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The Negative Priming Effect: Inhibitory Priming by Ignored Objects

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A priming paradigm was employed to investigate the processing of an ignored object during selection of an attended object. Two issues were investigated: the level of internal representation achieved for the ignored object, and the subsequent fate of this representation. In Experiment 1 a prime display containing two superimposed objects was briefly presented. One second later a probe display was presented containing an object to be named. If the ignored object in the prime display was the same as the subsequent probe, naming latencies were impaired. This effect is termed negative priming. It suggests that internal representations of the ignored object may become associated with inhibition during selection. Thus, selection of a subsequent probe object requiring these inhibited representations is delayed. Experiment 2 replicated the negative priming effect with a shorter inter-stimulus interval. Experiment 3 examined the priming effects of both the ignored and the selected objects. The effect of both identity repetition and a categorical relationship between prime and probe stimuli were investigated. The data showed that for a stimulus selected from the prime display, naming of the same object in the probe display was facilitated. When the same stimulus was ignored in the prime display, however, naming of it in the probe display was again impaired (negative

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The experiments were conducted as part of work towards the author's doctoral dissertation,[1] reported to the Meeting of the Experimental Psychology Society, Amsterdam, July 1984, and briefly described in Allport, Tipper and Chmiel (in press) as Experiment 3 and part of Experiment 5.

[1]S. P. Tipper (1984), "Negative priming and visual selective attention". University of Oxford, D.Phil.

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priming). That negative priming was also demonstrated with categorically related objects suggests that ignored objects achieve categorical levels of representation, and that the inhibition may be at this level.

GENERAL INTRODUCTION

Biological organisms are bombarded by sensory information. A basic issue is how organisms select particular objects for action and successfully ignore other competing objects. One approach to the study of selection mechanisms is to examine the processing of the objects that are ignored. Two central questions are at issue: What level of representation does the ignored object achieve, and what is the subsequent fate of this representation? The main two opposing positions concerning the level of internal representation achieved by the ignored object can be termed prceategorical and postcategorical selection. The precategorical view maintains that the initial parallel analysis of a visual scene achieves internal representations of only the physical features of objects, for example, the colour of an object, its location in space, etc. (Broadbent, 1971; Kahneman and Treisman, 1984). Representations of what an object "means" to an organism are only achieved when the object is selected for further processing. The contrary position of postcategorical selection maintains that the initial parallel analysis of a visual scene achieves at least categorical levels of internal representation, as well as lower physical features (Deutsch and Deutsch, 1963; Allport, 1977, 1980; Van der Heijden, 1981).

The second question is this: During and after selection of the target, what happens to the representations of ignored objects, whether these representations are at low level (physical) or higher (categorical) levels? Again, there are two opposing views. The first can be termed passive decay. This position is held by both pre~ and postcategorical theorists. For example, Broadbent (1970) represents the precategorical view. He suggests that information is initially received into a buffer store of low-level physical representations. Some of this information may then proceed to further processing mechanisms. The information that fails to pass this stage of serial processing before the time limit on the buffer store expires will be lost. Van der Heijden (1981) holds a postcategorical view of the initial processing of a display prior to selection. However, like Broadbent, he feels that distractors decay when not selected. Indeed, he goes further and suggests that distractor decay is one of the mechanisms of selection. He says: "Attention functions by maintaining the count level of the correct logogen until the count level of the other [irrelevant distractors] logogens are sufficiently decreased" (p. 188).

The alternative view can be termed distractor inhibition. That is, the internal representations of competing distractor representations are associated with inhibition during target selection. Keele and Neill (1978) write: "... when it [the control process of attention] selects some information, other conflicting information can be inhibited" (p. 42). In this view the mechanisms of selection involve target facilitation/maintenance *and* distractor inhibition. Such a dual mechanism may explain the remarkable efficiency of selection.

To examine whether decay or inhibition occurs, it is necessary to observe the fate of the representation of the ignored object subsequent to the initial encounter with the object. Previous methods have looked for the effect of an ignored distractor on the processing of a simultaneous target, for example, Stroop (1935). Such an approach can show that ignored objects achieve particular levels of internal representation, but cannot tell us whether these representations then passively decay or are actively inhibited. One way to study the fate of a representation over time is to use a priming paradigm. A display containing a prime object is presented, then, after a delay, a probe display is presented for rapid naming. Previous research has shown that when the prime is attended to and is the same as, or semantically related to, a subsequent probe, the response to the probe is facilitated (Warren and Morton, 1982; Carr, McCauley, Sperber and Parmelee, 1982; Meyer and Schvaneveldt, 1975).

