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Do semantic priming and retrieval of stimulus-response associations depend on conscious perception?

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ABSTRACT

What function does conscious perception serve in human behavior? Many studies relied on unconscious priming to demonstrate that unseen stimuli can be extensively processed. However, showing a small unconscious priming effect falls short of showing that the process underlying such priming is independent of conscious perception. Here, we investigated to what extent the retrieval of learned stimulus-response associations and semantic priming depend on conscious perception by using a liminal-prime paradigm that allows comparing conscious and unconscious processing under the same stimulus conditions. The results revealed two striking dissociations. First, S-R priming was entirely independent of conscious perception, whereas semantic processing was strongly enhanced by it. Second, while priming emerged on fast trials for all conditions, only conscious semantic priming was observed on slow trials. The implications of these findings for the time course of response priming and for the contribution of unconscious processes to fast vs. slow responses are discussed.

1. Introduction

To what extent can stimuli that are not perceived consciously be processed? In recent years a flurry of studies have demonstrated that semantic interpretation of stimuli outside of consciousness is possible. These studies have typically employed the *subliminal response priming paradigm*. On any given trial in this paradigm, participants are required to categorize a target. Shortly prior to the target, a subliminal (most often masked) prime, appears and is either mapped to the same response as the target (congruent prime) or to the alternative response (incongruent prime). Response priming refers to better performance when the prime is congruent with the target than when it is incongruent with it and is taken as evidence for unconscious processing.

For instance, in Dehaene et al. (1998) study, both the masked prime and the target were numbers, and both were presented in either Arabic (e.g., 1, 6) or word (e.g., one, six) format, independently. The task was to indicate whether the target was smaller or larger than 5.[1] To ascertain that participants were indeed unaware of the prime, forced-choice performance at discriminating prime-absent from prime-present trials was measured in a subsequent awareness-test phase. A response priming effect was observed for all participants although these were at chance on the prime-awareness test. The authors concluded that a subliminal stimulus can be

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[1] In the present paradigm, priming is based on arbitrary category relationships between the prime and the target, rather than on purely associative relatedness. Therefore, "categorical priming" would be a more accurate label for the effect. Yet, it should be noted that semantic processing is nevertheless required in order to assign a given number to the appropriate category. Thus, in order to remain consistent with the literature that employs the same paradigm (e.g., Dehaene et al., 1998; Damian, 2001), we nevertheless refer to this priming as semantic priming.

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categorized at the semantic level.

1.1. Comparing conscious and unconscious semantic priming

The subliminal priming paradigm has been criticized on several grounds (see e.g., Amihai, 2012; Avneon & Lamy, 2018; Lamy, Carmel, & Peremen, 2017; Lin & Murray, 2014; Pratte & Rouder, 2009 for details). A prominent disadvantage of that paradigm for the present purposes (see also Avneon & Lamy, 2018; Lamy, Alon, Carmel, & Shalev, 2015; Van den Bussche et al., 2013), is that it does not provide a conscious-prime condition against which to compare unconscious priming, since primes are selected to be subliminal on all trials. Though some studies using the subliminal-prime paradigm did compare priming between subliminal and supraliminal conditions, (e.g., Ansorge, Khalid, & Koenig, 2013; Armstrong & Dienes, 2013; Desender, Van Lierde, & Van den Bussche, 2013; Goller, Khalid, & Ansorge, 2017; Goodhew, Visser, Lipp, & Dux, 2011; Sand & Nilsson, 2017; Tapia, Breitmeyer, & Shooner, 2010; Van Gaal, Lamme, Fahrenfort, & Ridderinkhof, 2011; van Gaal et al., 2014), these conditions typically differed not only in terms of visibility but also in terms of physical stimulation parameters, such as prime-mask stimulus onset interval or whether a mask was used at all. Thus, the effects of conscious perception were conflated with those of the objective salience of the prime.

In a recent study (Avneon & Lamy, 2018), we therefore reexamined unconscious semantic processing using the liminal-prime paradigm. In this paradigm, the prime stimulus is at the limen of consciousness, such that its visibility varies across trials from total invisibility to clear perception. On each trial, participants first make a speeded response to the target and then rate the prime visibility with no time pressure, using a variant of the Perceptual Awareness Scale (PAS, Ramsøy & Overgaard, 2004). Thus, conscious perception of the prime and the impact of this prime on responses to the target (i.e., response priming) are concomitantly assessed under the same stimulus conditions on each trial and unconscious and conscious semantic priming can therefore be compared. It should be noted that an important difference between the subliminal- and the liminal-prime paradigm is that the former relies on an objective definition of conscious perception, whereas the latter relies on a subjective definition. Thus, while null sensitivity (d′) across trials for a given stimulus is the required condition for invisibility in the subliminal-prime paradigm, reports of null subjective visibility on a given trial is the required condition in the liminal-prime paradigm.

The adaptation of Dehaene et al. (1998) semantic priming experiment to the liminal-prime paradigm yielded two main findings. On the one hand, confirming Dehaene et al. (1998) conclusions, we found unconscious response priming, that is, a prime-response congruency effect with primes reported to be invisible. On the other hand, this effect differed from conscious priming in two important aspects: it was smaller, and waned faster as response times increased. These findings suggest that stimuli that are not consciously perceived can be processed to a semantic level but that their impact on behavior is much weaker than that of consciously perceived stimuli.

1.2. Learned stimulus-response associations or semantic priming?

The objective of our previous study (Avneon & Lamy, 2018) was to reexamine Dehaene et al. (1998)'s findings using the liminal-prime paradigm.[2] Thus, except for our use of liminal instead of subliminal primes, our procedure was similar to theirs. However, some authors suggested an alternative interpretation of Dehaene et al.'s findings. Specifically, they argued that when the prime stimuli also serve as targets, as was the case in our study as well as in Dehaene et al. (1998), the observed priming effect can reflect learned, low-level, stimulus–response associations rather than genuine high-level semantic processing (e.g., Abrams & Greenwald, 2000; Damian, 2001; see also Kunde, Kiesel, & Hoffmann, 2003 for a related interpretation not based on S-R associations). According to this rationale, the association between a visible target and a response is learned during the experiment and unconscious perceptual processing of the prime suffices to elicit the associated response. This account predicts that unconscious response priming should only occur for prime stimuli that have been encountered and responded to as targets (henceforth, "used primes"), whereas no effect should be observed for prime stimuli that do not belong to the target set (henceforth, "novel primes").

Damian (2001) provided clear empirical support for this prediction. However, later studies reported unconscious response priming with novel primes (e.g., Kinoshita & Hunt, 2008; Klauer, Eder, Greenwald, & Abrams, 2007; Naccache & Dehaene, 2001; Ortells, Kiefer, Castillo, Megías, & Morillas, 2016; Pohl, Kiesel, Kunde, & Hoffmann, 2010; Reynvoet, Gevers, & Caessens, 2005). In an important step towards reconciling these discrepant findings, Van den Bussche and Reynvoet (2007), Van den Bussche, Notebaert, and Reynvoet (2009) showed that subliminal priming with novel primes was observed with large but not with small target category sets. They suggested that large target sets promote semantic processing of the target and prime, while small sets promote shallower, low-level perceptual processing (see also Forster, 2004).

Recently, Kinoshita and Hunt (2008) shed new light on masked response priming with used vs. novel primes by analyzing RT distributions in a masked response priming paradigm similar to Naccache and Dehaene (2001). The target set included 1, 4, 6 and 9, such that the same digits served as used primes and 2, 3, 7 and 8 served as novel primes. All primes were presented briefly (53 ms) but

[2] An additional objective of Balota et al. (2018) study was to examine the impact of several aspects inherent to the liminal-prime paradigm that may modulate the usefulness of this paradigm for detecting unconscious processing. In particular, we examined the influence on the response priming effect of using a dual task (speeded response to the target and unspeeded rating of the prime's visibility), and primes that are relevant to the task and benefit from temporal attention (see Lamy, Ophir, & Avneon, 2018, for a detailed discussion of the pros and cons of the liminal-prime paradigm relative to other available methods for investigating unconscious processing and for a review of recent uses of the paradigm outside our lab, e.g., Kimchi, Devyatko, & Sabary, 2018; Van den Bussche et al., 2018).

conscious perception of these primes was not measured. The authors found response priming to decrease as RTs increased, with a larger decrease for used than for novel primes: whereas priming on the slowest trials vanished for used primes, it remained significant for novel primes. The authors concluded that unconscious response priming reflects both learned stimulus-response associations, the effects of which wane over time (as a result of either passive decay or active suppression) and semantic processing, the effects of which are independent of passing time.

