

Emotion

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No Impact of Affective Person Knowledge on Visual Awareness: Evidence From Binocular Rivalry and Continuous Flash Suppression

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Stimuli with intrinsic emotional value, like emotional faces, and stimuli associated with reward and punishment are often prioritized in visual awareness relative to neutral stimuli. Recently, Anderson, Siegel, Bliss-Moreau, and Barrett (2011) demonstrated that simply associating a face with affective knowledge can also influence visual awareness. Using a binocular rivalry task (BR), where a face was shown to one eye and a house to the other, they found that faces paired with negative versus neutral and positive behaviors dominated visual awareness. We were interested in whether faces associated with negative information would also be capable of reaching awareness more quickly in the first place. To test this, we set out to replicate Anderson and colleagues' finding and to examine whether it would extend to breaking continuous flash suppression (b-CFS), a technique where a dynamic mask shown to one eye initially suppresses the stimulus shown to the other eye. Participants completed a learning task followed by BR and b-CFS tasks, in counterbalanced order. Across both tasks, faces associated with negative behaviors were treated no differently from faces associated with neutral or positive behaviors. However, faces associated with any type of behavior were prioritized in awareness over novel faces. These findings indicate that while familiarity influences conscious perception, the influence of affective person knowledge on visual awareness is more circumscribed than previously thought.

Keywords: affect, breaking continuous flash suppression, binocular rivalry, facial recognition, person knowledge

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The world is filled with an exquisite amount of visual detail, but we are only able to take in a very limited amount of this information at a time. The affective or emotional value of a stimulus can help determine whether it gains access to awareness (for a review, see Vuilleumier, 2005; for a recent meta-analysis, see Hedger, Gray, Garner, & Adams, 2016). The prioritization of stimuli in awareness has often been studied using a technique called binocular rivalry (BR). In BR, different images are shown to the two eyes and the images compete for visual awareness, with conscious perception alternating back and forth between the stimuli (for reviews, see Blake & Logothetis, 2002 and Tong, Meng, & Blake, 2006). The stimulus that is consciously perceived is said to be dominant, while the other stimulus is said to be suppressed. Researchers have investigated the influence of emotion on visual awareness by showing an emotional stimulus to one eye and a neutral stimulus to the other and asking participants to report their perception over time. When emotional faces or scenes are shown to one eye and neutral faces or scenes to the other, the emotional

stimuli have often been found to dominate visual awareness, meaning they are perceived for longer periods of time than the neutral stimuli (e.g., Alpers & Pauli, 2006; Bannerman, Milders, De Gelder, & Sahraie, 2008).

One challenge for studies that use stimuli with intrinsic emotional value is that it is difficult to match the emotional and neutral stimuli in terms of low-level visual properties, such as luminance distributions, effective contrast, or spatial frequency content (for a discussion of this problem, see Hedger et al., 2016). Because dominance durations in BR are sensitive to such visual properties, it is possible that the observed differences are due to visual aspects of the stimuli, rather than the emotional meaning. Studies where carefully matched visual stimuli are associated with threat or reward in the form of electric shocks or monetary loss or gain avoid this concern and confirm that emotion can influence access to visual awareness (Alpers, Ruhleder, Walz, Mühlberger, & Pauli, 2005; Balcetis, Dunning, & Granot, 2012; Marx & Einhauser, 2015; Wilbertz, van Slooten, & Sterzer, 2014).

In the real world, affective learning often involves other people. We learn about other people very quickly: Seeing a face paired with a description of a behavior for as little as 2 s is enough for observers to associate the trait implied by the behavior with the face (Todorov & Uleman, 2003). Once observers have learned about a person's past behavior, they integrate that information into judgments of facial appearance, for example judging faces of people who have performed negative behaviors as looking less trustworthy than those who have performed positive behaviors

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(Todorov & Olson, 2008). Moreover, affective knowledge does not simply influence evaluation of the faces associated with behaviors, but also evaluation of faces that are perceptually similar to those faces, suggesting that observers retrieve the learned information without intending to do so (Verosky & Todorov, 2010, 2013). Thus, seeing a face paired with a verbal description of the person's behavior is an indirect, yet powerful form of learning.

Recently, Anderson, Siegel, Bliss-Moreau, and Barrett (2011) investigated whether learning to associate affective knowledge with faces influences the amount of time those faces spend in visual awareness. Participants in their study viewed faces paired with descriptions of negative, neutral, and positive behaviors. Next, participants completed a BR task where a previously learned or novel face was shown to one eye and a house was shown to the other eye. They found that faces previously associated with negative behaviors dominated visual awareness for longer than faces associated with neutral and positive behaviors or novel faces that had not been associated with behaviors.

In BR, increased predominance could reflect differential processing of a stimulus when it is consciously perceived, for example through top-down attention (reviewed by Paffen & Alais, 2011). It is therefore unclear whether increased predominance reflects initial unconscious or later conscious prioritization. A more direct measure of the early, unconscious perceptual processes that lead to awareness in BR consists of recording which stimulus is the first to achieve dominance (cf. Hedger et al., 2016). However, in the study by Anderson et al. (2011) faces associated with negative information did not appear more often as the first percept.

