each group, and one additional space of the same size was left blank in the middle of the row. There were three blank rows between each pair of rows.

## Procedure

The experiment was run in a dimly lit room, and the search lists were presented by means of a projection tachistoscope. The subject sat in a distance of 120 cm from the projection screen. The search lists had an horizontal extent of 53 cm and a vertical extent of 34 cm. One letter space on the search lists corresponded to a visual angle of 16'; consequently; the largest letter groups (group size 12) subtended a visual angle of $3^{\circ}$ 9'.

The letter "K" was designated as target. Due to the way in which the search lists were generated, on the average there were 20 occurences of the target in each search list, with a range from 16 to 24. This aspect of the structure of the search lists was carefully explained to the subjects. Equal care was taken to ensure that they understood the "minimal distance" condition; for instance, in Condition 1 it was pointed out that the target could occur more than once in each group. Subjects were encouraged to take advantage of the "minimal distance" structure.

The subject was seated in front of an ASR-33 teletype which was connected to a DIETZ 621-C laboratory computer system. Subjects were instructed to work through the lists in a horizontal left-to-right order, starting with the top row and finishing with the bottom row. Each occurence of the target letter was to be signaled by hitting a predesignated key on the teletype. Another key was used to finish exposure of the search list when the subject had reached the right end of the bottom row. The subject was asked not to correct errors which were noticed by herself/himself; specifically, subjects were discouraged from "making up" for a commission error by leaving out the next appropriate key press for a target letter. Subjects were told to work as quickly and as accurately as possible.

The whole experiment was under the control of the DIETZ 621-C computer system, and the data analysis was done on-line with immediate feedback about the results. At the beginning of each trial, a question mark was printed out on the teletype. When the subject pressed the "return" key on the teletype, a search list appeared on the screen after an interval of 1 sec. After completion of a trial, the number of errors was printed out on the teletype, and after a variable interval which depended on the number of errors which were made, the rate parameter and the correlation coefficient of the regression equation were printed out. When more than three errors had been commited, the computer printed a message to the effect that the data could not be analyzed, and the trial was then repeated without the subject's knowledge.

Subjects were encouraged to take a rest pause whenever they needed one. After two sessions, the typical subject was able to run the experiment without assistance by an experimenter.

Comments concerning the on-line analysis of the data

The time intervals between two successive presses on the teletype key serving as a detection signal were measured, cumulated, and entered into a linear regression analysis with the positions of the target letters, which were stored on the disk system of the DIETZ 621 C. (Thus, the on-line analysis was done according to a slightly different, cumulative version of the analysis outlined in the introduction. This was motivated by the necessity of retaining the temporal information for the first key press in order to discover potential misses in the detection of the first target occurence. However, the final, off-line analysis of the data was done according to the distance-model.) When the number of key presses did not match the number of target occurences in the search list, the most probable location of ommission and commission errors was determined by a correlation-maximizing algorithm. For commission errors, the algorithm deletes detection responses; for ommission errors, "gaps" are inserted between pairs of successive detection responses. The algorithm deletes responses or inserts gaps in all possible locations, or combinations of locations; it then assigns the error(s) to those location(s) which produce the highest correlation with the cumulated detection times for the remaining locations. No heuristic was used in this process. Consequently, occasionally upwards of 5000 correlations had to be computed when 3 errors were made. This resulted in a delay of more than 5 minutes before the feed-back could be given. This was a sufficient incentive for our subjects to keep error rates as low as possible. - Of course, the algorithm is insensitive to the case where the number of key presses matches the number of target occurences, but this results from an equal number of ommission and commission errors. However, severe departures from the requested order of searching could be detected. One subject fell to searching the lists column-wise instead of row-wise. This was immediately detected due to the abnormally low correlation obtained in such a case.