1.3. The present study

As is clear from the foregoing review, the question of how conscious perception affects genuinely semantic priming vs. the retrieval of learned stimulus-response associations, remains open. On the one hand, it is uncertain whether the dissociation between conscious and unconscious response priming reported by Avneon and Lamy (2018) pertains to semantic priming or to lower-level stimulus-response mapping: all primes could serve as targets, such that stimulus-response associations could account for response priming (e.g., Damian, 2001), yet, the target set was fairly large (it comprised of 16 different stimuli: 8 numbers written in Arabic or in word format), which may have promoted semantic processing of the target and prime (e.g., Forster, 2004; Van den Bussche & Reynvoet, 2007). On the other hand, it is also unknown whether the dissociation between semantic priming and stimulus-response mapping reported by Kinoshita and Hunt (2008) pertains to conscious processing, unconscious processing or a mixture of both, since conscious perception of the prime was not assessed in that study. It should be noted that a similar dissociation was replicated by Ansorge et al. (2013) who did assess the subliminality of the primes. However, they used a different task (a space-valence across-category congruence paradigm rather than a numerical comparison paradigm) and participants were considered to be unaware of the prime whenever they were wrong at determining whether the prime was congruent or incongruent with the target. Thus, the prime visibility test was relatively liberal and did not exclude the possibility that partial awareness of the prime occurred.

The objective of the present work was to clarify the role of conscious perception in response priming resulting from semantic processing vs. learned stimulus-response associations. We used a paradigm similar to Avneon and Lamy (2018). The main change was that the primes could be either used or novel. In Experiment 1, both primes and targets were always digits written in Arabic format. The target set included 2, 4, 6 and 8, such that the same digits were the used primes and 1, 3, 7 and 9 were the novel primes.[3] In Experiment 2, primes were again always written in Arabic format but targets were always written in word format. Thus, the primes were always novel. Following previous authors (e.g., Damian, 2001; Kinoshita & Hunt, 2008), we assumed that response priming from used primes would mainly reflect the application to the prime of the stimulus-response mapping learned through responding to the targets, whereas response priming from novel primes would reflect semantic processing of the primes. Accordingly, we expected practice with the task to enhance response priming with used primes but not with novel primes. Of main interest was whether and how the two types of response priming would differ for primes rated to be completely invisible (henceforth, *unaware* primes) and clearly seen primes (henceforth, *aware* primes) and how response priming would vary across the RT distribution in the four resulting conditions.

1.4. Statistical analyses

1.4.1. Outliers

In both experiments, trials with an RT below 200 ms were excluded from all RT analyses as anticipatory responses, and for each participant, a trial with an RT deviating from the median RT of its cell by more than 3 median absolute deviations (MAD) was excluded as an outlier (Leys, Ley, Klein, Bernard, & Licata, 2013).

1.4.2. Visibility ratings

In each experiment, the prime was absent on 20% of the trials. These catch trials were included in order to determine whether for each participant, the reported visibility ratings corresponded to different perceptual states or were randomly distributed. In previous experiments (Avneon & Lamy, 2018), we adopted the most conservative criterion for absence of conscious perception: the unaware condition included only trials on which visibility was rated 0.

We examined whether 1, 2 and 3 visibility ratings were predictive of cue presence in preliminary analyses. Given that the proportion of cue-present trials was 80%, if a visibility rating indicating some subjective awareness is predictive of cue presence, more than 80% of the trials receiving this visibility rating should be cue-present trials. We thus compared the random distribution (80% vs. 20%) and the observed ratings distributions in a series of binomial tests on the raw number of ratings for each visibility rating and for each subject (see Ophir, Sherman, & Lamy, 2018 for a similar rationale). Visibility ratings of 2 and 3 were predictive of cue presence for 69% and 100% of the subjects, respectively, in Experiment 1, and for 86% and 92% of the subjects, respectively, in Experiment 2. In sharp contrast, visibility ratings of 1 were predictive of cue presence for only 12% and 41% of the subjects in Experiments 1 and 2, respectively. Therefore, only ratings 2 and 3 were included in the aware-prime condition (but see the supplementary data for RTs on congruent and incongruent trials for all visibility ratings including 1).

[3] Note that the term "novel primes" usually refers to primes that were presumably never seen by the participants (i.e., 'subliminal primes'). In the present experiment, however, participants are likely to have consciously perceived all primes at some point during the experiment, because primes were liminal rather than subliminal. Hence, we refer to "novel primes" as stimuli that were never responded to as targets, regardless of their visibility.

1.4.3. RT and accuracy analyses

Used- (Exp. 1) and novel-prime trials (Exp. 1 and Exp. 2) were examined in separate analyses. These included linear mixed-effects model (LMM) analyses for RTs and generalized linear mixed-effects model analyses (GLMM), an extension of LMM that allows categorical data analysis (Jaeger, 2008), for accuracy. These analytic techniques are increasingly used within the cognitive-psychology community, as they offer many advantages over the traditional ANOVA test (see Boisgontier & Cheval, 2016 for a detailed argumentation). In particular, LMM and GLMM are well suited for handling unbalanced data sets. This feature was especially important in the present study, because when using the PAS, the distribution of visibility ratings can vary widely among participants.

All analyses were carried out using "R" statistical software (R Core Team, 2017). To determine the appropriate random structure of the model, we began with the maximum model for RT data (Barr, Levy, Scheepers, & Tily, 2013), including all fixed factors and their interactions, as well as a random intercept for participants and a by-participant random slope for each fixed factor. The model was progressively simplified by excluding each random factor if the more complex model did not fit the data better. The model that best fit the data in most analyses included response congruence (congruent vs. incongruent) and prime visibility (aware vs. unaware) as predictors (with an interaction term) and a random subject-specific intercept. This model is formally described as: RT ~ Visibility + Congruence + Visibility: Congruence + (1| Subject). For consistency purposes, it was used in all RT and accuracy analyses. Congruence refers to the compatibility between the response associated with the prime number and the response associated with the target number, with poorer performance on incongruent relative to congruent trials indicating the presence of response priming.

For RT analyses, effects were tested in a type III ANOVA, using the *lmer* function of the *lme4* package (version 1.1-13; Bates, Mächler, Bolker, & Walker, 2014). The *p-value*s of the effects were determined using Satterthwaite approximations to degrees of freedom, as implemented in the *anova* function from the *stats4* package (version 3.4.1). For accuracy analyses, a GLMM for binary data was fitted by using the *glme* function and a *logit* link function (Jaeger, 2008) with the same predictors as for the RT analyses. The summary output of the GLMM function of the *lme4* package provides p-values based on asymptotic Wald tests, which is common practice for generalized linear models (Bolker et al., 2009). In contrast, the summary output of the *anova* function for LMM models provides F-values. We thus report z-values for error-rates and F-values for response times. For both RT and accuracy data, the p values for post-hoc comparisons are reported following Tukey adjustments for multiple comparisons.

Next, in order to examine how the size of the congruency effect varied across the RT distribution in the different conditions, we used a vincentization procedure (Ratcliff, 1979): quantiles of RT distributions were computed for each participant, each summarizing 10% of the cumulative RT distribution, and were then averaged to produce the group distribution (Rouder & Speckman, 2004). This nonparametric procedure was applied separately for each condition. Because there were not enough trials per condition to conduct meaningful statistical analyses of the vincentized data with 10 bins, we aggregated the data into just two bins (50% fastest and 50% slowest trials) and conducted separate analyses for fast and for slow trials. Note that such a median-split analysis does not run the risk of misrepresenting the data, since we also present the complete RT distribution in graphs.

