I-Interruption Effects in Backward Pattern Masking: The Neglected Role of Fixation Stimuli

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## I-Interruption effects in backward pattern masking: The neglected role of fixation stimuli

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Visual backward masking occurs when presentation of a visual stimulus (the mask) impairs perception of a prior briefly-presented visual stimulus (the target). A fixation stimulus (e.g., a dot or four dots demarcating a square) directs the subject's attention (i.e., fixation) to the place where target and mask will appear.

Two parameters often manipulated in backward masking research are: energy properties of mask and target, and time lag between appearance of the target and appearance of the mask (stimulus onset asynchrony-SOA). Two sorts of explanation exist for backward masking: (1) interruption theory (e.g., Turvey, 1973; Hellige et al., 1979), which interprets backward masking as a time-dependent central phenomenon, i.e., interruption by the mask's signal of processing of the target's signal; and (2) sensory integration theory (e.g., Felsten & Wasserman, 1980), which posits that the mask impairs the perception of the target by causing a peripheral or central fusion of the two sensory signals.

We present here a series of experiments which establish the importance of a new process-analytical model of backward masking. The model predicts very strong and developmentally stable, heretofore unknown, effects that no available perceptual theory can explain. One of these effects is the role of size of the fixation stimulus in moderating the disrupting impact of the mask on recognition of the target. This moderating effect of size of fixation stimulus suggests the existence of content-free central attentional processes, which regulate the influence of the mask on target recognition. After Piaget, we call this fixation-stimulus effect a centration effect; we describe briefly below the process theory and its task-analytical model of backward masking that led to the prediction of this effect.

The Theory of Constructive Operators (TCO) (Pascual-Leone & Goodman, 1979) formulates in functional terms the psychological processes which within the organism co-determine performance. These processes are of two sorts: (1) Situation-specific processes or "soft-ware" of the organism, which the theory conceptualizes as schemes; and (2) situation-free processes or "hard-ware" of the psychological organism, which the theory conceptualizes as silent operators (i.e., resources). At least four silent operators are needed to account for cognitive performances: the L, M, I, and F operators.

The L operator is the Logical learning operator. The result of L learning is the formation of habitual structures which represent frequent patterns of co-activation and of co-application of schemes. Executives are L structures that represent goal-directed generic sequences of schemes (i.e., plans). In a given situation, the dominant executive mobilizes the silent operators to produce performance.

The M and I operators represent, together, the mental effort that the organism applies on schemes to ensure that the relevant schemes will produce performance. The I operator, I for interruption (hereafter called I-interruption), represents the active inhibition that the dominant executive can monitor and use to inhibit schemes (including other conflicting executives) irrelevant for its executive-planned performance. The M operator, M for mental, is the mental attentional energy that the dominant executive mobilizes and allocates to increase the activation of (i.e., boost) task-relevant schemes. Attentional M-energy is a limited resource, able to boost only a small number of schemes simultaneously. The cardinal number of the largest set of schemes that M can boost at any one time is called the M power, and has been shown to increase developmentally (e.g., Pascual-Leone & Goodman, 1979).

The F operator, F for subjective/cognitive Field factor, corresponds to the tendency to structure performance in congruence with the subjectively salient structural features of the situation.

The operative system constituted by the executives and by the M, I, and F operators, that the dominant executive monitors and allocates in any given situation, constitute the TCO-model of the Centration Mechanism.

Consider the general backward masking paradigm we employed: after adaptation to the fixation stimulus, one of three specified target letters is flashed for 9 msec., the fixation stimulus reappears for 91 msec., following which a line-pattern mask is presented for 50 msec. Subjects must report one of the three possible targets, guessing if necessary. The masking effect occurs to the extent that the Orienting Reflex (OR) reaction (an innate executive) elicited by the mask I-interrupts processing of the target, thus allowing the target and mask signals to fuse. Recognition of the target is possible to the extent that the target executive elicited by the task instructions (i.e., "try to recognize and report the target letter") is stronger than the OR reaction so as to I-interrupt the schemes of the mask while M-boosting the schemes of the target. The target executive's task should be facilitated greatly if the target as a whole falls topographically in a retinal area which is already being M-centrated by virtue of the fixation stimulus, but should be difficult if the discriminant features of the letter fall outside the M centration. This is so because the discrimination among schemes which are "outside" versus "inside" the M centration is primary (perhaps innate) according to the theory; and the theory prescribes that the organism considers as relevant schemes which in the course of the task appear to be inside M (M-boosted). Thus, the target executive's I-interruption of irrelevant mask processes should be much easier to achieve if no task-relevant scheme (no perceptual feature of the target) falls outside the M centration initiated by the fixation stimulus.