## Structure of experimental sessions

An experimental session consisted of 35 trials; five trials were run for each group size condition. The group sizes were arranged in cyclical ascending and descending sequences. The particular sequence in which the slides were to be shown in a given session was indicated to the analysis program, which then selected the appropriate position information for the search lists from the disk system. All subjects participated in nine sessions; depending on the pace of the subject, a session lasted between 3/4 to two hours. The subjects participated in the experiment during nine consecutive working days. Because a total of 315 trials was run and an average of 20 detection responses occured on each trial, the data for each subject comprised a total of 6300 responses. A given search list occured three times during the experiment, but there were always two sessions between two successive occurences of the same search list.

Befor the first experimental session was begun, subjects were given practice with the task and the handling of the interactive computer program. For this purpose, seven search lists, one for each group size condition, were employed.

## RESULTS

The correlations between the distance between two succesive target occurences and the interresponse intervals centered around a value of .95. The rare instances where the correlation coefficient was below .75 were excluded from the analysis; it was suspected that they reflected deviations from the prescribed order of searching. For each subject and session, the arithmetic mean of the rate and the intercept parameters of the regression equations was computed across the five trials per group size. Analyses of variance (ANOVAs) were computed on the arithmetic means; a significance level of .01 was adopted throughout.

## Overall practice effects

Under all three conditions, a substantial and regular improvement in search speed (as reflected in a decline of the rate parameter) occurred across sessions. The average value of the rate parameter was 153.8 msec/letter in the first session and 67.2 msec/letter in the last session. In a Sessions x Conditions ANOVA, significant effects of Sessions ($F_{8,96} = 85.8$) and of Sessions x Conditions ($F_{16,96} = 2.54$) were found; however, the effect of Conditions failed to reach significance ($F_{2,12} = 2.03$). The top panel of Fig. 1 shows that the interaction is explained by the fact that in Condition 2 a greater practice effect was found than in the other two conditions.

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Fig. 1 about here

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The error rate was verly low; on the average, there were 1.60 % ommissions and .35 % commissions. Because of the high number of responses on which these error figures are based, an ANOVA on the error rates was possible and was undertaken in order to asess the extent to which an improvement in search speed might be gained at the expense of accuracy. For ommissions, there were significant effects of Sessions ($F_{8,96} = 5.74$), Conditions ($F_{2,12} = 18.06$) and Sessions x Conditions ($F_{16,96} = 2.30$); for commissions, only the Conditions effect reached a marginal ($p < .05$) significance level ($F_{2,12} = 4.72$). The error data (summed across ommissions and commissions) are displayed in the bottom panel of Fig. 1; they present a rather complicated picture with two main features: (1) In terms of overall error rate, the following ordering of conditions was obtained: Condition 1, Condition 3, Condition 2; (2) Except for Condition 3, the number of errors decreased rather than increased with practice. Thus, there was practically no indication that the improved search rate was caused by a speed-accuracy tradeoff.

An analysis of the intercept parameter revealed the total absence of a practice effect; $F_{8,96} < 1$; the Sessions x Conditions interaction equally failed to reach significance ($F_{16,96} = 1.10$). However, there was a very pronounced effect of Conditions ($F_{2,12} = 46.18$). For the three conditions, the following average intercept values were found: Condition 1: 425.91 msec; Condition 2: 193.41 msec; Condition 3: 22.71 msec.

Effects of group size: rate parameter

In Figure 2, the search rates for every second session are plotted as a function of the size of the letter groups. Because practice resulted in a considerable compression of the range of values, a reciprocal transformation was applied to the data in order to homogenize variances and bring out the trend more clearly. Inspecting Figure 2, we notice that excepting slight irregularities all group-size curves are U-shaped; we further notice that in all three conditions the minimum of the U-function shifts toward greater group sizes with the progress of practice. The statistical tests for the effects of group size were done on the reciprocal values which had been averaged across three successive sessions. Both overall and for the three individual conditions, Group Size and Group Size x Sessions were significant effects (Overall: $F_{6,72} = 17.59$ and $F_{12,144} = 11.13$; Condition 1: $F_{6,24} = 6.47$ and $F_{12,48} = 2.89$; Condition 2: $F_{6,24} = 5.62$ and $F_{12,48} = 3.32$; Condition 3: $F_{6,24} = 8.18$ and $F_{12,48} = 7.40$). However, neither the Group Size x Conditions interaction ($F_{12,72} < 1$) nor the Group Size x Sessions x Conditions interaction ($F_{24,144} = 1.45$) reached significance. Thus, we have no evidence that either the shape of the group size function or the change of its shape with practice were different between the three conditions.

