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Priming by "predictive" context stimuli in visual classification

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Subjects participated in visual character- and word-classification tasks for which spatially contiguous context stimuli were exposed 100 or 1,000 msec prior to target onset. These context stimuli were physically identical to the target on 75% of the trials. Substantial facilitation of RT occurred for "valid" trials at both SOA levels. When the target differed from the context stimuli, evidence for priming the response category, as well as the semantic category of the target (letters vs. digits; metal names vs. furniture names), was obtained at the 100-msec SOA, but these effects were attenuated with the 1,000-msec SOA. With a full second to process a stimulus-predictive cue, subjects appear to develop a stimulus-specific expectation of the target that does not involve maintaining the category or response-mapping codes that are active with shorter delays.

When observers are required to classify a visual target that appears in a prespecified location, target-classification speed may be strongly influenced by the information content of spatially contiguous "noise" items, even if observers are instructed to attend exclusively to the target. The effects of the noise elements may include not only Stroop-like response competition effects (Eriksen & Eriksen, 1974), but influences of category relationships between the noise elements and the target (such as letter-digit distinctions or word categories) that are independent of response assignments (Flowers, 1990; Flowers & Wilcox, 1982; Shaffer & LaBerge, 1979). The relative magnitude of these various context effects changes with the relative onset time of the noise elements and target. Response competition is typically strongest with nearly simultaneous onset of noise and target, while category-congruity effects are most apparent when the noise elements precede the target onset by 100 msec or more (Flowers, 1990). However, with onset separations of more than 500 msec, all content-specific effects of the flanking noise elements tend to vanish. Thus, even under instructions to ignore information that spatially flanks a target, and under conditions in which the flanking context provides no information about target or response identity, noise elements produce involuntary priming effects that indicate activation of both response and categorical codes that have distinct and transitory time courses.

The present experiment explored priming effects that occur when subjects try to use, rather than ignore, surrounding context. In this experiment, flankers predicted target identity with 75% reliability; subjects were instructed to make use of that information to facilitate performance. While it is known that expectancy-based priming by statistically valid context develops and extends over a longer time course than do automatic or involuntary priming effects (Flowers, Nelson, Carson, & Larsen, 1984; Neely, 1977; Taylor, 1977), we were interested in the degree to which the expectancies and predictions would reflect expectation of a specific visual stimulus code, a bias for a particular response, activation of categorical information that is not directly related to the predicted stimulus or response, or some mixture of all of these. By examining RTs (and error patterns) for *nonpredicted* stimuli that nevertheless share one or more of the attributes (semantic category, response category, or both) with the target predicted by flankers, inferences can be made about the "content" of the subjects' expectancies and how that content might change over preparation time. By using stimuli identical to those of Flowers (1990), qualitative comparisons between involuntary and expectancy-based priming effects generated by a similar task and stimuli can be undertaken.

METHOD

Subjects

Fifty students participated in a single session lasting about 1 h 15 min. Twenty of the subjects were paid $4 for participation, and the remaining volunteered as an alternative means of satisfying a course requirement. All subjects claimed to have normal or corrected-to-normal vision. English was the native language of all subjects.

Apparatus and Procedure

Display equipment and the general procedure were identical to that used by Flowers (1990). Control of stimulus displays and data acquisition were performed by an Apple II+ computer (modified for monitoring the video synchronization) and a P31 phosphor monitor, located on a table at which the subject was seated. Stimulus displays were printed on the monitor screen in uppercase text letters, which, at the typical 50-cm viewing distance, produced an angular separation of about 0.8° between adjacent characters.

Each experimental trial consisted of the following display sequence: An alerting message, such as "GET READY FOR TRIAL #1" was shown for 3 sec, followed by a fixation field of 2 sec in duration. The

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fixation field was replaced by the flanker display, to which the target stimulus was added after an SOA of either 100 or 1,000 msec (for different subject groups). The subject then responded to the target stimulus by pressing one of two keys on the computer console. RT was measured to the nearest millisecond as the time between the start of the raster scan on which the target was added and the depression of the response key. During the session, each subject responded to nine blocks of 75 trials, for which the first block was discarded as a practice trial. The first five trials on each of the remaining eight trial blocks were block warm-up trials for which display conditions were randomly assigned; data from these warm-up trials were also excluded from analysis.