The research reported here, however, looks at the priming effects of ignored objects. If an ignored object influences the subsequent processing of the same, or a semantically related object presented as a probe, it may be possible to infer the type of internal representation achieved in the processing of an ignored object and what happens to this representation. For example, if the selection process functions by inhibiting the internal representations of the ignored object, then we might predict that the processing of a probe related to the ignored object may be subsequently impaired or delayed.

Some previous research using a priming paradigm has indeed suggested that ignored distractors are associated with inhibition. Dalrym-ple-Alford and Budayr (1966), Neill (1977) and Tipper[2] have demonstrated that in a Stroop colour-word ink-naming task, if the word ignored on trial *N* is the same as the ink name response to be output on trial N+ 1, then naming latencies are longer. This suggests that inhibition of the response to the distracting word on trial *N* carries over and impairs naming of the ink on trial *N*+ 1. Greenwald (1972) produced analogous results employing a task where subjects named visual digits

[a]S. P. Tipper (1984). "Negative priming and visual selective attention". University of Oxford, D.Phil.

whilst ignoring auditory distractors. The data showed that when an auditory distractor was re-presented as a visual target, naming latencies were impaired. (See also Harvey, 1980.)

The experiments described below employ a similar priming paradigm. Subjects are presented with two competing objects and are told by means of a physical cue which one to select and which to ignore. Both objects are presented above threshold, thus they are both potentially available to control overt response. These objects will be referred to according to the directions given to subjects, i.e. as the "selected" and "ignored" objects.

Throughout the experiments, selection is by colour. For example, a red selected object may be superimposed over a green ignored object. Previous research has suggested that subjects are able to select successfully targets superimposed on the same spatial location as distractors, when using colour as the selection cue (Rock and Gutman, 1981; Irwin, 1979, 1981). Neisser and his colleagues (Bahrick, Walker and Neisser, 1981; Neisser and Becklen, 1975) have also demonstrated selection of targets from spatially superimposed distractors when using kinetic information as the selection cue.

In the current paradigm, subjects were presented initially with a pair of superimposed objects: the prime display. They were always told to identify one, specified by colour, and to ignore the other. A second display containing a pair of objects was then presented: the probe display. Subjects were requested to name the selected probe (specified by colour) as fast as possible. The main experimental manipulation was whether or not the ignored prime was the same as or related to the subsequent selected probe.

EXPERIMENT 1

This experiment examined the effect of ignored primes on the naming of identical selected probes. The latency to name the selected probe was used to examine the processing of the ignored prime. Subjects' abilities to recall and to recognize the ignored stimuli were also examined. Hence both indirect (priming) and direct (recall/recognition) measures of the processing of ignored stimuli were available.

Method

Subjects

Twenty-four female subjects from the Oxford subject panel were each paid £1.25 to take part in the experiment. They were aged between 18 and 45. All were right-handed and had normal colour vision and normal or corrected-to-normal acuity in both eyes.

Apparatus and Materials

A six-field tachistoscope having 2 three-field power units (Electronic Developments Ltd) was used for stimulus presentation. A hand-held microswitch was used by subjects for starting each trial. A voice key and a millisecond timer (Behavioural Research and Development Electronics Ltd) were used to measure oral naming latencies.

Simple line drawings of objects were used to construct the stimuli. All drawings had previously been shown to have better than 90% naming agreement, using other similar subjects (G. Ratcliffe, M.R.C. Neuropsychological Unit, Oxford, personal communication). Examples can be found in Figure 1. The drawings were traced onto white paper (with Platignum nylon-tip pens), centralized, and glued onto 6x4" cards. Red was used as the colour for the selected drawing that was superimposed over *a green ignored* drawing. [In other experiments' selected and ignored colours were reversed, ensuring that the effects obtained were not due to the particular pertinence of one colour.] Red and green were chosen for compatibility with Rock and Gutman (1981), Goldstein and Fink (1981) who used similar superimposed figures, and Irwin(1979, 1981) who used superimposed words.

The colour and contrast of the selected drawing was enhanced slightly by drawing over its contours twice, while the ignored drawing was traced over once. This was done to facilitate selection of the selected object and reduce possible intrusions of the ignored. Humphreys (1981) has pointed out that the contrast of a stimulus influences processing speed as reflected by reaction times. (In his data black stimuli with greater contrast had shorter reaction times than red stimuli.)

The drawings ranged in size from 6^0 vertical visual angle and 6^0 horizontal to 8^0 vertical and 10^0 horizontal. Figure 1 demonstrates examples of typical prime and probe displays used. The prime display contained two superimposed figures: a selected (red) figure and an ignored (green) figure. In all cases the selected prime was unrelated to the following selected probe and to the ignored prime. This ignored prime was either identical to the following selected probe (ignored repetition) or unrelated to it (control). The ignored drawings in the ignored repetition and control conditions were approximately matched for size and physical complexity. The selected drawings in the control and ignored repetition conditions were the same.

