

# PRIMING THE PRIMES: SUBSEQUENT TARGETS DISTINCTLY AFFECT PRECEDING-PRIME TRACES ACQUIRED WITH AND WITHOUT AWARENESS

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## Abstract

*Priming is commonly viewed as altered subsequent target processing by preceding prime stimuli. Here, we ask how, if at all, subsequent salient targets modulate memory-trace processing of preceding primes (i.e., backward priming) accomplished with and without awareness. On a trial, participants saw a prime, a mask, and a target in succession, pressing a respective key to report prime identity (a square with or without gaps in its outline that was either congruent or incongruent with the target). In Experiments 1 and 2, prime identification was above and at chance level, respectively. With prime awareness (Experiment 1), target-prime congruency yielded reduced response times, while without prime awareness (Experiment 2), reduced error rates occurred for the congruent primes. The results show for the first time the existence of backward (retroactive) priming of the prime's memory traces by subsequent salient targets. Moreover, the findings suggest an awareness-dependent dissociation of backward priming that engages either response processing or solely sensory representations of stimuli with discriminable and indiscriminable prime identity, respectively.*

Perceptual priming is commonly viewed as either enhanced or deteriorated processing of subsequent target stimuli by preceding primes (Eimer & Schlaghecken, 2003; Henson, 2003). This implies feedforward succession of processing such that prime traces either boost or break down later target analysis. More generally, these studies look at how our previous experience affects current perception and performance. However, both daily-life observations and cognitive neuroscience of long-term memory suggest that what we remember about particular past events is largely determined by what we know and perceive now. That is, our current experience can considerably modify memory traces of previous experience such that memory retrieval can be conceived as a constructive rather than a merely reproductive process.

In this work, we argue that, much as with long-term memory, in an ordinary perceptual-priming paradigm with much shorter delays between successive stimulus presentations, subsequent salient target stimuli substantially modulate previously acquired memory traces for prime stimuli. In contrast with common feedforward priming of subsequent targets by preceding primes, we refer to such modulation of preceding-prime traces by subsequent targets as *backward* (retroactive) priming, and show specific processing advantages for the congruent (matched) as compared to incongruent (non-matched) target-prime associations. Research on priming indicates that feedforward-priming effects can differ as a function of prime awareness (i.e., whether or not, and to what extent, observers

perceive the prime; e.g., Henson, 2003). In the present study, we therefore varied prime discriminability to examine how, if at all, backward priming depended on prime awareness.

On a trial, participants were presented with three successive stimuli (a prime, a mask, and a target that could be either congruent or incongruent with the prime), and required to judge, upon target offset, the identity of the prime. We hypothesized that if backward masked priming does occur for prime identity, then it would result in (i) altered response times, RT, and/or error rates for prime identification with congruent compared to incongruent targets and primes, and (ii) distinct outcomes for prime traces acquired with and without awareness.

## Method

### *Participants*

Two separate groups of eight and fourteen (Experiments 1 and 2, respectively) volunteer participants each (female and male; mean age, 28.6 years) took part in the study. They had normal or corrected vision, were right-handed and unaware of the aim of the research, and run individually.

### *Stimuli and procedure*

We used three consecutive stimuli presented on a trial: a prime, a mask, and a target; each represented as a bright-outline square of the same dimensions and centered at the same location in the middle of the monitor screen. Two distinct kinds of squares served both as the prime and target stimuli. One square had an intact outline (side, 32 mm [80 pixels, 3 pixels thick], or  $0.046^\circ$  viewed from an observation distance of 70 cm; a no-gap stimulus type), and the other was created by removing a 35-pixel part of the outline in the middle of the square's both vertical sides (a gap stimulus type). Using the two-side gaps avoided likely contamination of left/right responses with an asymmetrical (e.g., left/right-hand located) relevant target feature. The mask was a square with the dashed outline (alternating 5-pixel gaps and lines). The stimuli were presented on a 17-in. monitor (refresh rate, 75 Hz) driven by the Matlab Psychophysics Toolbox extensions for Microsoft Windows (Brainard, 1997; Pelli, 1997), running on a Pentium-4 PC. The duration of a screen frame was 13.3 msec.