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Fig. 2 about here

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The possibility of a contaminating effect of differential accuracy on these effects was assessed by means of an ANOVA for the frequency of ommission errors. For this purpose, the error figures were regrouped according to the group size variable; due to a high number of zero cell frequencies, it was not possible to test the Group Size x Sessions interaction. No significant effect of Group Size was obtained, neither overall ($F_{6,72} = 1.83$) nor for individual conditions.

In order to obtain estimated values for the location of the minima, the group size data for individual subjects and sessions were fitted to third-degree polynomials, which were analytically solved for their extreme values by taking their first derivatives. In 133 of 135 data sets, this led to a minimum value within the range of group sizes which were actually employed in the experiment, thus testifying to the generality of the U-shaped function across subjects and sessions. (The theoretically preferable second-order polynomial proved too sensitive to purely local disturbances of the U-shape, which occasionaly resulted in flat or indeterminate minima.) The estimated locations of the minima were entered, after a least-squares estimation of the 2 missing cells, into an ANOVA. A significant effect of Sessions ($F_{8,96} = 14.31$) emerged, but neither Conditions ($F_{2,12} = 1.07$) nor Conditions x Sessions ($F_{16,96} < 1$) were significant. The data are plotted in Fig. 3. A linear increase of the estimated location of the minimum is observed; it shows a slight tendency to taper off for Sessions 7 - 9. For Session 1, the average estimated minimum was located at a group size of 4.95; the coresponding value for Session 9 was 8.73.

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Fig. 3 about here

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Effects of group size: intercept parameter

Here, the group size data for individual subjects and sessions were rather variable, but averaging across three successive sessions permitted to obtain a clear picture of the effects of group size and to obtain acceptably homogeneous error terms for the statistical analysis. The ANOVA revealed a significant effect of Group Size ($F_{6,72} = 13.89$), but equally significant Group Size x Conditions ($F_{12,72} = 15.13$) and Group Size x Conditions x Sessions ($F_{24,144} = 2.75$) interaction terms necessitated an analysis for individual conditions. In all three conditions, there was a significant effect of group size (Condition 1: $F_{6,24} = 11.97$; Condition 2: $F_{6,24} = 26.49$; Condition 3: $F_{6,24} = 5.72$), but the Group Size x Sessions interaction was significant in Condition 3 only ($F_{12,48} = 6.72$; Condition 1: $F_{12,48} = 1.58$; Condition 2: $F_{12,48} < 1$).

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Fig. 4 about here

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The average values of the intercept parameters are displayed in Fig 4. In Condition 2, the intercept decreases linearly with an increase in group size. In Condition 1, a U-shaped function with a minimum at group size 3 or 4 is seen. Clearly, in these two conditions the shape of the group size data does not depend on practice. Condition 3 presents a more complicated picture. In the early stages of practice, the group size data coincide with those from Condition 2 for group size 3 - 12. (If session 1 is taken individually, this coincidence is nearly complete even for the smaller group sizes.) With progress in practice, the relationship between intercept and group size flattens out, but for group size 12 the coincidence with Condition 2 remains, leading to an inverted U-shape with a maximum at group size 8.

## DISCUSSION

The predictions concerning the relationship between the size of the letter groups and the search rate were fully borne out by the data. Inferring the size of the functional visual field from the minimum of the group size function, we are justified to conclude that the practice effect in our visual search task was mediated by an expansion of the functional visual field. After nine practice sessions, the functional visual field has almost doubled its size, and a striking parallelism between the expansion of the visual field and the improvement in search rate was observed. Moreover, the expansion of the functional field was the same for all three minimal distance conditions. Apparently, the expansion of the functional field is a rather non-specific mechanism which does not depend on the particular distribution of target letters in a given search task. Of course, the generality of this mechanism for other types of search task, or still other types of sensorimotor skills, remains to be shown. Also, we do not know whether further amounts of practice would have succeeded in pushing the limits of the functional visual field still farther into the periphery.