The probe drawings were prepared in a similar way. They were red and were superimposed over random green lines. The requirement of selecting the probe from distracting contours was to make it more sensitive to priming effects. Meyer, Schvaneveldt and Ruddy,[4] Becker and Killion (1977), Sperber, McCauley, Ragain and Weil (1979) have shown that the processing of degraded probe words or drawings is facilitated more than the processing of undegraded probes, by a semantically related prime. A second reason for requiring selection of the

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'See S. P. Tipper (1984). "Negative priming and visual selective attention". University of Oxford, D.Phil.

[4]D. Meyer, R. W. Schvaneveldt and M. G. Ruddy (1972). Activation of lexical memory. Paper presented at the meeting of the Psychonomic Society, St Louis.

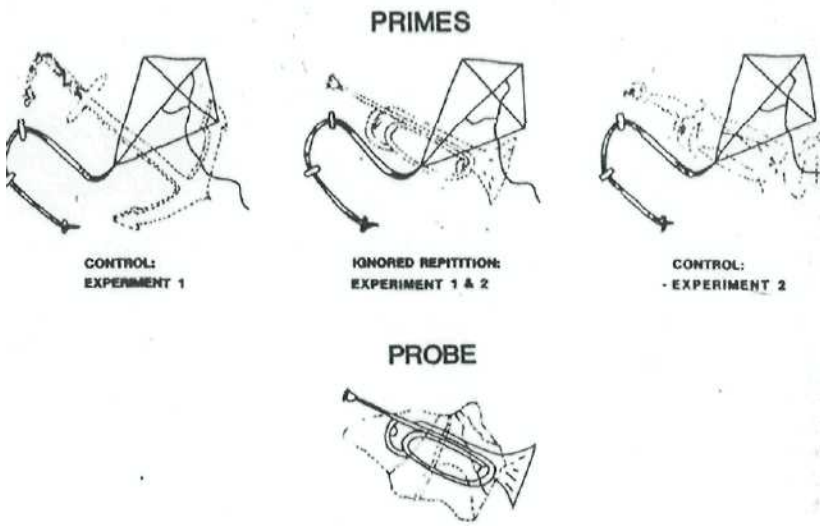


Figure 1. Prime and Probe displays used in Experiments 1 and 2. The lines depicted as solid were Red (selected); the lines depicted as broken were Green (ignored).

probe was to make processing of prime and probe displays as similar as possible. That is, they both require selection from superimposed green distractors. A constant selection strategy should allow subjects to become adjusted to this somewhat unusual selection task quickly, and thus allow efficient selection.

Five pairs of superimposed drawings were used in the initial procedure for setting stimulus onset asynchrony (SOA) between priming stimulus and a pattern mask. Nine superimposed priming pairs, plus nine probes, were used in die priming practice session; 24 priming pairs plus 24 probes were used in the experimental trials (i.e. 12 RTs in each priming condition). Each drawing was only presented once. Using different stimuli on every trial put a severe constraint on the number of trials available for SOA setting and RT data.

Stimuli for a recognition memory test were also prepared. Five drawings were randomly chosen from the selected primes, five were chosen from the ignored primes of the control condition, and five were previously unseen drawings. These were drawn in random order onto a large (11 1/2 ×24") sheet of paper and numbered.

Two black fixation crosses and two red and green picture fragment pattern masks were used. The pattern masks were picture fragments drawn with the same pens used to prepare the experimental stimuli.

Design

A within-subjects design was used in which the independent variable was the nature of the distractor prime, either identical or unrelated to the following selected probe. The dependent variable was the latency to name the selected probe drawing.

Each subject received half ignored repetition and half control trials. The stimuli were counterbalanced such that one-half occurred in ignored repetition trials for subjects 1 to 10 and in control trials for subjects 11 to 20, and vice versa.

Procedure

Subjects were informed that the experiment was concerned with recognition memory for line drawings. They were shown an example of the stimuli they would see throughout the experiment. Subjects were told to select the red drawing and ignore the green drawing. It was emphasized mat the green drawing was irrelevant and only there to make the task harder, so the more it was ignored, the better they would perform.

There were four parts to the experimental procedure: Part 1 established the appropriate masking SOA for each subject. These durations were approximate minimum viewing times required to identify the selected drawing explicitly in the absence of any other interfering or intervening task. Evidence for explicit identification was the subjects' ability to name the drawing. Brief exposure durations and pattern masking were employed to reduce the possibility of switching attention to the ignored object after selection of the attended object.

When subjects pressed the microswitch, a fixation cross appeared for 900msec, followed by the selected and ignored drawings superimposed; both were presented monoptically to the left eye. This was followed by a pattern mask to the right eye for 100msec. All presentation fields in the tachistoscope were adjusted to be of equal luminance.