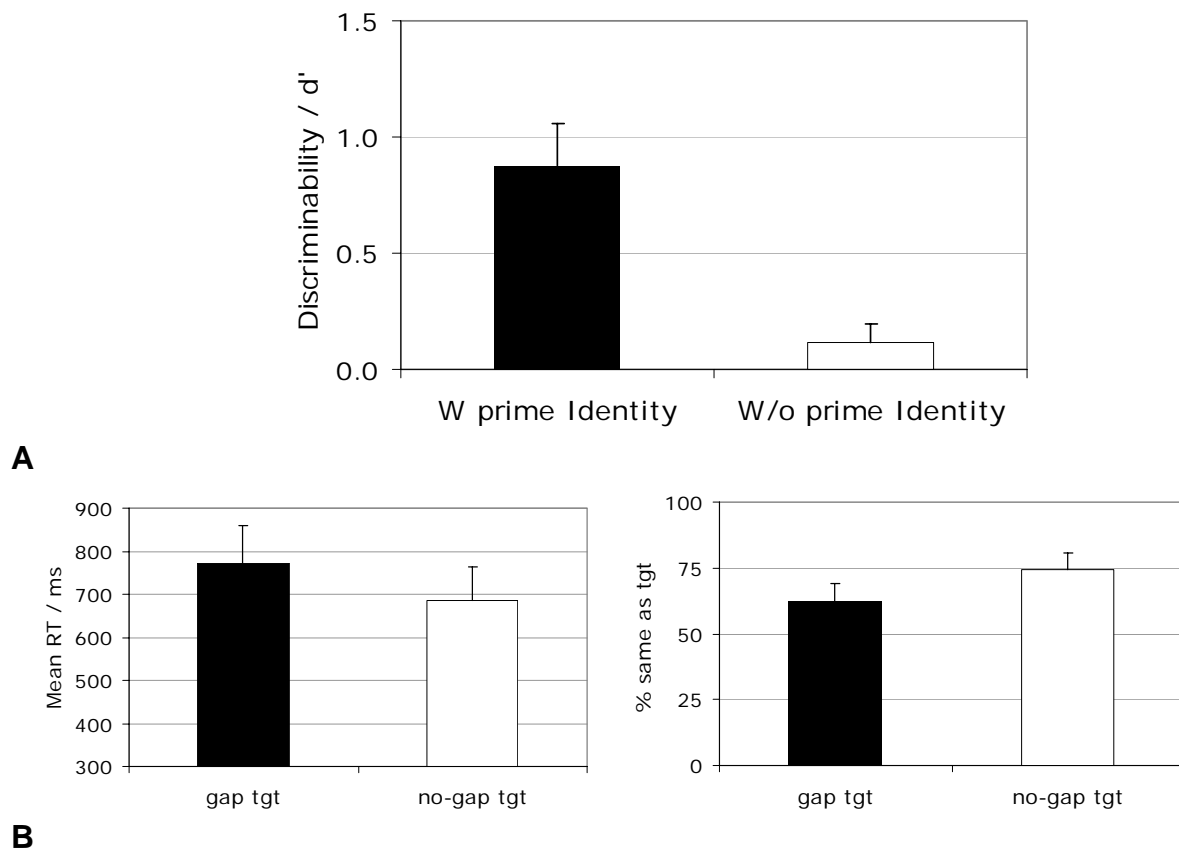
Four different types of trials were built by using the gap and no-gap squares: two congruent trial types (with the matched prime and target: gap/gap, no-gap/no-gap) and two incongruent types (with the non-matched prime and target: gap/no-gap, no-gap/gap). The proportion of distinct trials within each trial type was always equal (e.g., gap/gap and no-gap/no-gap for congruent trials, 1:1) and balanced throughout the experiments. A total of 80 congruent and incongruent trials were presented in random order in Experiments 1 and 2. In order to manipulate prime awareness, we used either two-frame (duration, 26.6 msec; Experiment 1) or one-frame primes (13.3 msec; Experiment 2). In addition, in Experiment 2 without prime awareness, we introduced 20 catch trials with no any prime shown prior to the target stimulus (equal number of trials with the gap and no-gap targets) to control for possible preference of the *gap/no-gap* responses. The experiments were conducted in a dimly-lit room. The participants viewed the stimuli with both eyes; a head-and-chinrest ensured stable observation distance.