Finally, the above analyses were complemented with Bayesian analyses using the JASP software package (version 0.8.1.2). Bayes factors (BFs) were computed to quantify the evidence for the presence or absence of a congruency effect. Following Dienes and McLatchie (2016) we consider a BF_{10} to provide evidence for H0 if it stands between 0 and 0.33, "inconclusive" evidence if it stands between 1/3 and 3 and evidence for H1 if it exceeds 3 (with a BF_{10} between 3 and 10, 10 and 30, 30 and 100 and > 100 providing substantial, strong, very strong and decisive evidence, respectively, for H1, Jeffreys, 1961). Default priors implemented by JASP were used in all analyses. Note, however, that all results were the same when we used narrower (0.5) or wider (1.0) priors.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twenty students (15 female, mean age = 23.15 years, SD = 3.8) participated in the experiment for course credit. All reported normal or corrected-to-normal vision. Written consent was obtained after the general experimental procedures were explained. Based on a previous similar study of unconscious processing using the liminal-prime paradigm (Avneon & Lamy, 2018), the number of participants was preset at 16 participants.

2.1.2. Apparatus

The experiment took place in a dimly lit room. All stimuli were presented on a 23-in. LED screen, using 1920 × 1280 resolution graphics mode and 120-Hz refresh rate. Responses were collected via the computer keyboard. Viewing distance was set at approximately 50 cm from the monitor.

2.1.3. Stimuli and procedure

The fixation was a 0.4 × 0.4° plus sign (+). The target was a digit (1, 4, 6, or 9) written in Arabic format. The prime was similar to the target, except that it was one of eight possible digits (1–9 excluding 5). The pre- and post-mask consisted of a string of 4 symbols randomly drown from the same pool ($,%,@,#). Each digit and symbol was drawn in a 28-point Arial font (~1.15° of visual angle), and enclosed in a 4.8 x1.6° of visual angle 1-pixel thick frame, centered at fixation. All stimuli were gray (RGB: 127, 127, 127, with a luminance of about 33 cd/m^2) and centered at fixation.

The sequence of events is shown in Fig. 1. It consisted of the successive presentation of the fixation (500 ms), pre-mask (75 ms), prime (58 ms), post-mask (83 ms) and target (200 ms) displays. Following the target, the fixation was again presented for 1000 ms or

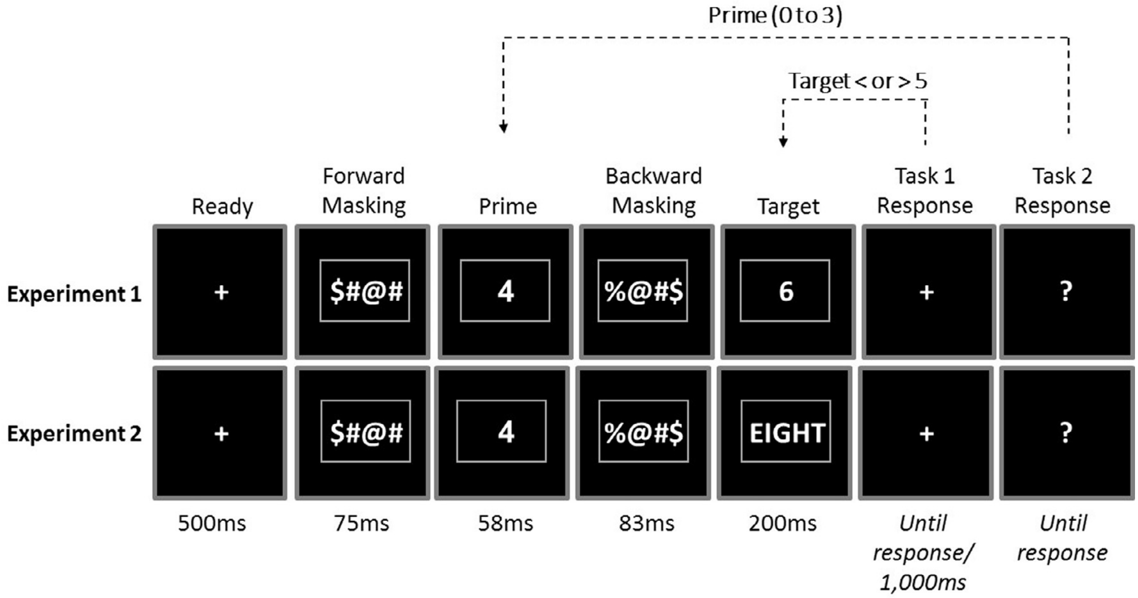

Fig. 1. Sequence of events in Experiment 1 (upper panel) and Experiment 2 (lower panel). This example depicts an incongruent trial: the prime and target numbers ("4" in Experiments 1 and 2, "eight" written in Hebrew in Experiment 2, and "6", respectively) were associated with different responses. In both experiments, the first task was to report whether the target was smaller or larger than 5, and the second task was to rate the prime visibility on a scale ranging from 0 to 3. Eight numbers (1–9 excluding 5) could serve as primes and four numbers (2, 4, 6, and 8) as targets. In Experiment 1, all primes and targets were digits. In Experiment 2, all primes were presented in Arabic format and all targets were presented in a word format. Stimuli are not drawn to scale.

until the first response was given, and was immediately followed by a question mark, which remained on the screen until the second response was given.

On each trial, participants were asked to provide two responses: (1) First, they had to determine whether the target was smaller or larger than 5, and respond by pressing designated keys (left or right arrow) with their right hands as fast as possible, while maintaining high accuracy. (2) Second, they had to provide a non-speeded subjective report of the prime visibility using a scale ranging from 0 ("I saw nothing at all") to 3 ("I saw the number clearly"), by pressing four different designated keys with their left hands.

Eye movements were not monitored, but subjects were explicitly requested to keep their gaze on the center of the screen throughout each trial. Erroneous responses as well as failures to respond during the presentation of the response display were followed by a 150-ms 1000 Hz beep.

2.1.4. Design

The experiment began with two practice blocks. During the first one (20 trials), participants performed only the speeded target categorization task and did not report the prime's visibility. The rationale for this practice was to get participants used to prioritizing the first task. The second practice block included 20 trials similar to the experimental trials. After practice, participants performed 640 experimental trials divided into 8 blocks separated by a self-paced break. Twenty percent of the trials were "catch trials", in which the masks were presented alone, without a prime.

On each trial, prime and target identities were randomly selected and were thus equally likely to be congruent (e.g. both smaller than 5) or incongruent (e.g. prime larger than 5 and target smaller than 5). All conditions were randomly mixed within each block of trials.

2.2. Results

The data from four participants were excluded: two because their percentage of 3- visibility ratings on prime-absent (catch) trials exceeded the group's mean by more than 2.5 standard deviations (21% and 40% relative to an average of 4.8%, SD = 3.9%, for the group), and two because their accuracy on the target categorization task departed from the group's mean by > 2.5 standard deviations (72% and 75%, relative to an average of 89%, SD = 3.8% for the group).

Participants rated prime visibility to be 0, 1, 2 and 3 on 30%, 16%, 18%, and 36% of prime-present trials, and on 70%, 19%, 6% and 5% of prime-absent trials, respectively. The unaware condition included only trials on which visibility was rated 0. Mean response times and error rates are presented in Fig. 2.

2.2.1. Reaction times

Prime-absent trials were excluded from all RT analyses and so were trials in which responses to the target were inaccurate

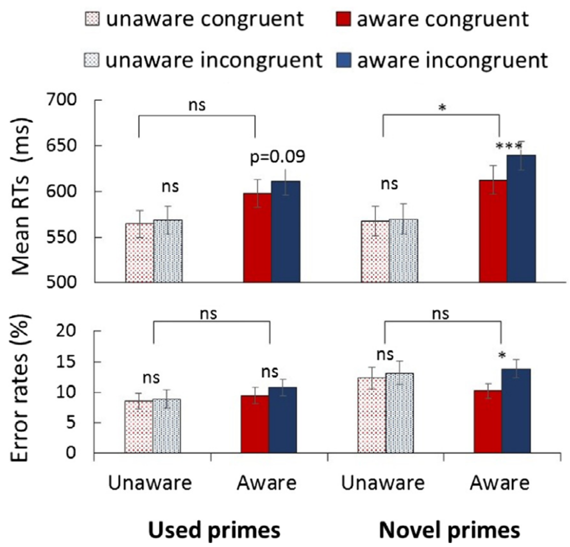

Fig. 2. Mean RTs and error rates in Experiment 1 for congruent- and incongruent-prime trials as a function of prime visibility rating (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition), and prime type (novel vs. used). Textured bars depict unaware-prime trials and plain-color bars depict aware-prime trials. Light (red) bars depict congruent trials and dark (blue) bars depict incongruent trials. Error bars indicate standard errors. * < 0.05; ** < 0.001, *** < 0.001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(11.0%), anticipatory responses (less than 0.3%) and outlier RT trials (1.0%). Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality.