Stimulus-mask SOA began at 10msec and was increased using the method of ascending limits, by 5 msec steps. The same stimulus drawing was repeatedly presented, until subjects correctly identified it. Five msec was then added to the longest SOA required for the five stimuli presented. This was then used as the presentation SOA for the prime for that subject. A further 5 msec was added for presentation SOA for the probe. Mean SOA for the prime was 35 msec (range 20~45msec) and 40msec for the probe.

Part 2 consisted of the experimental trials. When subjects pressed the microswitch they saw a series of events as follows:

1. a fixation cross presented to their left eye for 900 msec;
2. a red line drawing superimposed on a green drawing to their left eye;
3. a pattern mask presented for 100msec to their right eye;
4. a fixation cross presented to their right eye for 900msec;
5. a second red drawing superimposed on a green fragmented picture, presented to their right eye;
6. Finally, a pattern mask presented for 100msec to their left eye.

Subjects were not informed about the pattern masks. No subject complained about, or questioned them in pilot studies, and some subjects appeared not to notice them. Subjects were, however, informed that the stimuli alternated between eyes. This presentation of the prime to the left eye and the probe to the right ensured that the priming effects were not due to peripheral (retinal) factors.

Subjects were then given instructions concerning the stimulus sequence. They were told that they should correctly identify the first red (prime) drawing, as they would have to recall it shortly afterwards and recognize it in a later recognition test. However, it was stressed that they should not name the drawing when It was presented. When the second (probe) stimulus appeared, subjects were requested to name the red drawing as fast as possible. They were then asked to recall the selected prime. The recall and recognition of the selected prime were used to ensure that subjects attended to the red drawing.

The intertrial interval was approximately 15 to 20sec, during which subjects noted down weir own reaction times, thus receiving feedback on naming latency performance; these were verified by the experimenter.

Part 3 comprised a test for subjects' awareness of the ignored distractor drawing and was adapted from the procedures used by Rock and Gutman (1981). On the last trial only, there was no probe drawing to be named. It was replaced by a white card. As this blank white card was presented, subjects were asked the surprise question of what the previous green drawing had been. Thus they were asked to recall any information that may have been available for conscious scrutiny at about the time when the probe would have been presented.

Part 4 was a recognition test, also adapted from the procedures used by Rock and Gutman (1981). A sheet containing attended, ignored and new drawings was presented to subjects; they were instructed to call out the numbers of any drawings they recognized from the experiment, independent of whether it had teen red or green, or whether it had been named.

Results

1. *Direct Reports of Distractor Drawings*

In the single catch trial at the end of the experiment, subjects were asked to report the identity of the distractor drawing. (The same stimulus was used for all subjects.) Four subjects were able to report the distractor. These subjects were replaced (preserving the counterbalancing of materials) until there were 10 in each item assignment group. It was suspected that the replaced subjects may have been poor selectors (as reported by Goldstein and Fink, 1981). The fact that these four subjects failed to report the selected prime correctly on 36% and 29% of trials in the control and ignored repetition conditions, as opposed to 14% and 13.6% for the remaining 20 subjects, was further evidence for this interpretation. These four subjects reported the ignored prime on 6.8% and 2.3% of trials in the control and ignored repetition conditions, while the remaining 20 subjects reported 2.3% and 3% in the control and ignored repetition conditions.

In the recognition test at the end of the experiment, subjects gave confident recognition judgements for 73% of the attended target drawings. For ignored drawings, 12% received confident recognition judgements. Finally, for new control drawings, subjects confidently recognized 8%. Statistical analysis of the confident recognition raw data in a one-way within-subjects ANOVA was significant [$F(2,38)= 105.65$, $P< 0.001$]. Further analysis using the Newman-Keuls test showed a significant difference between positive recognition of selected stimuli versus both ignored and new stimuli, but there was no significant difference between the false positive rate to the new drawings and recognition of the ignored objects.

2. Indirect Measures: Reaction Time to Name Probe Drawings

When subjects failed to name correctly the selected probe, 5.5% and 5.8% of RTs were lost in the control and ignored repetition conditions, respectively. Also, trials in which subjects failed to recall the selected prime (termed "misses" from now on) were dropped from RT analysis.

The average RT to name the selected probe drawing in the ignored repetition condition was 797msec. For the control it was 749msec. These data were analysed in a one-way within-subjects ANOVA. This contrast was significant [F (1, 19)= 17.39, p<0.01]. Analysis within materials did not reach significance [F (l, 23) = 2.31].