With respect to the efficiency of skipping irrelevant context letters, our predictions have had a somewhat ambiguous fate. Contrary to our expectations, no practice effect for the intercept was found. It should be remembered, however, that the subjects were informed about the minimal distance properties of the target letter distributions; it could thus be argued that little room was left for the acquisition of an efficient skipping strategy, and the data reflect only the execution of the skipping strategy.

On the whole, there is ample evidence that our subjects employed skipping strategies which closely reflected the minimum-distance properties of the target letter distributions. If we turn to the overall size of the intercept first, we notice that the expected ordering of the conditions was obtained. In

Condition 1, only one letter could be skipped; in Condition 2, an average number of 4.7 letters could be skipped; and in Condition 3, 12 letters could be skipped. The average intercept values exactly correspond to this ordering.

Among the individual conditions, Condition 2 presents unequivocal evidence for the operation of an efficient skipping strategy. Here, the minimal distance was equal to the size of the letter groups, and the intercept did in fact linearly decrease when the size of the letter groups was increased. In addition, it is remarkable that the group-size data for Condition 2 are very similar to those Condition 1 and 3, respectively, for those group sizes where the minimal distance was equal to that in Condition 1 (group size 1) or Condition 3 (group size 12). We conclude that the efficiency of the skipping strategy is the same in all three conditions, provided that an equal number of context letters can be skipped.

In both Conditions 1 and 3, the relationship of the intercept to the size of the letter groups was expected to be flat; yet curvilinear functions, albeit of a different type, were found for both conditions. For Condition 1, the minimum at group size 3 or 4 can be explained if it is taken into account that here the target letter could occur more than once in a given letter group. Because the functional field, as assessed by the rate parameter, was never smaller than four letter spaces even at the beginning of pratice, it may be assumed that this enabled the subjects to simultaneously detect two target occurences in a given group, rather than searching for the next target after the preceding target was detected. The interval between the two detection responses would then be reduced to a purely motor delay between two successive taps on the same teletype key.

In Condition 3, an inverted U-shape for the intercept data was found, which moreover interacted with practice. We have noticed already that for the first three sessions the intercept data resembled those for Condition 2; that is, a steep decline with increasing group size was found for group sizes larger than 3. We take this as an indication that at the early stages of practice the subjects behaved as if the minimal distance was equal to the group size. That is, though they were intellectually aware of the true minimal distance property, they resorted to the much easier strategy of jumping to the next letter group after having detected a target. (The low error rate for Condition 2 shows that this task indeed was easier than the others.) With progress in practice, subjects started to transform their knowledge of the minimal distance property into a sensory-motor skill, but even at the end of practice this was still more efficient when the minimal distance matched the size of the letter groups, that is, for group size 12. Thus, we are arguing that the curvilinear shape of the intercept values reflects a composite of a linearly decreasing and a flat function, with the flat function "taking over" during the course of practice. Unfortunately, we do not know whether a still more extended practice period would eventually have produced an entirely flat intercept function.

Expressed at a more general level, our explanatory attempts for the unexpected features of the intercept data amount to the acknowledgment that the intercept contains one additional factor which is not constant with respect to group size. Among the potential other contributors to the intercept - different aspects of target processing time, motor response time - the <u>time needed to locate the target</u> is the most plausible candidate. This component is reduced by the co-occurence of targets within a letter group and increased by a mismatch between the size of the letter groups (which is a perceptually salient feature of the search lists) and the size of the minimal distance (which is represented on a more abstract, "cognitive" level only). There is thus one boundary condition to the optimal adjustment of the search activity to the distributional properties of targets in a search field: Optimal search strategies require a suitable perceptual articulation of the search field.

In conclusion we must admit that optimal search activity is even more specific than we had anticipated. But among the variety of searching strategies there is one constant component of practice in visual search: the expansion of the functional visual field.