To track how the size of the congruence effect varied across the RT distribution in the aware and in the unaware-prime conditions, we used the Vincentization procedure. Figs. 3 and 4 show the mean RT separately for aware- and unaware-prime trials on congruent and on incongruent trials for each decile of the RT distribution. Fig. 5 shows the mean RT as a function of prime-target congruency and prime awareness, separately for the 50% fastest trials and for the 50% slowest trials.

2.2.2. *Used primes*

The main effect of visibility was significant, $F(1, 2970.9) = 54.35$, $p < .001$ and the main effect of congruency was marginally significant, $F(1, 2965.2) = 3.7$, $p = .055$. The interaction between the two factors was not significant, $F(1, 2965.6) = 1.08$, $p = .29$, with strong evidence for the null, $BF_{10} = 0.065$. Post-hoc comparisons showed that the congruency effect did not reach significance for either aware primes, $t(2959.1) = 2.34$, $p = .09$, or unaware primes, $t < 1$.

2.2.3. *Used primes – fast trials*

The main effects of congruency and visibility were significant, $F(1, 1493.7) = 69.25$, $p < .0001$, and $F(1, 1503.3) = 26.93$,

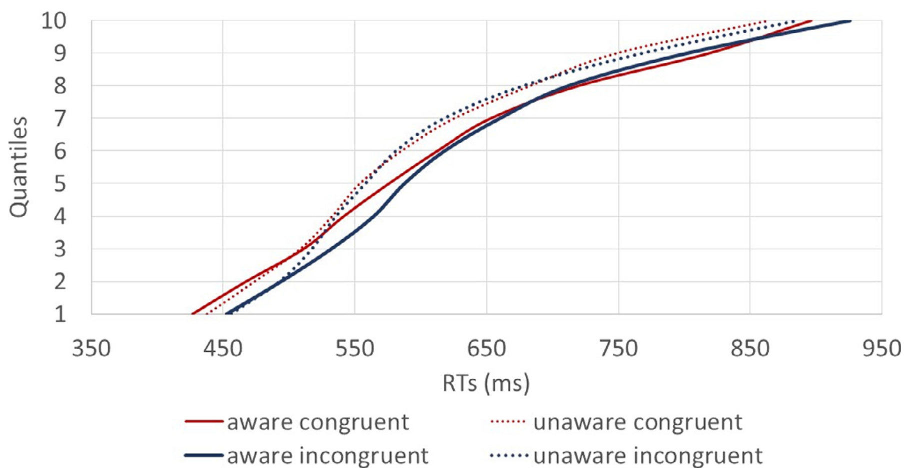

Fig. 3. Vincentized reaction time distributions on congruent- and incongruent-response trials for aware (PAS = 2 + 3) and unaware (PAS = 0) *used* primes in Experiment 1.

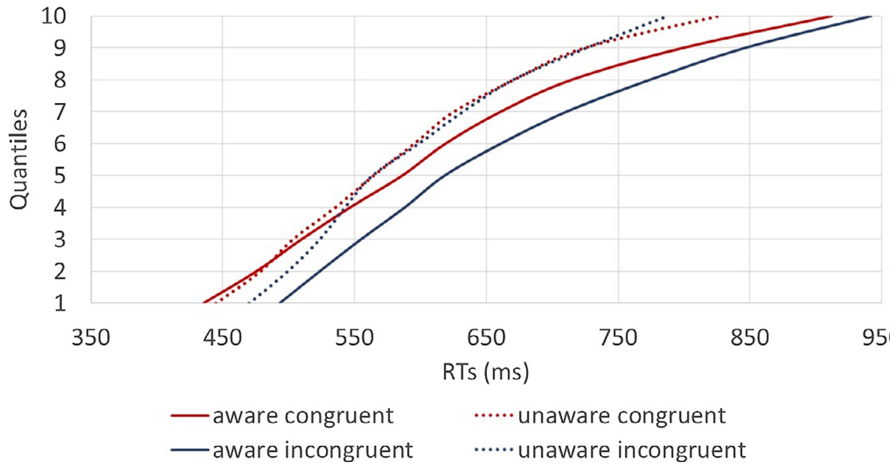

Fig. 4. Vincentized reaction time distributions on congruent- and incongruent-response trials for aware (PAS = 2 + 3) and unaware (PAS = 0) *novel* primes in Experiment 1.

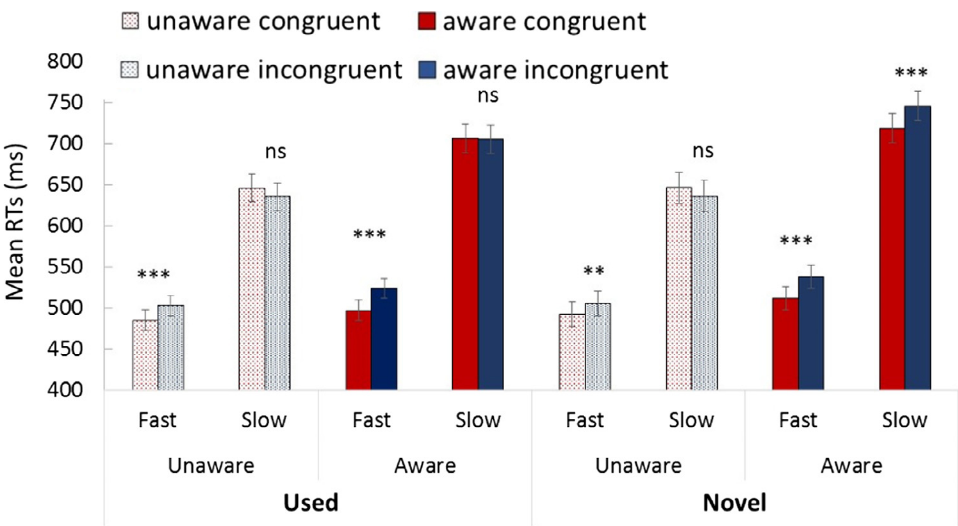

Fig. 5. Mean RTs in Experiment 1 for congruent- and incongruent-response trials in fast and slow trials as a function of prime-visibility rating (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition), and prime novelty (novel vs. used). Textured bars depict unaware-prime trials and plain-color bars depict aware-prime trials. Light (red) bars depict congruent trials and dark (blue) bars depict incongruent trials. Error bars indicate standard errors. * < 0.05; ** < 0.001, *** < 0.001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

$p < .0001$, respectively. The interaction between congruency and visibility was not significant, *$F(1,1493.8) = 2.44$, $p = .11$,* suggesting that response priming was of similar magnitude for aware and for unaware primes, although evidence for a null interaction was not conclusive, *$BF_{10} = 0.79$*. Post-hoc comparisons confirmed that the congruency effect was significant for both aware primes, *$t(1493.0) = 7.78$, $p < .0001$,* and unaware primes, *$t(1493.8) = 4.36$, $p = .0001$,* with decisive evidence for both effects, both *$BF_{10} > 100$*.