Stimuli and Classification Rules

Twenty-six subjects participated in a character-classification task, identical to one used by Flowers (1990, Experiment 1). Target stimuli were selected from the character set A, B, 1, 2, Y, Z, 8, 9, for which the classification rule required a "left" keypress (the F key on computer) for A, B, 1, or 2, and a "right" keypress (the J key) for Y, Z, 8, or 9. Each response category thus contained two letters and two digits. The flanker stimuli used on a trial consisted of two identical characters selected from the same set of four digits and four letters, plus the nontarget character * (which served to provide a neutral, or noninformative, prime). A typical display sequence for this task was:

+++	→	B+B	→	B2B
(fixation)		(flankers)		(target)

The remaining 24 subjects performed a word-classification task identical to Flowers (1990, Experiment 2). The target alternatives were the uppercase nouns SILVER, GOLD, TABLE, and CHAIR, which were assigned to the left key, and IRON, BRASS, LAMP, and PHONE, which were assigned to the right key—a mapping that assigned two metals and two office furniture items into each response category. The flanker alternatives consisted of these items plus the string XXXXX, which served as a neutral prime. A typical display for this task was:

-----		SILVER		SILVER
-----	→	-----	→	TABLE
-----		SILVER		SILVER
(fixation)		(flankers)		(target)

The response and categorical relationship between flanker and target determined the flanker condition variable for each of these two classification tasks. The ID (identical) condition consisted of flankers and targets that were physically identical. Condition SCSR (same category, same response) included displays for which flankers and targets were both categorically similar and mapped to the same response but were physically different (e.g., ABA). Condition DCSR (different category, same response) included displays for which flankers and targets shared response assignment but were categorically different (e.g., A2A). Condition SCDR (same category, different response) included categorically similar flankers and targets that were mapped to opposite response categories (e.g., 828). Condition DCDR (different category, different response) included flankers and targets differing in both category membership and response mapping (e.g., A8A). For Condition N (neutral), the neutral nontarget flanker was used (e.g., *8*).

Pairings of flankers were constrained so that flankers and targets were identical on 75% of the trials (except for the N condition in which the * or XXXXX flankers were paired equally often with each target alternative). The subjects were read written instructions that informed them that, except for the neutral symbol flankers, the target "would be identical to the flanker on three out of four trials" and that they could use that information to try to improve speed of responding. On the trials in which flankers and targets were nonidentical (excluding the neutral trials), each target alternative was paired equally often with each flanker. As a consequence of these distributional constraints, the number of trials during the experiment (excluding the practice block and the five warm-up trials in each block) was 336 for ID, 16 for SCSR, 32 each for DCSR, SCDR, and DCDR, and 112 for Condition N.

Stimulus Onset Asynchrony

For each classification task, half of the subjects (13 for the character task and 12 for the word task) received a 100-msec stimulus onset asynchrony (SOA) between flanker and target onset, and the remaining subjects received 1,000 msec on each trial. One hundred milliseconds represents an SOA level for which robust facilitative and inhibitory priming effects have been observed with these types of stimuli under conditions in which flankers provide no predictive validity (Flowers, 1990; Flowers & Wilcox, 1982). Qualitative and quantitative differences in such effects under instructions to use predictive validity could indicate an additional use of voluntary preparation effects or attention strategies at this short SOA. An SOA level of 1,000 msec is well beyond the point at which involuntary priming has been shown to be operative, so that flanker condition effects at that level would be almost exclusively attributable to voluntary preparation.

Speed/Accuracy Instructions and Feedback

In addition to instructions about the predictability of the target, subjects were told to respond "as rapidly as possible, avoiding errors," and "not to respond prior to the appearance of the target." Trials on which RT exceeded 1,000 msec caused a "TOO LONG" message to be displayed on the screen; RTs for such trials were excluded from analysis. Trials with less than 100-msec RT caused a "YOU JUMPED THE GUN!" message to be displayed; these trials were also discarded. RTs of less than 100 msec and RTs greater than 1,000 msec, together, made up less than 2% of all trials. Misclassification errors, which were also excluded from RT analysis, caused an "ERROR" message to appear. Additional feedback on RT performance was not given.

RESULTS

Table 1 displays the mean RT and misclassification error rates for the character task; Table 2 displays corresponding data for the word task. Additionally, each table lists the RT difference between the neutral flanker and every other flanker condition as a measure of the priming effect. Positive values indicate facilitative priming; negative values indicate inhibition. Error rates were relatively low, and they generally correlated with RT. Several

Table 1
Mean RT, Priming Effect, and Error Rate for the Character Task

	ID	SCSR	SCDR	DCSR	DCDR	N
			100-msec SOA			
RT	392	420	493	452	493	445
Priming Effect*	+53	+25	−48	−7	−48	
Error Rate†	.010	.010	.110	.007	.085	.019
			1,000-msec SOA			
RT	393	478	494	508	509	486
Priming Effect*	+93	+8	−8	−22	−23	
Error Rate†	.027	.020	.027	.019	.070	.023

Note—+ = facilitation; − = inhibition. *Difference in RT relative to Condition N. †Includes misclassification errors only.

