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ON THE RELATION BETWEEN IDENTIFYING AND LOCATING MASKED TARGETS IN VISUAL SEARCH

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Three experiments were designed to determine whether naming is contingent on locating in a visual search task. Subjects were required to identify a masked target whose location was known (I|L) or unknown (I) and to locate a masked target whose identity was known (L|I) or unknown (L). The location-contingent hypothesis predicts a relationship among the tasks such that $P(\text{L})\,P(\text{I}|\text{L}) = P(\text{I})$, since $P(\text{I})$ and $P(\text{L})\,P(\text{I}|\text{L})$ both estimate the joint probability of identifying and locating the target (i.e. $P(\text{I} \cap L)$). This relationship held in Experiment I where targets were presented alone, and in Experiment II where targets were presented with dots as noise elements, but not in Experiment III where Xs were noise elements. The results are discussed in terms of the generality of the location-contingent hypothesis.

Introduction

In recent discussion of visual search tasks, Snyder (1972) and von Wright (1970) have suggested that targets are selected for identification by location. This implies a definite sequence of processing in which target location must be encoded before identification can begin. Thus identification is contingent on locating. Some support for this hypothesis is found in Baron's (1973) experiments. If locating must occur before identification, the accuracy of judgements which require identifying the target should not be better than chance if the larget is located incorrectly. For the most part, Baron's results confirmed this prediction.

The experiments reported here provide a convergent test of the location-contingent hypothesis. Subjects were required to identify and locate single target letters in a backward masking paradigm. Independent estimates of subject's accuracy were obtained in identifying targets whose location was either known in advance or not known, and in locating targets whose identity was either known in advance or not known. If a letter whose location is not known prior to stimulus presentation must be located as well as identified, the proportion correct in that condition is an estimate of the joint probability of identifying and locating a letter [i.e. $P(I \cap L)$]. On the assumption that the availability of target location for report reflects its availability in directing identification, this probability can also be estimated from the product of the proportion correct in the location, identity unknown, condition [$P(L)$] and the proportion correct in the identification, location known, condition [$P(I|L)$], since from the definition of conditional probability,

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$P(L)\,P(I|L) = P(I \cap L)$. The location-contingent hypothesis predicts a close agreement between these two estimates of the joint probability of identifying and locating.

Alternatively, if identification and location are strictly independent, there should be no difference between the two identification conditions [i.e. $P(I) = P(I|L)$] and a significant difference between the two estimates of the joint probability, $P(I \cap L)$. However, it is also possible that locating and identifying are independent but interacting processes. Thus locating and identifying may begin simultaneously, but if the target is located before it is identified, location information may be used to reorganize the identification process so as to improve the speed or accuracy of identification. Support for this alternative will be found if the location-contingent hypothesis is confirmed under some conditions but not under others.

Three experiments were conducted to test these predictions. In each experiment a single target letter was presented in one of four possible positions. What varied between experiments was the content of the remaining three positions. In the first experiment they were blank, in the second they contained dots, and in the third they contains Xs. The backward masking paradigm was employed so the predictions could be tested over a wide range of accuracy.

Method

Subjects

All subjects in the three experiments were graduate or undergraduate students at McGill University who reported having normal or corrected vision. All subjects were paid for participating. Sixteen subjects, five male and 11 female, served in Experiment I, 12 subjects, four male and eight female, served in Experiment II, and eight subjects, four male and four female, served in Experiment III.

Apparatus and stimuli

The stimuli were presented binocularly in a Gerbrands 3 channel tachistoscope (model T-3B-1). The target letter was a lower case a, o, e or c appearing in one of the four corners of an imaginary square centered on the fixation point. In Experiment I the other three positions were blank, in Experiment II they contained solid black dots made by filling in lowercase Os and in Experiment III they contained lowercase Xs. The masking stimulus was made from crosses superimposed on capital Os (i.e. ⊕). One such mask was centered on each corner of the imaginary square around the fixation point so that a target letter and noise elements presented simultaneously would be imbedded in the masks. Black Letraset 36 pt Futura Medium letters were mounted on white cards to make the targets and mask. Viewed at a distance of 80 cm, each target letter and noise element subtended approximately $26' \times 26'$ of visual angle and each mask in the masking stimulus subtended approximately $43' \times 43'$ of visual angle. The sides of the imaginary square which defined target, noise element and mask position subtended about 2° of visual angle.