2.2.4. Used primes – slow trials

The main effect of visibility was significant, *$F(1, 1462.6) = 102.4$, $p < .0001$*. The main effect of congruency was not significant, *$F(1, 1449.1) = 1.56$, $p = .21$*. The two factors did not interact, *$F < 1$,* with very strong evidence for the null, *$BF = 0.025$,* suggesting that response priming was of similar magnitude for aware and for unaware primes. Post-hoc comparisons confirmed that the congruency effect was not significant for either aware primes, *$t < 1$*, or unaware primes, *$t(1448.92) = -1.39$, $p = .51$*, with strong and substantial evidence for the null, respectively, *$BF_{10} = 0.056$* and *$BF_{10} = 0.24$*.

2.2.5. Novel primes

The main effect of congruency was significant, *$F(1, 3012.2) = 9.23$, $p = .002$,* and so was the main effect of visibility, *F(1,* *3005.0) = 91.87, p < .0001*. The interaction between the two factors was also significant, *F(1, 3012.7) = 6.67, p = .01*, with substantial evidence for this interaction, $BF_{10} = 4.5$, suggesting that the congruency effect was larger for aware than for unaware primes. Post-hoc comparisons revealed that the congruency effect was significant on aware-prime trials, *t(3012.2) = 5.15, p < .0001*, with decisive evidence for this effect, $BF_{10} > 100$, and non-significant on unaware-prime trials, $t < 1$, with strong evidence for the null, $BF_{10} = 0.056$.

2.2.6. Novel primes – fast trials

The main effects of congruency and visibility were significant, *F(1, 1519.4) = 38.93, p < .001,* and *F(1, 1532.1) = 36.73, p < .001,* respectively. The interaction between congruency and visibility did not reach significance, *F(1, 1519.6) = 2.97, p = .085*, suggesting that the congruency effect was of similar magnitude for aware and for unaware primes, although evidence for a null interaction was not conclusive, $BF_{10} = 1.09$. Post-hoc comparisons confirmed that the congruency effect was significant for both aware primes, *t(1519.5) = 7.31, p < .001,* and unaware primes, *t(1519.5) = 2.69, p < .001,* with decisive and substantial evidence for these effects, $BF_{10} > 100$, and $BF_{10} = 5.34$, respectively.

2.2.7. Novel primes – slow trials

The main effect of congruency did not reach significance, *F(1, 1476.8) = 2.73, p < .099.* The main effect of visibility was significant, *F(1, 1491.6) = 202.93, p < .001*, and interacted with congruency, *F(1, 1477.0) = 13.11, p < .001*, with decisive evidence for this effect, $BF_{10} > 100$, suggesting that the congruency effect was larger for aware than for unaware primes. Post-hoc comparisons revealed that the congruency effect was significant for aware primes, *t(1475.4) = 4.86, p < .001,* with decisive evidence for this effect, $BF_{10} > 100$, but not significant for unaware primes, *t(1475.6) = −1.17, p = .64,* with substantial evidence for the null, $BF_{10} = 0.23$.

As converging evidence for the observed dissociation between used and novel primes, we examined how practice with the task affected response priming with each type of prime. Following Damian (2001) we predicted that if response priming with used primes indeed reflects the retrieval of learned stimulus-response associations, while priming with novel primes reflects genuine semantic priming, response priming should build up across the experiment with used primes but not with novel primes.

We thus conducted an analysis with experiment part (1st, 2nd, 3rd and 4th quarter), prime visibility, congruency, prime novelty and response speed (fast vs slow) as fixed factors. This analysis fully supported our predictions. Fig. 6 depicts the mean RT in each condition. The analysis revealed a significant four-way interaction between congruency, visibility, experiment part, and prime novelty, *F(3, 5939.8) = 5.2, p = 0.001*. The significant three-way interactions involving congruency were with response speed and prime novelty, *F(1, 5939.7) = 4.2, p = 0.04,* with visibility and prime novelty, *F(1, 5939.9) = 5.8, p = 0.016,* and with visibility and experimental part, *F(3, 5939.8) = 3.6, p = 0.013* (the 3-way interaction between visibility, prime novelty, and experimental part was also significant, *F(3, 5939.8) = 2.6, p = 0.05)*.

To further explore these interactions, we conducted separate analyses for used and for novel primes on fast and on slow trials.

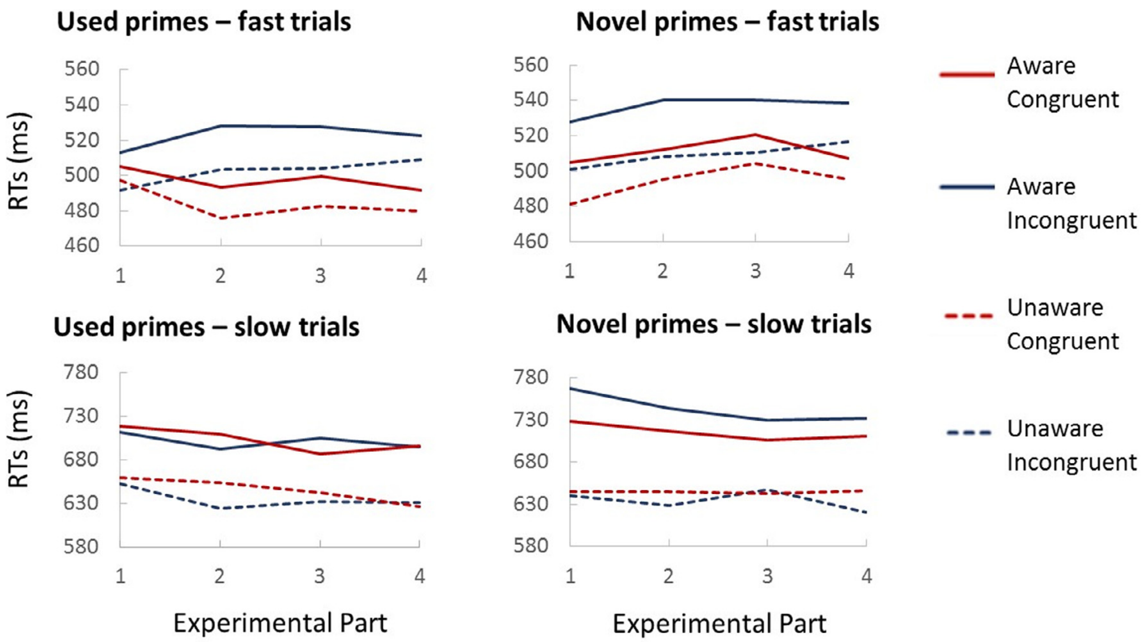

Fig. 6. Mean RTs in Experiment 1 for congruent- and incongruent-response trials on fast and on slow trials as a function of experimental part (1st, 2nd, 3rd, 4th), prime-visibility rating (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition), and prime novelty (novel vs used).

Table 1
Model output for the fixed and random factors for used and novel-prime trials in Experiment 1.

Used prime trials				
Fixed effects	Coefficient	Std. err	Z-value	*P-value*
(Intercept)	2.11	0.14	15.55	< 0.001
Visibility (PAS = 0)	0.21	0.18	1.14	0.25
Congruency (congruent)	0.14	0.15	0.93	0.35
Interaction	−0.01	0.24	−0.42	0.68
Random effects	Variance	Std. dev		
Subject (intercept)	0.15	0.38		
Novel prime trials				
Fixed effects	Coefficient	Std. err	Z-value	*P-value*
(Intercept)	1.83	0.13	14.41	< 0.001
Visibility (PAS = 0)	0.06	0.16	0.36	0.72
Congruency (congruent)	0.35	0.12	2.8	0.005
Interaction	−0.28	0.22	−1.28	0.20
Random effects	Variance	Std. dev		
Subject (intercept)	0.14	0.38		

With used primes, on fast trials, the interaction between experiment part and congruency was significant, $F(3, 1481.3) = 5.44$, $p = .001$, and was not modulated by prime awareness, $F < 1$. Post-hoc comparisons confirmed that the priming effect was smaller in part 1 than in parts 2, 3, and 4 on both aware- and unaware- prime trials. Specifically, the interaction between congruency and experiment part was significant for part 1 vs. 2, $F(1, 625.4) = 12.96, p = .0003$, part 1 vs. 3, $F(1, 670.3) = 8.02, p = .005$, and part 1 vs. 4, $F(1, 690.4) = 9.5, p = .002,$ whereas it was not significant for part 2 vs. 3 vs. 4, $F < 1$. In addition, none of the interactions was modulated by prime visibility, all $Fs < 1$. On slow used-prime trials, there was no significant interaction involving congruency and experiment part, *all* $ps > 0.23$, indicating that the congruency effect was equally absent across experiment parts on both aware- and unaware-prime trials.