A further post hoc analysis was carried out to compare probe naming RT as a function of whether subjects could recall the selected prime after naming the selected probe. Successful report of the selected prime may reflect successful selection, while failure to report anything from the priming display may reflect a failure of target selection. Fourteen subjects failed to report at least one attended prime drawing in both the prime and control conditions. When the subject reported the selected prime, there was *inhibitory* priming by the ignored prime of 51msec; when the subjects failed to report the prime target, there was *facilitative* priming by the ignored prime of 52 msec. This contrast between inhibitory and facilitatory priming was significant [F (1,13) = 5.17, p<0.05]

Discussion

As in previous work by Rock and Gutman (1981) and Goldstein and Fink (1981), the majority of subjects could effectively select (for later report and recognition) between two superimposed stimuli using colour as the selection cue. For the ignored prime, however, there was little ability to recall the stimulus shortly after presentation (only 16% of subjects could do so), and recognition was no better than chance.

The RT data from this experiment indicate that the time taken to name a selected object is increased when that object is identical to one previously ignored. This effect is opposite to the usual priming effects produced by repetition primes (whether attended or subliminal), where facilitation of the probe processing is found. An appropriate term for this (opposite) priming effect is thus "negative priming" (Marcel, 1980, p. 453). In this experiment, "negative priming" only occurred when subjects reported the selected prime. When they failed to report the selected prime (misses), facilitative priming was produced. This suggests that "negative priming" only occurs when selection is successful.

EXPERIMENT 2

This experiment was designed in order to confirm and extend the effect of negative priming found in Experiment 1.

One difference from the first experiment concerned the ignored prime in the control condition. These were changed from meaningful drawings that were unrelated to the probe, to structural parts of the ignored repetition prime broken down into meaningless contours (see Figure 1). The rationale for this change was to explore the possible level or levels at which the inferred inhibition takes place. Thus, inhibition may occur at a low-level (structural) representation of the ignored object. If this is correct, then the similar structure between ignored repetition prime and control objects may reduce the effect.

Two further changes were introduced: first, the inter-stimulus interval (ISI) between prime and probe was reduced from 1,000 to 300msec to examine whether the negative priming effect was influenced by the time between prime and probe displays. Second, monoptic rather than dichoptic masking was employed to examine whether presenting a pattern mask to the same eye as the prime display influenced the priming effects.

Method

This was as in Experiment 1, except for the following details. There were 22 subjects.

Stimuli were taken from the same source as those used in Experiment I, but the ignored prime in the control condition was produced by arranging the structural information in the ignored object in such a way that the object was no longer recognizable. The contours of this stimulus crossed the contours of the selected prime in approximately the same place as those of the ignored repetition prime (see Figure 1). There were now 17 trials in each priming condition.

The timing of events on a trial was as follows: A fixation cross was presented for 600msec (as against 900msec in Experiment 1), the prime display (duration was adjusted for each subject) and a pattern mask (presented for 100msec) were presented to the subject's left eye; followed by a fixation cross (presented for 200msec), the probe display (duration adjusted for each subject) and a pattern mask (presented for 100msec) presented to the subject's right eye.

Mean SOA was 74msec for the prime (range 50 to 100msec) and 79msec for the probe. The recognition test was not used, as there were no meaningful ignored primes in the control condition.

Results

In the catch trial at the end of the experiment, two subjects were able to recall the ignored drawing, and were thus replaced (to yield 10 subjects in each item assignment group). As in Experiment 1, it was suspected that these two subjects were poor selectors, or that their SOAs were not correctly adjusted. Like the four rejected subjects in Experiment 1, they were poorer at reporting the selected prime (24% and 21% failures in control and ignored repetition conditions, as opposed to 9% and 11.2% for the 20 subjects unable to report the ignored drawing). They also reported 6% of ignored primes in the ignored repetition condition, as opposed to 1.5% for the other subjects.

RT Data

Subjects failed to name the selected probe correctly on 9.4% and 6.2% of trials in the control and ignored repetition conditions, respectively. All errors were dropped from the main RT data analysis. The overall average RT for naming the selected probe was 909 msec in the ignored repetition and 865 msec for the control condition. These data were analysed in a one-way within-subjects ANOVA. The difference was significant [$F(1,19) = 7.31$, $p<0.05$]. Analysis within materials did not reach significance [$F(1,33) = 2.58$].

As in Experiment 1, RT to name selected probes was given further post hoc analysis in terms of hits and misses in selected prime report. Nine subjects were available for this analysis, showing misses in both ignored repetition and control conditions. The hits showed an overall cost of -43.45 msec, the misses showed a benefit of + 101.22msec. This pattern of costs (inhibition) and benefits (facilitation) in the hit and miss trials parallels that found in Experiment 1, though this was non-significant [$F(1,8)= 2.63$] due to the small number of subjects and RTs in each cell.

Discussion

This experiment has replicated the negative priming obtained in Experiment 1 with a different kind of ignored prime in the control condition, shorter ISI and monoptic masking. However, RTs in this experiment are approximately 100 msec longer than those in Experiment 1, perhaps because of the reduced ISI between prime and probe displays. The fact that the effect has been obtained when the ignored prime of the ignored repetition and control conditions contain the same features suggests inhibition is not at the level of local features.