The target letters were exposed for 10 ms and the masking stimulus was exposed for 25 ms, both at a luminance of approximately 8 ft lm. Between trials and during interstimulus intervals a fixation field was exposed. It contained a small white dot in the centre of a black field, presented at a luminance below the lower limit of the measuring device (an SEI spot photometer). Interstimulus interval was varied from 0 to 100 ms in 25 ms steps. On one-sixth of the trials, no mask was presented. In Experiment I the room lights were on during testing while in Experiments II and III the room was dimly lit by a 40 W bulb. In Experiments II and III the time alloted for instructions and practice served as a dark-adaptation period.

Procedure

The following procedure was used in all three experiments. On each trial subjects reported the identity or the location of the target letter. Forced-choice responding was required. Four letters (a, o, e and c), four locations (top left, top right, bottom left and bottom right) and six interstimulus intervals (0, 25, 50, 75, 100 ms and no mask) produced 96 different trials, each occurring once in random order in each condition. The same order of trials was used in each condition.

Each subject was tested in four conditions: *location* (L), where the location of unknown target letters was to be reported, *location-given-identity* (L|I) where subjects located a target letter whose identity was told to them prior to each trial, *identification* (I), where subjects identified the target letter without prior knowledge of its location, and *identification-given-location* (I|L), where subjects identified the target letter whose location was told to them prior to each trial. These conditions were run in separate blocks. Four orders of blocks were used with an equal number of subjects in each block in each experiment. The orders were: (1) L|I, I, L and I|L; (2) L, L|I, I|L and I; (3) I, I|L, L|I and L; (4) I|L, L, I and L|I.

The nature of the stimuli and the responses appropriate to each condition was described to the subjects and the importance of maintaining rigid fixation prior to stimulus exposure was stressed. The subjects were given 32 practice trials in which the identity and the location of the target letter was reported on each trial. During practice each Letter × Location combination occurred twice and each interstimulus interval, excluding no-mask trials, five times. Any subject who made errors on the seven no-mask trials was excluded from the experiment. In Experiment I, three subjects were replaced for failing to meet this criterion.

To begin each trial the subject was asked whether he was ready. If he had the fixation point in sharp focus he answered affirmatively and about 0·5 s later the experimenter initiated the timer sequence and the target letter appeared.

Results

Accuracy data

In all three experiments each subject had 16 forced-choice trials at each interstimulus interval in each condition. To correct for guessing, 4/3 of the errors were subtracted from 16. The means across subjects are presented in Table I. The rows of the table represent conditions within experiments and the columns represent interstimulus intervals and the row means.

The important results can be summarized as follows: with no noise and with dots as noise (Experiments I and II) the I|L, L and L|I conditions did not differ and performance in each of them was *more* accurate than performance in the I conditions. By contrast, I, L and L|I did not differ with Xs as noise elements (Experiment III) except at the 75 ms interstimulus interval where L was lower than I and L|I. Performance in each of these conditions was *less* accurate than L|I performance. Thus the relative performance in I|L and I did not change across experiments while the relation between L and I did.

Support for these conclusions is found in the separate five-way analyses of variance carried out for each experiment (subjects within-orders, orders, information, identification versus location, and interstimulus interval). The information effect compared the I|L and L|I conditions with the I and L conditions. In all

TABLE I

Mean number of correct responses, corrected for guessing, in location (L), location-given-identity (L/I), identification (I), and identification-given-location (I/L), at each interstimulus interval in each experiment