In contrast to used primes, with novel primes, experiment part did not modulate the congruency effect, $F < 1,$ nor its interaction with prime visibility on either fast or slow trials, $F < 1$. Thus, the congruency effect was significant for both aware and unaware primes on fast trials, and was absent for unaware primes and significant for aware primes on slow trials, with the magnitude of these effects remaining stable across the experiment.

2.2.8. Accuracy

The model output for the fixed and random factors for used and for novel primes is presented in Table 1. Only the congruency effect in the novel-prime condition was significant.

2.3. Discussion

The results of Experiment 1 revealed a strikingly different pattern for used vs. novel primes. With used primes, it did not matter whether the prime was consciously perceived or entirely missed: on both aware- and unaware-prime trials, response priming was equally large, occurred only for fast responses, and built up as participants became more practiced with the task. The latter finding supports the notion that response priming with used primes indeed reflects stimulus-response associations established as a result of responding to visible targets.

It should be noted, however, that when the prime belonged to the used set, the prime and target were identical on 25% of the congruent trials. If the congruency effect resulted only from those trials, then the effect would reflect simple perceptual priming rather than the retrieval of stimulus-response associations. To test this possibility, we reexamined the congruency effect on used trials when identical prime-target trials were excluded. The pattern of results remained the same: for fast trials, the main effect remained significant, $F(1,1104) = 30.21$, $p < 0.0001$, and the interaction with visibility remained non-significant, $F(1,1104) = 1.96$, $p = 0.16$, with a significant congruency effect on aware-prime trials, $t(1104) = 5.85$, $p < 0.0001$, and a marginally significant congruency effect for unaware-prime trials, $t(1104) = 2.54$, $p = 0.055$. Likewise, for slow trials, neither the main effect of congruency nor its interaction with visibility was significant, both $Fs < 1$. Thus, stimulus repetition does not account for the congruency effect from used primes in this experiment.[4]

[4] We thank an anonymous reviewer for this suggestion. It prompted us to conduct the same analyses on the experiments reported in Balota et al. (2018), in which repetition trials accounted for 1/16 of all trials. Again, excluding identical prime-target trials did not affect the pattern of results.

Novel primes, in contrast, had a markedly different impact when they were consciously perceived relative to when they were not: unconscious response priming occurred only on fast trials (and as is clear from Fig. 4, it was half the size of conscious priming even for the fastest trials, although this difference did not reach statistical significance when an arbitrary 50% cut-off was adopted), whereas conscious priming occurred across the RT distribution. For both aware and unaware primes, response priming did not develop across the experiment, supporting the idea that response priming with novel primes does not result from stimulus-response associations and instead reflects semantic processing of the primes.

3. Experiment 2

The objective of Experiment 2 was to provide converging evidence for the differences observed in Experiment 1 between conscious and unconscious semantic priming. In this experiment, all primes were presented in Arabic format, while all targets were presented in a word format. Thus, all primes were novel and priming could only result from semantic processing of the primes and not from learned stimulus-response associations.

3.1. Methods

3.1.1. Participants

Twenty students (16 women, mean age = 23.4 years, SD = 1.6) participated in the experiment for course credit. All reported normal or corrected-to-normal vision. Written consent was obtained after the general experimental procedures were explained.

3.1.2. Apparatus, stimuli, procedure and design

The apparatus, stimuli, procedure and design were similar to those of Experiment 1 except that targets were number words instead of digits. Thus, the format of the prime (digit) was always different from the format of the target (word), such that primes were novel on all trials (i.e., the prime stimuli were never encountered as targets).

3.2. Results

The data from three participants were excluded from all analyses: two because the percentage of 3-visibility rating on prime-absent (catch) trials exceeded the group's mean by more than 2.5 standard deviations (14% and 38% relative to an average of 1.2%, SD = 1.7%, for the group), and one because his accuracy on the target-categorization task departed from the group's mean by more than 2.5 standard deviations (76% relative to an average of 91.4%, SD = 3.6%, for the group). Prime-absent trials were excluded from all RT and accuracy analyses. The participants rated prime visibility to be 0, 1, 2 and 3 on 46%, 25%, 16%, and 13% of the trials, respectively, on prime-present trials and on 75%, 19%, 5% and 1%, respectively, on prime-absent trials. Mean response times and error rates are presented in Fig. 7.

3.2.1. Reaction times

Trials in which responses to the target were inaccurate (13.0%), as well as outlier RT trials (0.4%) were excluded from all RT analyses. There were no anticipatory responses. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. Fig. 8 shows the mean RT separately for aware- and for unaware-prime trials on congruent and incongruent trials, for each decile of the cumulative RT distribution. Fig. 9 shows the mean RT as a function of prime-target congruency and prime awareness, separately for the 50% fastest trials and for 50% slowest trials.

The main effects of congruence and visibility were significant, $F(1, 5925.3) = 205.24$, $p < .0001$ and $F(1, 5912.6) = 32.07$, $p < .0001$, respectively. The interaction between the two factors was also significant, $F(1, 5913.0) = 9.12$, $p = .002$, and the evidence for this interaction was strong, $BF_{10} = 12.11$, suggesting that the congruency effect was larger for aware than for unaware primes. Post-hoc analyses revealed that the congruency effect was significant on aware-prime trials, $t(5912.87) = 5.55$, $p < .0001$, with decisive evidence for this effect, $BF_{10} > 100$, and non-significant on unaware-prime trials, $t(5912.67) = 2.11$, $p = .15$, with marginally conclusive evidence for this null effect, $BF_{10} = 0.32$.

3.2.2. Fast trials

The main effects of congruency and visibility were significant, $F(1, 2970.6) = 160.25$, $p < .001$, and $F(1, 2973.9) = 291.9$, $p < .001$, respectively. The interaction between the two factors was also significant, $F(1, 2970.7) = 22.9$, $p < .001$, with decisive evidence for this interaction, $BF_{10} > 100$, indicating that the congruency effect was larger for aware than for unaware primes. Post-hoc comparisons revealed that the congruency effect was significant for both aware primes, $t(2971.3) = 11.15$, $p < .001$, and unaware primes, $t(2971.25) = 6.3$, $p < .001$, with decisive evidence for both effects, both $BF_{10} > 100$.

3.2.3. Slow trials

The main effects of congruency and visibility were significant, $F(1, 2924.4) = 10.12$, $p = .001$, and $F(1, 2933.0) = 257.53$, $p < .001$, respectively. The interaction between the two factors was also significant, $F(1, 2924.6) = 8.23$, $p = .004$, with substantial evidence for this effect, $BF_{10} = 4.8$, indicating that the congruency effect was larger for aware than for unaware primes. Post-hoc comparisons revealed that the congruency effect was significant for aware primes, $t(2925.96) = 3.87$, $p = .0006$, with very strong evidence for this effect, $BF_{10} = 54.2$, but not for unaware primes, $t < 1$, with strong evidence for the null, $BF_{10} = 0.04$.