Furthermore, as in Experiment 1, there is some indication that negative priming is produced only when subjects can successfully report the selected prime; and that failure to report the selected prime leads to facilitative priming.

Finally, in both experiments analysis within materials did not reach significance. This is probably due to the large variance in the materials caused by their complexity. Examples of such complexity are: (1) familiarity of the object, (2) saliency of characteristic features, (3) typicality, (4) physical complexity (cf. Snodgrass and Vanderwart, 1980); in addition, these may interact when two drawings are superimposed. Further work is necessary for an understanding of the above factors in terms of object recognition and priming effects. However, a method of reducing such variance is to use a smaller set of materials, as used by Sperber ct al. (1979) and Carr et al. (1982), and this approach is adopted in the next experiment.

EXPERIMENT 3

Experiments 1 and 2 have tentatively demonstrated the phenomenon of negative priming by ignored primes on identical selected probes. The data, however, provide little information concerning the level of processing that the distractors may have achieved, or the levels of representation where the hypothesized mechanism of inhibition may take place. Thus, perceptual analysis and inhibition may have been confined to structural levels, as would be suggested by the precategorical selection view of attention. Alternatively, analysis and inhibition may be at some higher, more abstract level of representation. To resolve this issue, the priming effects of ignored primes that are categorically related to (but have few structural features in common with) subsequent selected probes were investigated.

A further aim of this experiment was to confirm the contrast between selected and ignored primes. As discussed, substantial amounts of research have confirmed that primes that subjects attend to facilitate responses to subsequent related probes. This may also occur with stimuli pattern masked to prevent identification (Marcel, 1983). The data in Experiments 1 and 2 have suggested a reversal of this facilitatory priming to one of negative priming when objects are ignored. In this experiment, therefore, the effects of both selected and ignored primes on subsequent selection were examined.

Method

Subjects

Eleven subjects from the long-term Oxford Subject Panel were paid £1.25 to take part in this experiment. All had normal or corrected-to-normal acuity and normal colour vision and were right-handed.

Apparatus and Materials

The apparatus was the same as described in the previous experiments.

Ten drawings were used in this experiment. They were adjusted to be approximately equal in size with the aid of a reducing photocopier. Visual angles ranged between 4.7^0 and 6.4^0. They were drawn with Bic Biros. The related pairswere: Cat-Dog, Chair-Table, Hammer-Spanner, Trumpet-Guitar, Hand--Foot.

As in previous work, the selected prime (red) was superimposed over the ignored prime (green), and similarly for the selected and ignored probes. This was to make selection of the target harder, as discussed. The superimposed drawings of a given display were always in different semantic categories.

Design

A within-subjects design was used such that each subject contributed naming RTs to each of five experimental conditions. The only relationships between prime and probe displays were as follows (see Figure 2 for examples). Except as mentioned, other components of the displays were unrelated.

1. *Attended Repetition:* The selected prime object was identical to the selected probe.

2. *Attended Semantic:* The selected prime was semantically related to the selected probe (Cat-Dog).

3. *Neutral Control:* The selected and ignored primes were both unrelated to the subsequent selected probe.

4. *Ignored Semantic:* The ignored prime was semantically related to the selected probe.

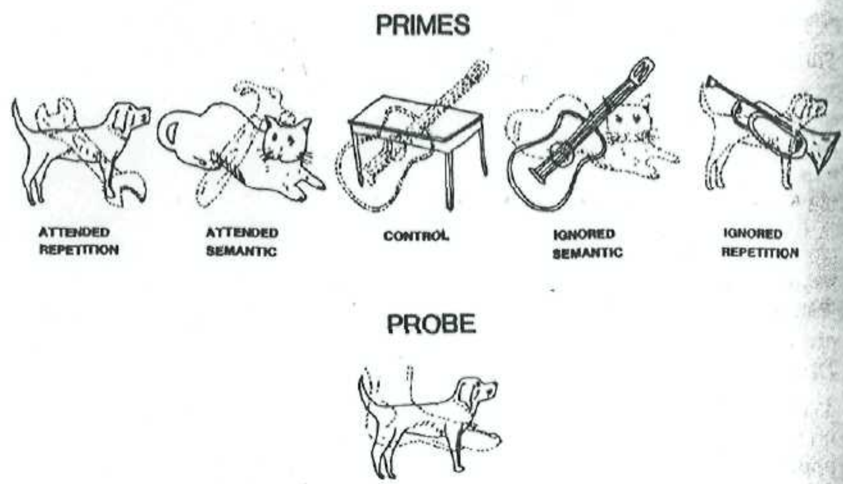
5. *Ignored Repetition:* The ignored prime was identical to the subsequent selected probe.