We modified the central backward masking paradigm by including three fixation-stimulus conditions: a point fixation stimulus (a small circled dot), a square fixation stimulus (four dots demarcating a square which in size covers fully the area where the targets appear), and a square-5 fixation stimulus (a similar four-dot pattern with a fifth dot in its centre). Blocks of trials corresponding to the fixation-stimulus conditions were presented in a within-subject design. Since the square fixation will lead the subject to M-centrate the entire area in which the target will appear and the point will lead him to M-centrate only a portion of that area, we predict that the masking effect will be stronger in the point condition. With the square-5 fixation, subjects may look at either the square dots or the central point and, thus, square-5 performance should be between the other two.

A detailed task analysis of backward masking suggests that an M power (Mp) of e+4 (e for the executive's M-boost) should suffice to handle the task easily, provided that the target executive is given sufficient processing time. Much experimental-developmental work (e.g., Pascual-Leone & Goodman, 1979) has demonstrated that Mp e+4 is not available till 9-10 years of age. Thus, we predict that 9-10 year olds should perform better than younger subjects and that older subjects will not perform better than 9-10's. This age effect should occur when sufficient target-processing time is allowed (Experiments 3A and 3C below), but may not appear when target-processing time is decreased (Experiments 1, 2 and 3B).

We also predict a main effect for cognitive style field dependence/independence. Field dependent (FD) subjects should experience stronger masking effects because of their strong field (F) factor which will lead them to fuse the target and mask, and their weak I-interruption ability (Pascual-Leone & Goodman, 1979). Field independents (FI) with their strong I-interruption ability should perform best, with field mediums (FM) performing in between. Since the cognitive style effect can manifest itself only if the subject is not hindered by insufficient Mp, we make this prediction only for adults and 11- and 12-year olds. In addition, we predict that the *square*-*point* performance disparity will be greatest for FI (or FM in children) subjects because their greater I-interruption ability will enable them to best take advantage of the facilitating *square*.

To test our model we conducted a series of studies.

### General Method

Subjects were group-tested with measures of field dependence/independence (FDI) and selected across the full FDI continuum. Children were also tested with a group measure of *M* power.

The tachistoscopically-presented stimuli were prepared on white cards. Two types of fixation stimulus were prepared: the *point* fixation, i.e., a red dot in the centre of the card with a small green circle hand-drawn around it ($.25^{\circ}$ visual angle); and the *square* fixation, i.e., four black dots ($.15^{\circ}$ each) arranged in a square-shaped pattern ($0.9^{\circ} \times 0.9^{\circ}$) around the centre of the card. The target stimuli (the Geotype black letters A, T, and U $0.9^{\circ}$ high x $0.7^{\circ}$ wide) fell within the fixation area defined by the *square* pattern. The mask stimulus, a variant of Turvey's (1973) pattern mask, was made of black lines the same width as the target letter lines ($0.2^{\circ}$ wide).

The subject's task was to indicate which of the three specified target letters had been presented on a given trial (guessing if necessary). On each trial the subject attended to a fixation stimulus, then a target letter was presented followed by the fixation again (or blank field for adults) and then the pattern mask. The subject responded after the mask went off. The experiments were run in blocks of fixation conditions with 18 trials per block. Within a block each target letter was presented six times in random order.

### Experiment 1

*Method*. Three age samples of 20 children each were selected; mean ages were 8;0, 10;0, and 11;10. A three-field tachistoscope was used; the fields were set to equal luminance by visual estimation. On each trial a fixation stimulus was followed by a target letter exposed for 9 msec., then the fixation for 71 msec., then the mask for 50 msec. (80 msec. SOA). Each condition had three introductory trials using 100x, 10x, and 1x the standard target duration. There were four blocks of 18 trials each. The fixed order of blocks was: *point*, *square*, *point*, *square*.

*Results*. An age x order x fixation ANOVA on the number of correct responses yielded a significant main effect for fixation ($F(1,57)$ 85.87, $p < .01$), with better performance in the *square* condition ($M$=15.1) than in the *point* condition ($M$=11.2). A significant order x fixation interaction ($F(1,57)$ 5.67, $p < .05$) reflected an increase in performance from the first to the second *point* block. Each *square* block showed significantly higher performance than either *point* block.