	Condition	Interstimulus interval 0	25	50	74	100	no mask	Row mean
Expt. I	L	3·38	5·69	11·75	14·56	15·68	16·00	11·18
	L|I	2·88	6·00	11·56	14·19	15·56	16·00	11·03
	I	0·94	3·19	8·56	13·81	15·00	15·81	9·55
	I|L	0·94	5·63	11·06	14·69	15·50	15·81	10·60
Expt. II	L	1·17	4·67	11·33	15·00	15·58	16·00	10·63
	L|I	0·83	5·17	12·42	15·67	15·92	16·00	11·00
	I	1·33	5·25	8·17	13·33	14·25	15·92	9·71
	I|L	1·75	6·83	11·41	14·08	14·58	16·00	10·78
Expt. III	L	0·38	1·38	6·13	10·00	13·88	16·00	7·96
	L|I	0·50	1·25	6·25	13·13	15·50	16·00	8·77
	I	1·25	1·88	7·75	12·25	14·00	15·88	8·83
	I|L	0·63	5·75	10·50	15·00	15·25	16·00	10·69

analyses the main effect for interstimulus interval was highly significant. The smallest F ratio for this effect was found in Experiment III, $F = 151·53$, $df = 5, 20$, $P < 0·01$.

In Experiment I the identification versus location effect was significant, $F = 7·39$, $df = 1, 12$, $P < 0·05$, as was its interaction with information, $F = 16·96$, $df = 1, 12$, $P < 0·01$, and interstimulus interval, $F = 3·27$, $df = 5, 60$, $P < 0·05$. In the former interaction, L was more accurate than I, $t = 7·76$, $df = 12$, $P < 0·01$, but the difference between I|L and L|I was not significant, $t = 2·04$, $df = 12$, $P > 0·05$. Though the main effect for information was not significant, $F = 3·15$, $df = 1, 12$, $P > 0·05$, I|L was more accurate than I, $t = 5·00$, $df = 12$, $P < 0·01$. There was no significant difference between L and L|I, $t < 1$, $df = 12$, $P > 0·05$.

Similar results were found in Experiment II. Though the identification versus location effect was not significant, $F = 3·07$, $df = 1, 8$, $P > 0·05$, L was more accurate than I averaged over interstimulus interval, $t = 2·47$, $df = 8$, $P < 0·05$, and I|L did not differ significantly from L|I, $t < 1$, $df = 8$, $P > 0·05$. The information effect was significant, $F = 13·55$, $df = 1, 8$, $P < 0·01$, as was its interaction with interstimulus interval, $F = 3·90$, $df = 5, 40$, $P < 0·01$. Averaged over interstimulus interval, accuracy, was higher in I|L than in I, $t = 4·03$, $df = 8$, $P < 0·01$, but no significant differences were obtained between L and L|I, $t = 1·42$, $df = 8$, $P > 0·05$.

In Experiment III the identification versus location effect was significant, $F = 30·43$, $df = 1, 4$, $P < 0·01$, as it was in Experiment I, but in the opposite direction. Locating was *less* accurate than identifying. Contrary to both of the previous experiments, no differences were obtained between I and L averaged across interstimulus interval, $t < 1$, $df = 4$, $P > 0·05$, and L was significantly less accurate than I at the 75 ms interstimulus interval, $t = 2·42$, $df = 20$, $P < 0·05$. The information effect was significant, $F = 52·85$, $df = 1, 4$, $P < 0·01$, with I|L more accurate than I, $t = 5{\cdot}62$, $df = 4$, $P < 0{\cdot}01$, and no overall difference between L|I and L by a two-tailed test, $t = 2{\cdot}26$, $df = 4$, $P > 0{\cdot}05$. However, at the 75 ms interstimulus interval, L|I was significantly more accurate than L, $t = 3{\cdot}36$, $df = 20$, $P < 0{\cdot}01$, contradicting the previous experiments.

To reiterate, the relation between the two identification conditions remained the same across experiments. I|L was superior to I. What changed was the relation between the location tasks and the two identification tasks. In Experiments I and II, L and L|I were at the level of I|L performance while in Experiment III, they dropped to the level of I.

Proportion data

In each experiment the accuracy data for each subject in the L, I and I|L tasks were converted to proportions for the direct test of the location-contingent hypothesis [i.e. $P(L)\ P(I|L) = P(I)$]. The means across subjects are presented in Table II where the rows represent conditions within experiments and the columns represent interstimulus intervals and the row means.