The experiments started automatically after the participant's entering gender and age information and confirming the understanding of on-screen instructions. A trial began with a fixation cross in the middle of the screen shown for 505 msec (38 frames). After that, three stimuli were consecutively presented: a prime (duration, 26.6 or 13.3 msec), the mask

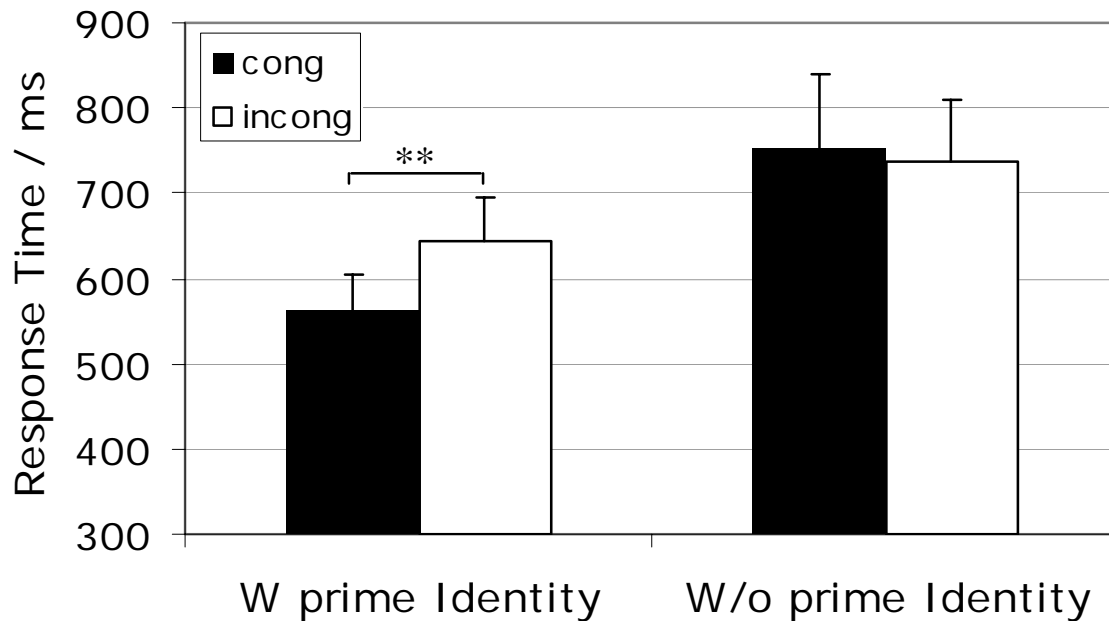
(79.8 msec), and a target (106.4 msec); thus, the prime-target stimulus onset asynchrony, SOA, was either 106.4 or 93.1 msec including the intermediate mask. In both experiments, participants had to make, upon target offset, speeded responses with their left or right index finger depending on whether or not the masked prime square had gaps in its outline. The two *Control* keys on the PC keyboard were labelled as *gap* or *no-gap*. The label positions were counterbalanced between participants. No information about trial probabilities was given to the participants prior to the experiment; no online feedback was provided regarding the participant's performance. However, participants did know that they would be presented with three stimuli in succession.