There were 20 trials in each condition. Stimulus presentation was randomized for each subject. Filler trials were implemented after subjects made an error in an effort to reduce the variability produced by longer RTs after errors (Rabbitt, 1966).

Procedure

Subjects were initially shown a series of 5 cards, each containing 2 drawings. The drawings were in their associate pairs on each card (e.g. Cat-Dog). Although it was not explicitly stated that the drawings were related, it was hoped that such paired presentations might increase the associative strength between the stimuli within the experimental context. The rationale for this procedure comes from McKoon and Ratcliffe (1979), who obtained contextual facilitation using newly learned experimenter-defined associates.

The SOA setting procedure was basically as described in Experiment 2.



Mean Naming Latencies

615 msec	677 msec	695 msec	726 msec	746 msec

Errors

Failures to recall the selected prime				
1%	4%	1.5%	2.5%	1.5%
Report of the ignored prime				
0%	0%	0.5%	1.5%	0%
Failures to name the probe				
1.5%	1.5%	1.5%	0.5%	1.5%

Figure 2. Examples of the Prime and Probe displays, and the corresponding mean probe naming latencies and errors, for the five conditions in Experiment 3. The lines depicted as solid were Red (selected); the lines depicted as broken were Green (ignored).

Subjects had to report the red drawing as soon as possible; 5 msec were added to the longest presentation time, and this became the presentation SOA of the prime; a further 5 msec were added for probe SOA. Means were 112 (range 70 to 140msec) and 117msec, respectively.

As previously described, after pressing the microswitch subjects saw the following sequence: (1) a fixation cross (600msec), (2) the prime display, from which subjects should identify but not name aloud the red drawing, (3) a pattern mask (100msec). These displays were all presented to the left eye. (4) A second fixation cross was then presented for 1,100 msec, (5) a second red drawing, which they were to name as fast as possible into the voice key, and, finally, (6) a second pattern mask was presented (100msec). These three displays were presented to the right eye. Subjects were then requested to report what the first red drawing had been. The ISI between prime and probe was 1,200msec (100msec pattern mask, 1,100msec fixation cross).

Subjects were informed that the first eight trials were practice. A further six trials in the experiment were also practice, although subjects were not informed of this. Probe naming reaction times were collected from 100 trials (20 in each of the 5 conditions, thus each probe object was named twice in each condition). Subjects were informed that trials only counted when they were able to recall the selected prime,

At the end of the RT data collection a catch trial was included. No probe drawing was presented, and subjects were asked the question of what the previous ignored (green) drawing had been.

Results

Only one subject was able to recall the ignored drawing in the catch trial at the end of the experiment. As in Experiments 1 and 2, this subject was replaced, to yield 10 subjects included in the data analysis. (This catch trial cannot be considered exactly equivalent to those used in Experiments 1 and 2. In Experiments 1 and 2 a different stimulus array was presented on every trial. Thus correct report of the ignored object could not be explained by a probabilistic guessing strategy, in this experiment, on the other hand, a small stimulus set of 10 drawings was used. After identifying the selected object, the ignored must be one of the nine possible drawings remaining. Therefore the expected frequency of correct guessing of the ignored object is 11% of trials.)

Each of the subjects contributed to a mean RT for each of the five conditions. The mean RTs and errors are shown in Figure 2.

The RT data were analysed in a one-way within-subject ANOVA, which was significant [F (4,36)=21.18, p<0.001]. Analysis within materials (the 10 possible probe objects) was also highly significant [$F(4,36)= 14.41$, $p< 0.01$]. Further post hoc analysis of the RT data was carried out using the Newman-Keuls test. The main contrasts of interest showed that attended repetition was significantly faster than control and attended semantic (which were not significantly different). Ignored repetition and ignored semantic were significantly slower than control, and there was no significant difference between them.

Discussion

The central concern of this experiment was to test for negative priming effects with semantically related stimuli. This effect was obtained: naming of the probe was 31msec longer when the selected probe was semantically related to the ignored prime (compared to the control condition). This implies that ignored objects may receive analysis to a categorical level and provides support for a postcategorical inhibition *model*

A further possibility is that this effect reflects a process of "spreading inhibition" in semantic memory networks, analogous to that of spreading activation (Meyer and Schvaneveldt, 1975, Collins and Loftus, *1975).* When an internal representation is activated this can lead to a spread of activation to related concepts in semantic memory space (Osgood, Suci and Tannenbaum, 1955) or hierarchical networks (Collins and Loftus, 1975). However, if a stimulus has been ignored during selection of a simultaneous target, the internal representation (of the ignored object) is associated with inhibition, which may spread to related concepts. Other theorists have proposed the possibility of spreading inhibition between related concepts in semantic memory, for example Roediger and Neely (1982).