Table 2
Mean RT, Priming Effect, and Error Rate for the Word Task

	ID	SCSR	SCDR	DCSR	DCDR	N
			100-msec SOA			
RT	408	448	511	477	515	466
Priming Effect	+58	+18	−45	−11	−49	
Error Rate	.028	.016	.116	.037	.120	.063
			1,000-msec SOA			
RT	355	511	498	506	486	495
Priming Effect	+140	−16	−3	−11	+9	
Error Rate	.009	.016	.065	.036	.073	.026

Note—+ = facilitation; − = inhibition.

subjects produced errorless performance in at least one flanker condition. RT was used as the dependent variable in all formal statistical analyses of performance.

Inspection of these tables reveals quite substantial effects of flanker condition on RT, which were highly significant [$F(5,120) = 66.42, p < .001$, for the character task, and $F(5,110) = 60.32, p < .001$, for the word task]. It is also apparent that the pattern of flanker effects, although relatively similar between the word and character tasks, differed for the 100- and 1,000-msec SOA levels; an SOA × flanker condition interaction was observed for both tasks [$F(5,120) = 7.23$ and $F(5,110) = 13.15, p < .001$ in both cases]. Both SOA levels produced substantial facilitation of responding to the predicted target (Condition ID); however, at the 100-msec condition, performance levels for the *nonpredicted* flanker conditions were much more strongly differentiated, revealing a similar pattern of costs and benefits between both the character and the word tasks. There is clear evidence of inhibition (> 45 msec) to response-incompatible conditions (SCDR and DCDR), yet evidence for facilitation (25 and 18 msec) to Condition SCSR (but not DCSR) relative to the neutral condition. At 100-msec SOA, RT for the nonpredicted targets thus appears to reflect influences of *both* response compatibility and category congruity. This pattern is highly similar to that obtained by Flowers and Wilcox (1982) and Flowers (1990) for a situation in which flankers did not constitute predictive cues. We performed ANOVAs on the subset of Conditions SCSR, DCSR, SCDR, and DCDR, treating them as a 2×2 combination of category congruency and response compatibility. For the 100-msec SOA only, these ANOVAs showed, for both tasks, significant effects of category congruency [$F(1,12) = 7.91$, $p < .025$ and $F(1,11) = 12.13, p < .01$], response compatibility [$F(1,12) = 31.19, p < .001$, and $F(1,11) = 100.73, p < .001$], and an interaction between them [$F(1,12) = 17.76, p < .001$, and $F(1,11) = 5.34, p < .05$].

An equivalent analysis for the 1,000-msec SOA groups showed that differentiation among these conditions had largely attenuated. For the character task, a significant effect of category remained [$F(1,12) = 19.6; p < .001$]; inspection of Table 1 shows that SCSR was only 8 msec faster than was N and 22 msec faster than was DCSR, as opposed to 25- and 32-msec differences at the 100-msec SOA. Thus, with a full second to prepare for the target onset, the subjects appeared to exhibit a pattern of strong facilitation of responding to expected target but little remaining sensitivity to the category- or response-mapping attributes of target stimuli that were different from the expected one. This pattern does *not* appear to be one of pure response biasing, however, since the modest error rates for the response-incompatible conditions of less than 8% (lower than those observed at the 100-msec SOA) argue against a speed-accuracy tradeoff.

DISCUSSION

With a relatively brief time (100 msec) to make use of predictive information by a prime, the pattern of flanker effects generally resembles that obtained when such primes have no predictive validity—except that the *magnitude* of the flanker effects is somewhat larger. We attribute the greater robustness of these response- and category-compatibility effects largely to increased voluntary attention given to the flankers in attempts to use predictive information, as opposed to a situation in which subjects are instructed to ignore the flankers. However, the transitory nature of these priming effects, as evidenced by their absence in the 1,000-msec SOA groups, suggests that they may not be fundamentally distinct from the presumably "involuntary" priming effects observed by Flowers (1990). Greater facilitation of the ID condition, relative to experiments involving nonpredictive flankers, suggests some additional influence of voluntary preparation, although it should be noted that the mere presence of correlations between flankers and response categories can lead to facilitation effects of which subjects are not necessarily aware (Miller, 1987).

With greater preparation time, effects of categorical congruity between flankers and nonpredicted targets, as well as response-compatibility effects, are diminished or absent. Expectation of a particular target does not appear to assist responding to nonpredicted targets that are either categorically similar or that share response mappings. The lack of evidence for a simple response-biasing strategy with the 1,000-msec SOA (e.g., lack of either response-compatibility effects to nonpredicted targets or inflated error rates on response-incompatible trials) is suggestive of some type of relatively specific visual code preparation, perhaps similar to that observed in other types of cuing experiments (e.g., Flowers, 1975; Tversky, 1969). Such a state of preparation does not seem to be accompanied by either sustained activation of category information or a large degree of "pure" response priming.

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