## Results

First, we examined if manipulation of prime duration yielded differences in prime awareness in Experiments 1 and 2, and if any preference existed for the target type (*gap/no-gap*) in the catch trials of Experiment 2. The signal detection theory measure of discriminability ( $d'$ ; *gap* versus *no-gap* prime) was computed for the long (two-frame) and short (one-frame) primes.



**Figure 1.** *A*, Mean discriminability ( $d'$ ) of the long-duration, *black*, and short-duration primes, *white* bars, in Experiments 1 and 2 with and without prime awareness, respectively. Long- and short-prime discriminability is above ( $p = .001$ ) and at chance level, respectively. *B*, Performance on catch trials for the *gap*, *black*, and *no-gap* targets, *white* bars, in Experiment 2 without prime awareness (*left*, mean RT; *right*, mean percentage of the *same as the target* responses). No any significant differences occur for the response type. Bars show group means  $\pm 1$  SEM for 8 and 14 participants in Experiments 1 and 2, respectively.

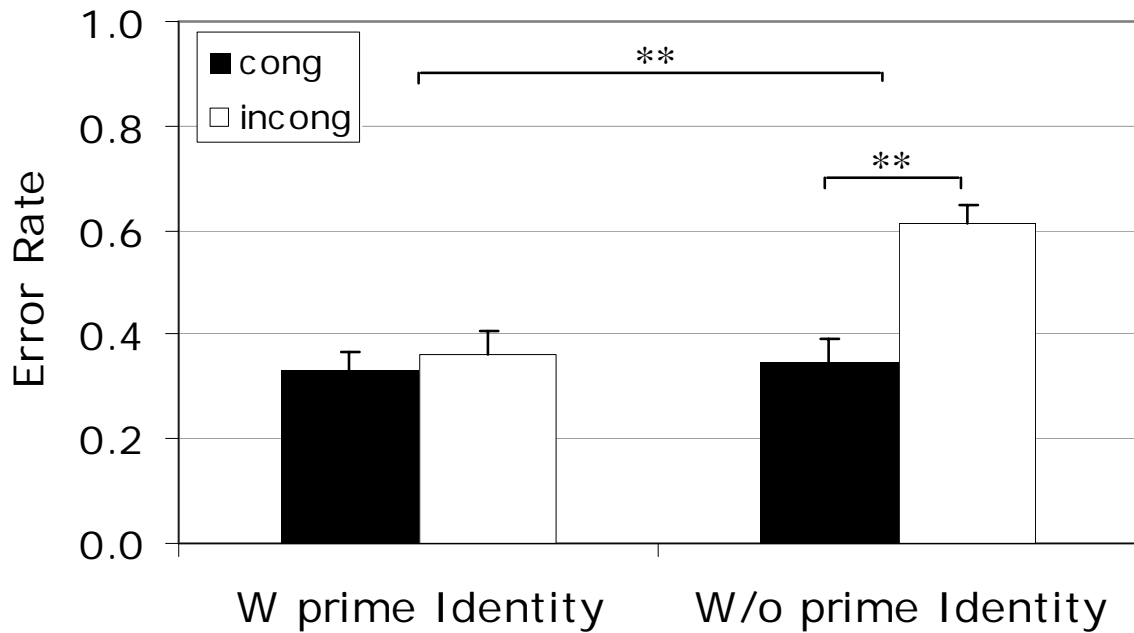


**Figure 2.** Mean response times, RT, for prime identification in congruent, *black*, and incongruent target-prime trials, *white* bars (Experiments 1 and 2 with and without prime awareness). With prime awareness, congruent targets and primes yield significantly shorter RT than incongruent targets and primes (\*\*  $p = .003$ ). No congruency advantage for RT occurs without prime awareness. Bars show group means  $\pm 1$  SEM for 8 and 14 participants in Experiments 1 and 2, respectively.