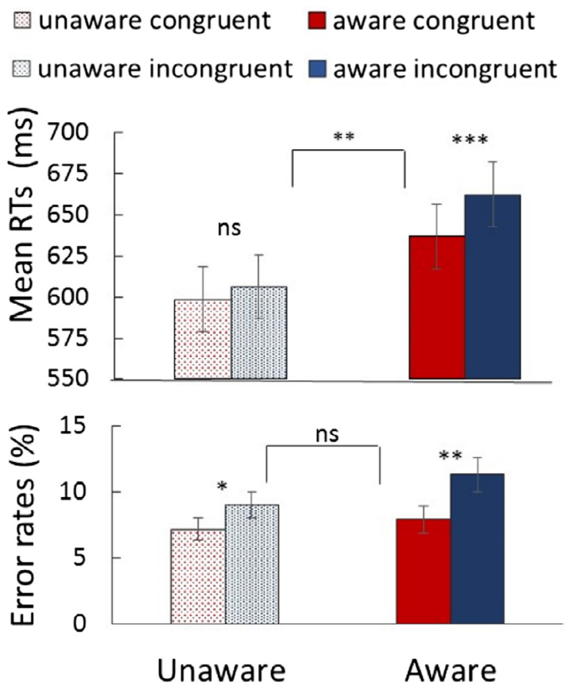

Fig. 7. Mean RTs and error rates in Experiment 2 for congruent- and incongruent-response trials as a function of prime awareness (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition). Textured bars depict unaware-prime trials and plain-color bars depict aware-prime trials. Light (red) bars depict congruent trials and dark (blue) bars depict incongruent trials. Error bars indicate standard errors. * < 0.05; ** < 0.001, *** < 0.001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

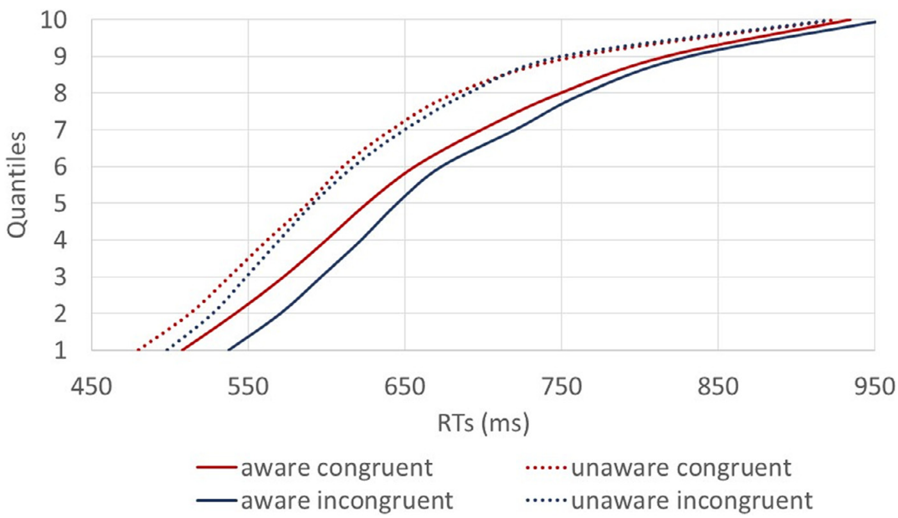

Fig. 8. Vincentized reaction time distributions on congruent- and incongruent-response trials for unaware-prime (PAS = 0) and aware-prime (PAS = 2 + 3) trials in Experiment 2.

To examine the impact of practice across the experiment on the congruency effect, we conducted an analysis with experiment part (1st, 2nd, 3rd and 4th quarter), prime visibility, congruency and response speed (fast vs slow) as fixed factors. Fig. 10 shows the mean RT in each condition. There was no significant interaction involving congruency and experiment part, all $ps > 0.2$. Specifically, the significant interactions between congruency and prime visibility found for fast trials and for slow trials were not modulated by experiment part, $F < 1$ and $p > .27$, respectively.

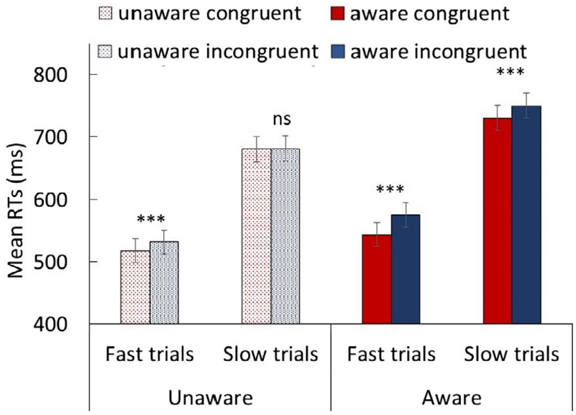

Fig. 9. Mean RTs in Experiment 2 for congruent- and incongruent-response trials for fast and slow trials, as a function of prime awareness (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition). Textured bars depict unaware-prime trials and plain-color bars depict aware-prime trials. Light (red) bars depict congruent trials and dark (blue) bars depict incongruent trials. Error bars indicate standard errors. * < 0.05; ** < 0.001, *** < 0.001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

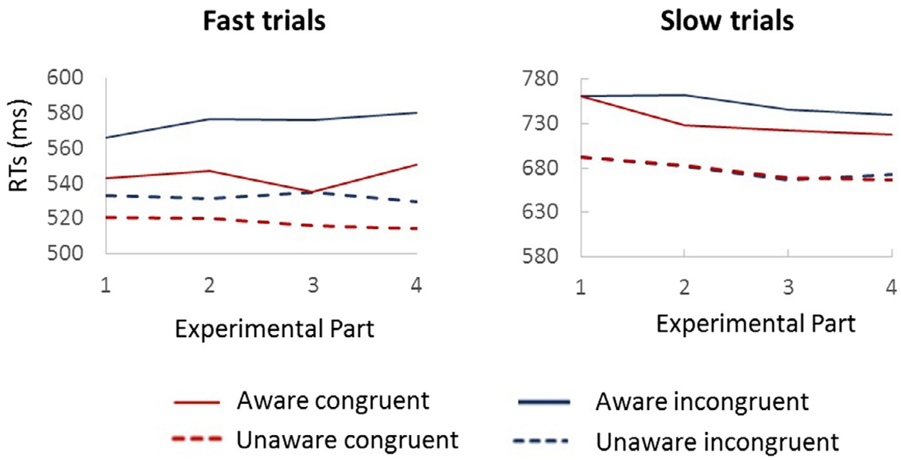

Fig. 10. Mean RTs in Experiment 2 for congruent- and incongruent-response trials on fast and on slow trials as a function of experimental part (1st, 2nd, 3rd, 4th), and prime-visibility rating (PAS = 0 for the unaware-prime condition vs. PAS = 2 + 3 for the aware-prime condition).

3.3. Accuracy

The model outputs for the fixed and random factors are presented in Table 2. Both main effects of congruency and visibility were significant.

3.4. Discussion

The results of Experiment 2 closely replicated the findings of Experiment 1 with novel primes. On fast trials, response priming was

Table 2
Model output for the fixed and random factors for unaware trials in Experiment 2.

Fixed effects	Coefficient	Std. err	Z-value	*P-value*
(Intercept)	2.05	0.13	15.95	< 0.0001
Visibility (PAS = 0)	0.25	0.12	2.09	0.036
Congruency (congruent)	0.39	0.13	2.99	0.002
Visibility * Congruency	−0.14	0.17	−0.83	0.404
Random effects	Variance	Std. dev		
Subject (intercept)	0.15	0.38		

Table 3
Mean response times (in milliseconds) from Experiment 1 as a function of prime type and congruency.

Visibility	Congruency	Inside the target range	Outside the target range
Unaware	Congruent	580.3	559.1
	Incongruent	577.3	565.6

significant both when subjects were aware of the prime and when they were not. However, even for the fastest trials, this effect was smaller on unaware- than on aware-prime trials. Note that in principle, this effect might result from the fact that the arbitrary cut-off between fast and slow trials adopted in our analyses might capture unconscious response priming after it already started waning. However, the difference between conscious and unconscious priming for the very fastest trials (at the intersection of the x-axis in Fig. 8) weakens this suggestion. On slow trials, response priming was robust with consciously perceived primes and totally absent with missed primes. As with the novel primes in Experiment 1, response priming was not modulated by practice in this experiment. Inspection of Fig. 10 suggests that for slow aware-prime trials, the congruency effect did not occur early in practice. However, this modulation was not reliable ($p > 0.17$ for the interaction between congruency and experiment part on slow aware-prime trials) and is likely to result from the relatively low number of trials per cell in this condition (< 8 trials per participant on average).

Taken together, these findings suggest that semantic processing of unconscious information is possible, but that its impact on behavior is much smaller and wanes much faster along the RT distribution than that of consciously perceived information.