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## F i g u r e   c a p t i o n s

Fig. 1: Mean search rate per letter (top panel) and percentage of error (ommissions and commissions; bottom panel) as a function of practice.

Fig. 2: Mean search rate per letter as a function of group size. The search rates are displayed in a reciprocal scale (1000/search rate).

Fig. 3: Average estimated locations of the minima of the group size function of the rate parameter as a function of practice. Circles: Condition 1; Squares: Condition 2; Triangles: Condition 3.

Fig. 4: Mean intercept values as a function of group size. Circles: Condition 1; Squares: Condition 2; Triangles: Condition 3.

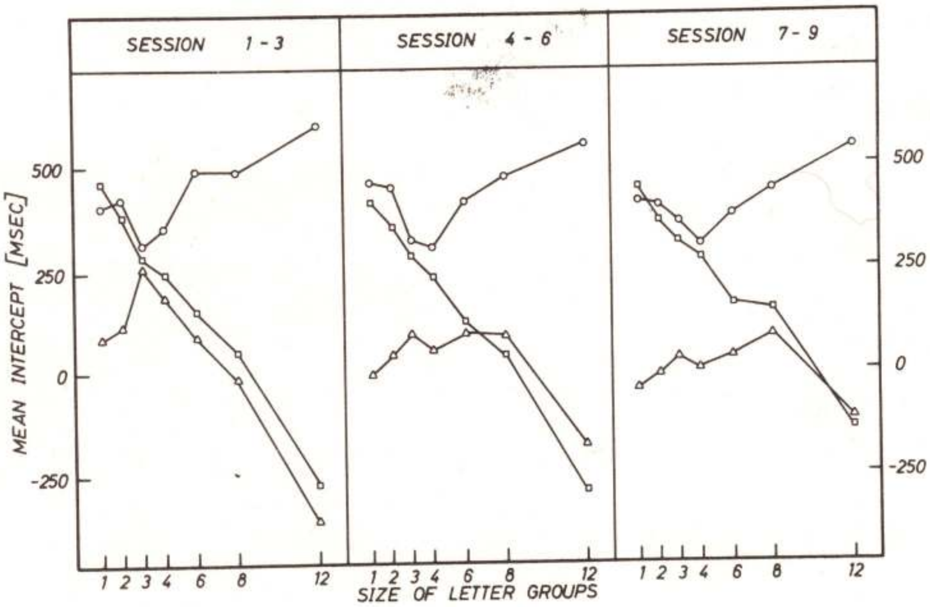
SESSION 1 - 3
SESSION 4 - 6
SESSION 7 - 9
MEAN INTERCEPT [MSEC]
500
250
0
-250
1 2 3 4 6 8 12
SIZE OF LETTER GROUPS

Figure 4

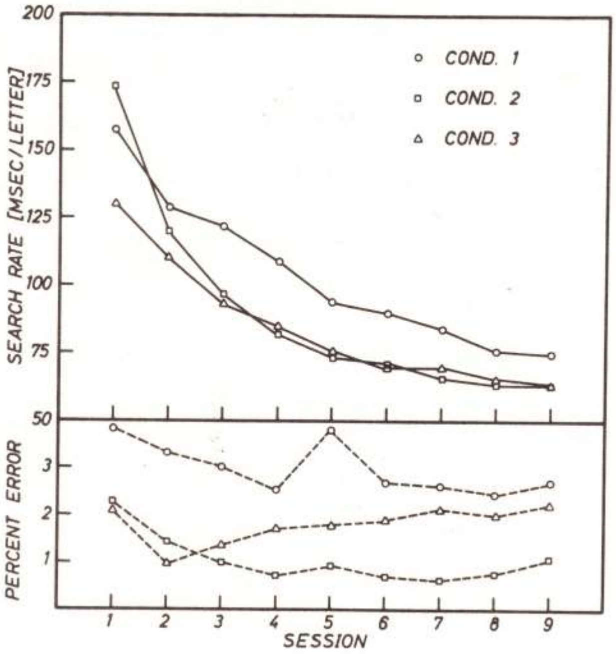
200
175
150
125
100
75
50
SEARCH RATE [MSEC/LETTER]
○ COND. 1
□ COND. 2
△ COND. 3
3
2
1
PERCENT ERROR
1 2 3 4 5 6 7 8 9
SESSION