As seen from Figure 1A, prime discriminability with long and short prime duration in Experiments 1 and 2 is either above chance ( $t$  test;  $p = .001$ ) or at chance level, respectively. Moreover, prime discriminability is much better with long than with short primes ( $p = .004$ ). By contrast, there are no any difference in performance on catch trials, both for RT and error rates, between *gap* and *no-gap* responses in Experiment 2 (Fig. 1B). That is, participants are aware of prime identity in Experiment 1, but they are unaware of it in Experiment 2. Also, in Experiment 2, participants do not exhibit any preference for the response type; therefore backward-priming outcome without awareness observed in this experiment (see below) can not be accounted for by such a preference.

In order to determine if backward priming for prime identification occurred with and without prime awareness, we further analyzed both RT and error rates for congruent and incongruent target-prime trials in the two experiments. Figure 2 shows RT obtained in the congruent and incongruent trials that were averaged across participants. Two-way repeated measures analysis of variance (ANOVA) with factors Prime Awareness (yes/no) and Trial Type (congruent/incongruent) was performed on individual RT values as a dependent variable. The results reveal no any significant main effects of the factors, but they do yield a significant Prime Awareness  $\times$  Trial Type interaction ( $p < .01$ ). Post-hoc comparisons indicate that with prime awareness (Experiment 1), RT for prime identification are significantly shorter with the congruent than with incongruent targets and primes [ $t(7) = 3.887$ ,  $p = .003$ ]. Without prime awareness (Experiment 2), there is no congruency effect on RT.

The error-rate analysis outcome is found in Figure 3 that represents group averages for congruent and incongruent trials in the two experiments. The results of two-way repeated measures ANOVA performed as above on individual error rates as a dependent variable show



**Figure 3.** Mean error rates for prime identification in congruent, *black*, and incongruent target-prime trials, *white* bars (Experiments 1 and 2 with and without prime awareness). Without prime awareness, congruent targets and primes yield significantly fewer errors than incongruent targets and primes (\*\*  $p = .002$ ). No congruency advantage for error rates occurs with prime awareness. With prime awareness, however, error rates are generally lower than without prime awareness (\*\*  $p < .002$ ). Bars show group means  $\pm 1$  SEM for 8 and 14 participants in Experiments 1 and 2, respectively.

a significant main effect of Prime Awareness ( $p < .002$ ) and no main effect of Trial Type. Similar to RT, a significant Prime Awareness  $\times$  Trial Type interaction ( $p < .01$ ) is observed for error rates. Unlike with RT, however, the error rates are significantly lower in the congruent than in incongruent trials without prime awareness [ $t(13) = 3.489$ ,  $p = .002$ ; Experiment 2], while they are indistinguishable with prime awareness (Experiment 1).

### Discussion and Conclusions

In this study, we for the first time demonstrate the existence of backward (retroactive) masked priming of a preceding-prime trace acquired with and without awareness, by subsequent target stimuli. That is, our processing of current stimuli can affect memories of other, recently acquired stimuli, even if their identity had not been revealed perceptually. This extends evidence on the effects of current experience on retrieval of long-term memory for previous events, showing similar effects for much shorter time intervals.

Moreover, backward masked priming of prime identification by subsequent targets exhibits dissociation depending on prime awareness. With discriminable prime identity, backward priming only occurs for response times, with the faster responses found in the congruent than incongruent target-prime trials. With indiscriminable prime identity, backward priming only occurs for error rates, with the fewer errors made on the congruent than incongruent trials. This is in contrast with the results typically seen with common feedforward

priming (when primes alter performance on subsequent target stimuli). Feedforward priming usually involves both response times and error rates (e.g., Henson, 2003; Schacter & Buckner, 1998). In contrast to feedforward priming, backward masked priming with prime awareness appears to engage solely response processing (e.g., Eimer & Schlaghecken, 2003), while backward priming without prime awareness, solely sensory representations (e.g., Mattler, 2003). However, future studies that combine functional brain imaging with psychophysics, are required to determine the precise neural mechanisms of backward priming (e.g., Schacter, Dobbins, & Schnyer, 2004).

**Acknowledgements.** This work was supported by a grant # SO 465/7 to A.S. from the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG).

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