4. General discussion

4.1. Summary of the findings

The present study yielded two main novel findings. First, we showed that stimuli that are not consciously perceived can trigger the retrieval of learned stimulus-response associations (S-R response priming) as efficiently as stimuli that are clearly perceived. That such retrieval can occur in the absence of conscious perception of the imperative stimulus has been demonstrated in many studies (e.g., Abrams & Greenwald, 2000; Damian, 2001; Naccache & Dehaene, 2001). However, we showed for the first time that this retrieval *does not even benefit* from conscious perception of the imperative stimulus and that in both cases, it occurs only when responses to the target are fast.

Second, in line with earlier reports (e.g., Kunde et al., 2003[5]; Naccache & Dehaene, 2001; Reynvoet et al., 2005), we showed that semantic processing of stimuli that are not consciously perceived is possible. However, we also showed that the impact of such processing is very small and emerges only when responses to the target are fast, while it totally vanishes for slow responses. By contrast, we found conscious semantic priming to be large both for fast and for slow responses.

4.2. Relation to previous studies

The previous literature has been inconsistent with regard to whether and under what conditions unconscious response priming can be observed with novel primes (e.g., Damian, 2001; Kunde et al., 2003; Van den Bussche et al., 2009). Even when significant effects were reported, they were very small, typically not exceeding 10 ms (e.g., Naccache & Dehaene, 2001; Van den Bussche, Van den Noortgate, & Reynvoet, 2009; Kunde et al., 2003; Reynvoet et al., 2005). Here, in two different experiments, we showed that unconscious semantic priming can prove to be twice as large, but since this effect wanes quickly along the RT distribution, its magnitude is underestimated or the effect missed altogether unless its variation across the RT distribution is taken into account. We thus suggest that discrepant findings in the extant literature may be reconciled if RT distribution analyses are considered (see also Ansorge, Kiefer, Khalid, Grassl, & König, 2010; Avneon & Lamy, 2018; Kinoshita & Hunt, 2008).

On a related note, we showed unconscious semantic processing even though we used a small target set. Van den Bussche et al. (2009) suggested that small target sets encourage shallower, perceptual processing of the primes and reported that unconscious semantic processing occurs only with large target sets. Two possible explanations for this discrepancy come to mind. The first is that unconscious semantic priming can occur with small target sets but is larger with large target sets, and it was not detected with small target sets in Van den Bussche et al. (2009) study because the analyses relied on mean RTs rather than on the RT distribution. The other is that the impact of the target set's size may differ for categorical priming (which is what we measured here, see footnote 3), and semantic priming (which is what Van den Bussche et al. (2009) measured). Further research is needed to settle this issue.

Finally, Kinoshita and Hunt (2008) proposed that unconscious response priming resulting from the retrieval of learned S-R associations (with used primes) is short-lived, whereas some genuinely semantic unconscious priming (with novel primes) is still

[5] Kunde and colleagues (Kunde et al., 2003, Kunde, Kiesel, & Hoffmann, 2005, Kiesel, Kunde, & Hoffmann, 2007) suggested an action-trigger hypothesis, according to which unconscious priming from novel primes occurs only with primes inside the range of the target set. To examine this hypothesis, for fast-response trials we compared unconscious response priming from novel primes inside the range of the target set (3 and 7) vs. outside the range of the target set (1 and 9). An analysis with prime type (inside vs. outside) and congruency revealed that the significant effect of congruency, $F(1, 439.6) = 8.93, p = .003$, did not interact with prime type, $F < 1$ (Table 3). Thus, the present finding do not support Kunde et al. (2003) action-trigger hypothesis.

observed for slow responses (see also Ansorge et al., 2013), although it is also vulnerable to the passage of time. Our findings only partially support this hypothesis. On the one hand, we showed that response priming from the activation of learned response codes was indeed observed only for fast responses, and that this pattern occurred irrespective of the prime visibility. The fact that the build-up of conscious and unconscious response priming across the experiment was highly similar, further supports the idea that they both reflect retrieval of S-R associations. On the other hand, however, we also showed that semantic priming was robust and unrelated to response times only when the prime was consciously perceived. When the prime was missed, semantic priming waned very quickly (see Figs. 4 and 8). We have no straightforward explanation or this discrepancy. Kinoshita and Hunt (2008) did not measure conscious perception of the primes and used a relatively long prime exposure duration (53 ms), such that the significant semantic priming effect for slow responses could result from trials in which their participants consciously perceived the primes. However, Ansorge et al. (2013) also observed semantic priming with used primes on slow trials, although they directly controlled stimulus subliminality. One may speculate that their visibility test was not stringent enough to prevent partial awareness: in our study, novel primes with a visibility rating of 2 (which can reasonably be held to index partial awareness) elicited a priming effect on slow trials. However, further research is clearly needed to settle this issue.

4.3. Learning effects on priming

Our results show that for used primes, priming builds up across the experiment, whereas for novel primes, the effect is present throughout experiment, even in the first blocks of trials. At first sight, these findings seem to support the hypothesis that response priming with used primes reflects the retrieval of learned stimulus-response associations, whereas with novel primes, it reflects genuine semantic priming (e.g., Damian, 2001). However, this account would also predict that some priming resulting from semantic processing of the used primes should occur at the beginning of the experiment, before S-R associations are formed. Yet, this did not occur: for reasons yet to be clarified, unconscious semantic processing of the primes affected responses to the target when the primes were novel, but not when the primes belonged to the targets set (i.e., used primes). One may speculate that unlike with novel primes, there is a potential confusion between the prime and target as to which should be responded to, with used primes. To avoid this confusion, participants might actively discard prime processing once the target is presented.[6]

4.4. Fast vs. slow trials: decay or two modes of processing?

The fact that unconscious response priming declines as responses to the target become slower has been interpreted as evidence that unconscious response priming is short-lived (e.g., Ansorge et al., 2010; Avneon & Lamy, 2018; Kinoshita & Hunt, 2008). Such an interpretation of RT distribution analyses is in line with reports that unconscious response priming is most robust when a stringent temporal deadline is imposed on responses to the target (e.g., Avneon & Lamy, 2018; Greenwald, Draine, & Abrams, 1996; Van Opstal, de Lange, & Dehaene, 2011) and with the finding that unconscious response priming also declines as the stimulus-onset asynchrony between the prime and target increases (Greenwald et al., 1996; Kiefer & Spitzer, 2000). According to this interpretation, our findings suggest that unconscious priming is short-lived irrespective of whether priming results from S-R learning or from semantic processing, whereas conscious priming is short-lived in the former case and long lasting in the latter.

However, alternative interpretations of these findings should be considered before firm conclusions can be established. Fast vs. long RTs differ in the time that elapses between prime presentation and response to the target, and as such, this difference might capture the decay of unconscious priming with passing time. However, fast and slow responses may also differ in the type of processes that underlie them. It has been suggested that our decisions rely to various degrees on two types of processing: fast-and-dirty intuitive processing vs. more thoughtful, time-consuming processing (e.g., Evans, 2003; Kahneman, 2011). Accordingly, fast trials may correspond to trials in which participants responded with little in-depth processing of the target, whereas slow trials may correspond to trials in which target-related evidence was more fully considered. Likewise, imposing a short response window may force participants to rely on fast, intuitive processing. According to this rationale, the weight of prime-related activation relative to target-related processing is larger on fast than on slow trials, which would explain why the prime had a stronger impact on the former than on the latter trials, irrespective of passing time.

This account cannot explain why unconscious priming becomes smaller with longer prime-target SOAs. However, Naccache and Dehaene (2001) suggested an interpretation of this finding that also challenges the decay-related account. They suggested that unconscious semantic processing requires temporal attention to be allocated to the prime, and that when the prime is removed further away from the time window during which the target is expected to appear, it benefits from less attention and its impact vanishes.

As is clear from the foregoing discussion, further research is required to clarify the mechanisms that account for the variations of response priming across the RT distribution. These mechanisms may differ for semantic and for S-R response priming. For instance, unconscious semantic priming may indeed be short-lived, whereas S-R response priming, both when the prime is consciously perceived and when it is not, may emerge only when observers' responses are based on quick-and-dirty processing of the target.

[6] We thank an anonymous reviewer for this suggestion.

Author's note

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2019.01.010.

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