Figure 1

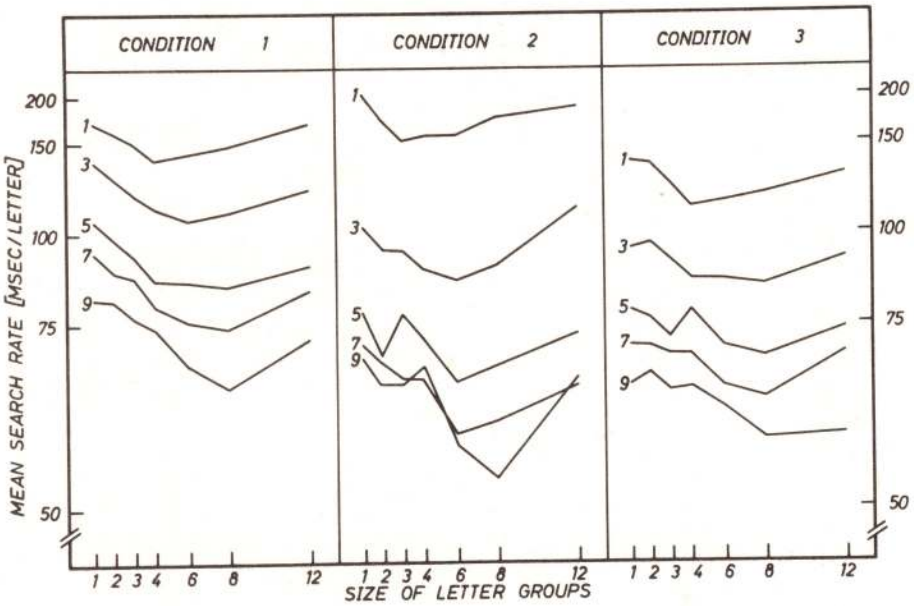
CONDITION 1
CONDITION 2
CONDITION 3
MEAN SEARCH RATE [MSEC/LETTER]
200
150
100
75
50
1
3
5
7
9
1 2 3 4 6 8 12
SIZE OF LETTER GROUPS

Figure 2

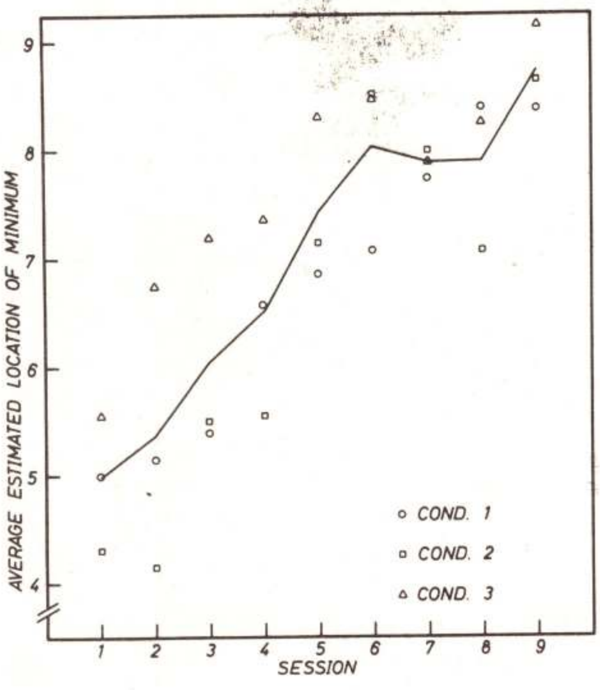
AVERAGE ESTIMATED LOCATION OF MINIMUM
9
8
7
6
5
4
1
2
3
4
5
6
7
8
9
SESSION
○ COND. 1
□ COND. 2
△ COND. 3

Figure 3