To illustrate the *point* versus *square* performance disparity, Figure 1 shows mean performance in the four fixation blocks for Experiments 1 and 2 (to be discussed below). The same general pattern shown here was found in all experiments.

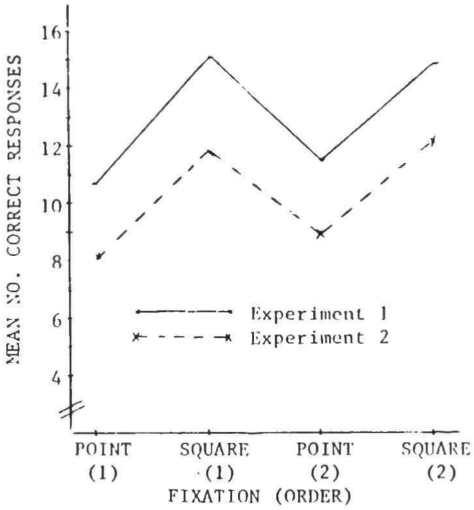

Figure 1. Mean performance across fixation blocks in Experiments 1 and 2.

### Experiment 2

*Method*. Three age samples were selected; mean ages (and *n*'s) were 7;4 (15), 9;4 (18), and 11;4 (15). Procedures were identical to Experiment 1.

*Results*. An age x order x fixation ANOVA yielded a main effect for fixation ($F(1,45)=74.11$, $p < .01$); again performance with the *square* ($M$=12.1) was superior to that with the *point* ($M$=8.5). See Figure 1.

### Experiment 3

*Method*. Seven I.Q.-normal age-group samples were selected; mean ages (and *n*'s) were 6;3 (21), 7;4 (24), 8;4 (24), 9;6 (20), 10;4 (25), 11;4 (23), and 12;6 (24). A three-field tachistoscope was used; its fields were set at a luminance of 6.5 $cd/m^2$. Introduction and fixation-block order were the same as in Experiments 1 and 2. The 6- to 8-year age samples were initially tested (*treatment condition 3A*) as follows: fixation stimulus, target for 9 msec., fixation for 91 msec., then mask for 50 msec. (SOA=100 msec.). The 9- to 12-year age samples were initially tested (*treatment condition 3B*) as follows: fixation, target for 7 msec., fixation for 93 msec., then mask for 50 msec. (SOA=100 msec). Weeks after initial testing, the samples of 8 to 12 years were re-tested (*treatment condition 3C*), under the conditions 3A given above.

*Results*. The three treatment conditions are presented successively.

*3A (9 msec. target)*. An age x order x fixation ANOVA yielded a significant main effect for fixation ($F(1,66) = 66.2$, $p < .01$); performance with the *square* ($M$=9.4) was better than that with the *point* ($M$=6.9). Other significant effects were for age ($F(2,66)$ 3.7, $p < .05$), with 6-year-olds doing less well than older subjects; and age x order ($F(2,66)$ 3.7, $p < .05$), with older subjects generally improving with practice (i.e., over blocks) more than 6-year-olds.

*3B (7 msec. target)*. The ANOVA yielded a significant main effect for fixation (*F*(1,88) = 40.5, *p* < .01); performance was better with the *square* (*M*=8.8) than with the *point* (M=7.0). There was an order x fixation interaction (*F*(1,88) 9.5, *p* < .01), with performance decreasing from first to second *square* presentation; still, each *square* block was significantly easier than either *point* block.

*3C (9 msec. target, re-test)*. The ANOVA yielded again a significant main effect for fixation (*F*(1, 111) 145.8, *p* < .01); *square* performance (*M*=11.4) was better than *point* performance (*M*=8.7). There were significant effects for age (*F*(4,111) = 4.08, *p* < .01), order x fixation (*F*(1,111) = 5.93, *p* < .05), and age x order x fixation (*F*(4,111) 2.98, *p* < .05). Overall performance peaked at 9 and 10 years followed by a dropping-off at 11 and 12 years. The order x fixation interaction rested on increased performance in the *point* condition from first to second presentation. We will not discuss the three-way interaction, but must emphasize that for all ages except 11 years, each *square* block was significantly easier than either *point* block.