This experiment has also confirmed the contrast between selected and ignored primes previously hypothesized. When primes received attentional processing, they facilitated processing of identical probes; when the same primes were ignored, processing of subsequent probes was delayed (negative priming). A similar contrast is seen when stimuli are semantically related, though the facilitative effect of the attended semantic prime did not reach significance, perhaps because of possible subject strategies (cf. Neely, 1977).

Finally, the replication of negative priming in this experiment is highly significant in both subjects and materials analyses, suggesting that the failure to produce significant materials effects in Experiments 1 and 2 was indeed due to the large variability among complex drawings.

GENERAL DISCUSSION

In summary, these experiments have raised the following points. Subjects appear to be able to select between briefly presented, spatially superimposed objects, using colour as a selection cue. Prior to selection, both objects were potentially available. The subjects generally could not recognize the ignored objects in subsequent recognition tests, though they could recognize selected objects. They also appeared to be generally unable to report the ignored object in a surprise catch trial, as in previous work that has examined report of unattended material (Rock and Gutman, 1981; Martin, 1978; FitzGerald[5]).

It has been pointed out (A. Treisman, personal communication) that

[5]P. FitzGerald (1984). "Memory for attended and unattended stimuli". University of Oxford, D.Phil

it is difficult to decide whether subjects were never aware of the identity of the ignored prime; or were briefly aware, but that target selection included the suppression of the ignored objects from conscious awareness. The phenomenological experiences of subjects subsequent to prime presentation would be the same in both cases. It is difficult to test between these alternatives. Obviously, the surprise element in the catch trial may disrupt any available representations of the "ignored" object. Alternatively, constantly requiring subjects to attempt to report the ignored objects would probably have changed their selection strategies.

The priming effects of these ignored drawings have revealed that reaction time to name a probe are increased if it has the same identity or is categorically related to a previously ignored object. The following theoretical points can be suggested from this negative priming effect. Following the interpretation offered by Tipper,6 the initial analysis of these kinds of displays takes place in parallel prior to selection. If the objects are well learned and meaningful to the subject, they appear to achieve categorical internal representations that are beyond the level of specific physical features.

During target selection, the initial representations produced of ignored and selected objects are both further processed, but in different ways. Representations of selected objects appear to receive further processing to enable naming of the object, recall some seconds later, and recognition some minutes later. The resulting internal representations facilitate selection of subsequent probes requiring identical or similar representations. Representations of the ignored object also appear to receive further processing, as opposed to passive decay. In this case, the internal representations produced are such that selection of subsequent objects requiring those representations is delayed. It may be suggested that this delay reflects inhibition associated with the internal representations of ignored objects during selection.

The hypothesized relationship between selective attention and inhibition was highlighted in Experiments 1 and 2, where negative priming by ignored objects appeared to depend on successful selection of the target. Similarly, Tipper7 demonstrated that when the prime display SOA was long enough for successful selection, negative priming was produced by ignored objects. However, when the same prime displays were pattern masked such that subjects were above chance in reporting whether objects had been presented but were unable to identify either selected or ignored drawings, facilitative priming was produced both for selected and for ignored drawings.

[6,7]S. P. Tipper (1984). "Negative priming and visual selective attention". University of Oxford, D.Phil.

However, an alternative interpretation for negative priming has been suggested by Allport, Tipper and Chmiel (in press) (see also Lowe, in press). In this model no mechanisms of inhibition are required to account for negative priming. Rather, the cost is due to an object being encoded as both green and ignored in the prime display, and subsequently as red and selected in the probe display. This dual representation of the same object requires further processing to resolve the ambiguity, reflected in the longer RTs. However, further work (Tipper and Cranston, this issue) has produced results that can only be accounted for by the inhibition model.

A final point that should be made is that negative priming effects are not confined to the selection of superimposed objects. Tipper[8] used the same stimulus set as that of Experiment 3. In this case, however, the selected object was always green and presented to fixation; the (red) ignored object was presented in a different location, i.e. its nearest edge was 2.4° to the right or left of fixation. Negative priming was again demonstrated. Similarly, further recent work by the author has demonstrated negative priming with letter displays where the ignored objects were presented 0.76° to the right and left of the fixated target.

GENERAL CONCLUSION

In conclusion, the priming paradigm employed in these experiments has demonstrated the phenomenon of negative priming. Negative priming may be a reflection of inhibition as one of the mechanisms of selective attention. Thus, the objects that impinge on an organism's senses, if meaningful and well learned, may achieve at least categorical levels of internal representation in the initial parallel analysis of a scene. Subsequently the unwanted competing representations of the distractor objects may be de-coupled from the overt response mechanisms by a process of inhibition. Further work is required to specify at what level(s) inhibition takes place—whether at perceptual or response stages.

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