TABLE II

Obtained and predicted probability of responding correctly in the identification condition at each interstimulus interval in each experiment (P(I) represents the obtained results, P(L) P(I/L) represents the prediction of the contingency hypothesis and P(I/L) represents the prediction of a strictly independent model)

		Interstimulus interval						Row
	Condition	0	25	50	75	100	no mask	mean
Expt. I	P(I|L)	0·06	0·35	0·69	0·92	0·97	0·99	0·66
	P(I)	0·06	0·20	0·54	0·86	0·94	0·99	0·60
	P(L)P(I|L)	0·01	0·14	0·54	0·84	0·94	0·99	0·58
Expt. II	P(I|L)	0·11	0·43	0·72	0·88	0·91	1·00	0·67
	P(I)	0·08	0·33	0·51	0·83	0·89	0·99	0·61
	P(L)P(I|L)	0·01	0·14	0·52	0·83	0·89	1·00	0·57
Expt. III	P(I|L)	0·10	0·36	0·66	0·94	0·95	1·00	0·67
	P(I)	0·08	0·12	0·48	0·77	0·87	0·99	0·55
	P(L)P(I|L)	0·00	0·04	0·25	0·60	0·83	1·00	0·45

Inspection of Table II reveals good agreement between the prediction and observed I results in Experiment I, satisfactory agreement in Experiment II, and substantial disagreement in Experiment III. These conclusions are supported by the results of separate four-way analyses of variance carried out for each experiment (subjects within orders, orders, conditions, and interstimulus interval).

In Experiment I the prediction did not differ from the observed I results, averaged over interstimulus interval, $t = 1{\cdot}21$, $df = 24$, $P > 0{\cdot}05$. By contrast, $P(I|L)$ was significantly higher than $P(I)$ averaged over interstimulus interval, $t = 4{\cdot}09$, $df = 24$, $P < 0{\cdot}01$.

A similar pattern of results emerged in Experiment II. Though overall the prediction differed from the observed I results, $t = 2{\cdot}70$, $df = 16$, $P < 0{\cdot}02$, the differences were only significant at the 0 and 25 ms interstimulus intervals, $t = 2{\cdot}03$ and $5{\cdot}00$ respectively, $df = 80$, $P < 0{\cdot}05$, where L was no more accurate than I. At all other intervals, the fit is very close.

The results of Experiment III, however, are different. Here the prediction was different overall from the observed I results, $t = 4{\cdot}47$, $df = 8$, $P < 0{\cdot}01$. This difference was greatest at the 50 and 75 ms interstimulus intervals where the agreement was substantial in Experiments I and II, $t = 3{\cdot}75$ and $2{\cdot}62$, respectively, $df = 40$, $P < 0{\cdot}05$.

Discussion

In these experiments, locating requires discriminating the target letter from the noise elements. When this discrimination was easy (Experiments I and II), the location-contingent hypothesis was reasonably well supported. Satisfactory agreement was obtained between the prediction and the observed I results, and L was more accurate than I as would be expected if locating must occur before identification. When it was difficult to separate the target from the noise (Experiment III), the location-contingent hypothesis was not supported. The prediction significantly underestimated observed I results and L was not more accurate than I. These results must temper the interpretation of the consistent superiority of I|L over I in all three experiments. While this superiority was predicted by the location-contingent hypothesis, the notion of independent but interacting processes outlined earlier can account for it and all other results. From this point of view, location information available early enough may serve to reorganize the identification process so as to improve accuracy. Location information provided prior to stimulus presentation would certainly be available early enough to alter processing while location information encoded from the stimulus array may not (Experiment III). Additionally, it is clear that the consistent superiority of I|L over I rules out any model proposing strictly independent processing.

The finding that knowledge of location facilitates identification is not consistent with Spencer's (1972) results. His subjects were not more accurate in identifying a target letter presented on the fixation point (I|L) than in identifying one presented in one of 12 positions around the fixation point (I). However, unlike the present experiments, target location changed as locational uncertainty was manipulated. This procedural difference may be important since van der Heijden and Eerland (1973) manipulated locational uncertainty independent of target location and found that a simultaneous location cue improved the accuracy of target detection.

Another problem with the present result lies in the lack of control for fixation. Subjects may have improved accuracy in the I|L condition by fixating on the designated position. Whether or not replication with appropriate controls will produce different results, the conclusions drawn earlier are still supported by the comparison between the I and L conditions.

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