To test style predictions, 11- and 12-year-olds in 3C were divided into FD, FM, and FI groups using scores on a group version of the Children's Embedded Figures Test (CEFT - Karp & Konstadt, 1963). An age x style x order x fixation ANOVA yielded (among other significant effects) a main effect for style (*F*(2,41) 11.49, *p* < .01), with FI's and FM's performing better than FD's; and a style x fixation interaction (*F*(2,41) = 4.17, *p* < .05), with disparity between FM and FD performance greater with the *square* than with the *point*. Pearson *r*'s between CEFT and mean performance were *r*(21) = .41, *p* = .05 for 11's and *r*(22) = .60, *p* = .002 for 12's.

## Experiment 4

*Method*. Thirty university undergraduates were selected to form FD, FM, and FI cognitive style groups (*n* 10 in each), using scores on the Group Embedded Figures Test (GEFT - Oltman, et al., 1971). A four-field tachistoscope was used. Fixation was followed by a target stimulus of 7 msec. duration, then a 0.1 cd/m$^2$ full-field illumination for 93 msec., and then the pattern mask for 50 msec. (SOA 100 msec.). All fields, except for the interstimulus interval, were set at a luminance of 6.5 cd/m$^2$. In addition to the *square* and *point* fixations employed in the previous experiments, a *square-5* fixation was used. The *square-5* was like the *square*, but with an additional dot (.15$^o$) in the centre of the visual field (i.e., in the centre of the *square*). Again each fixation condition was run within-subjects in two blocks of 18 trials each. A training block of 18 trials preceded the experimental fixation conditions; for the training block the fixation stimulus was an "x" exactly half the size of the *square*. The order of fixation blocks was: training, *square*, *square-5*, *point*, *square*, *square-5*, *point*.

*Results*. A style x order x fixation ANOVA yielded significant main effects for style (*F*(2,27) 7.77, *p* .01) and fixation (*F*(2,54) 18.90, *p* < .01). Recognition increased with degree of field independence, and decreased from the *square* (*M*=8.5) to the *square-5* (M=7.0) to the *point* (M=6.0) conditions. The Pearson *r*(28) between GEFT and mean performance was .57, *p* .001. There was a significant style x fixation interaction (*F*(4,54) 2.89, *p* < 05) which is plotted in Figure 2. This interaction shows

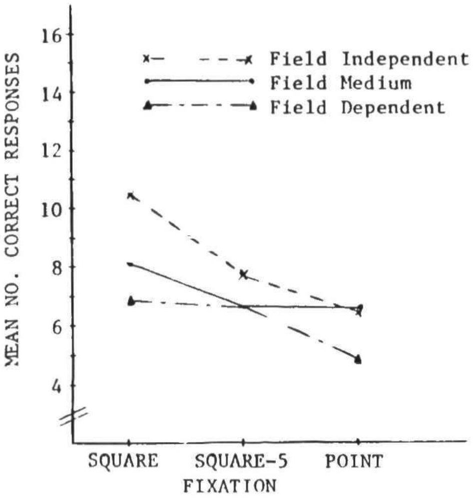

Figure 2. Mean performance by cognitive style and fixation in Experiment 4.

that the facilitating effect of the *square* fixation relative to the *square-5* and *point* is greatest for FI subjects, and the misleading effect of the *point* fixation is greatest for FD subjects. Note that as the theory predicts, FM subjects perform between FI and FD subjects, and performance with the *square-5* falls between that with the *square* and the *point* fixations.

## References

Felsten, G., and Wasserman, G. S. Visual masking: Mechanisms and theories. *Psychological Bulletin*, 1980, *88*, 329-353.

Hellige, J. B., Walsh, D. A., Lawrence, V. W., and Prasse, M. Figural relationship effects and mechanisms of visual masking. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 88-100.

Karp, S. A., and Konstadt, N. L. *Manual for the Children's Embedded Figures Test*. Cognitive Tests, P.O. Box 4, Vanderveer Station, Brooklyn, New York, 1963.

Oltman, P. K., Raskin, E., and Witkin, H. A. *Group Embedded Figures Test*. Palo Alto, Calif.: Consulting Psychologists Press, 1971.

Pascual-Leone, J., and Goodman, D. Intelligence and experience: A neoPiagetian approach. *Instructional Science*, 1979, *8*, 301-367.

Turvey, M. T. On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with pattern stimuli. *Psychological Review*, 1973, *80*, 1-52.