We were interested in whether faces associated with negative information would also be capable of reaching awareness more quickly in the first place. Although Anderson et al. (2011) failed to find evidence for an influence of affective knowledge on the first percept and suppression durations during BR, recently developed psychophysical techniques hold promise for reexamining this question with more sensitive methods. For example, although early studies indicated that only minimal processing occurs under BR suppression, more recent work using these novel techniques suggests more extensive processing than initially expected (reviewed by Gayet, Van der Stigchel, & Paffen, 2014). These recent findings rely on a technique called breaking continuous flash suppression (Jiang, Costello, & He, 2007; Stein, Hebart, & Sterzer, 2011), which is thought to be a variant of BR.

In continuous flash suppression (CFS), a stimulus is presented to one eye and a rapidly changing Mondrian-like pattern to the other eye. The pattern suppresses the other stimulus from awareness more reliably and for longer periods of time than in traditional BR (Tsuchiya & Koch, 2005). In breaking CFS (b-CFS), the contrast of the stimulus is gradually increased until it reaches full contrast and is kept constant until the participant reports awareness of the stimulus (Jiang et al., 2007). In this initial demonstration of b-CFS, Jiang and colleagues found that upright faces reach awareness more quickly than inverted faces. Similarly, they found that Chinese characters and Hebrew words reached awareness more quickly for participants who spoke each of these languages. Subsequent work provides additional support for the finding that familiarity acquired through long-term learning influences how quickly stimuli reach awareness (Geng, Zhang, Li, Tao, & Xu, 2012; Gobbini et al., 2013; Stein, End, & Sterzer, 2014; Stein, Reeder, & Peelen, 2016). For example, Caucasian participants

reported own age and own race faces breaking into awareness more quickly than other race and other age faces, presumably because of greater experience with these categories of faces (Stein et al., 2014). Moving beyond faces, degree of car expertise predicts the size of the inversion effect under b-CFS (Stein, Reeder, & Peelen, 2016).

Emotion also influences how quickly faces break into awareness. Fearful faces break into awareness more quickly than happy faces (Gray, Adams, Hedger, Newton, & Garner, 2013; Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009; Yang, Zald, & Blake, 2007) or neutral faces (Gray et al., 2013; Stein, Seymour, Hebart, & Sterzer, 2014; Yang et al., 2007). Although at first it appears as if degree of threat may predict how quickly faces break into awareness, angry faces break into awareness more slowly than neutral faces (Gray et al., 2013). One interpretation of these effects is that the differences in suppression time for fear versus anger have to do with the different implications of the emotions (Stewart et al., 2012). However, the differences in time to reach awareness can also be explained by low-level visual properties of the different emotional stimuli (Gray et al., 2013; Hedger, Adams, & Garner, 2015; Stein & Sterzer, 2012; also see the discussion in Hedger et al., 2016). For example, Stein and Sterzer (2012) demonstrated that positive schematic faces break into awareness more quickly than negative faces, but that the configuration of the mouth relative to the face contour can account for this difference. As with the BR studies, experiments that manipulate affective knowledge through learning can be used to help rule out low-level visual confounds.

The two studies to date that examine how affective learning influences b-CFS have yielded mixed results: One study found an influence of learning (Gayet, Paffen, Belopolsky, Theeuwes, & Van der Stigchel, 2016), whereas the other did not (Rabovsky, Stein, & Abdel Rahman, 2016). In Gayet and colleagues' study, pairing a colored annulus with electric shock led it to break suppression more quickly than a similar annulus that was not paired with shock. This was the case even though participants' task during the b-CFS portion of the experiment was designed to be orthogonal to the previous learning task. In Rabovsky and colleagues' study, participants learned to associate faces with negative, neutral, and positive biographical information. Learning influenced ratings of the faces, but it did not affect the amount of time it took the faces to reach awareness during b-CFS.

The goal of the current study was to investigate whether Anderson and colleagues' (2011) finding of longer dominance durations for faces associated with negative information in BR would extend to b-CFS. Despite Rabovsky and colleagues' (2016) findings, we were interested in the possibility that faces associated with negative information might gain access to awareness more quickly than faces associated with neutral or positive information. Because a failure to find an influence of affective knowledge could occur for a number of reasons, we decided to limit the range of possibilities by using Anderson and colleagues' study as a starting point for our own. We set out to replicate Anderson and colleagues' findings and then to see whether we would additionally observe an influence of affective knowledge on b-CFS. To increase our chances of reproducing Anderson and colleagues' findings, we used the stimuli from their experiment and we designed our learning and BR tasks to be as similar to theirs as possible.

Participants first learned to associate faces with negative, neutral, or positive behaviors and then they completed the BR and b-CFS tasks (see Figure 1). The order of the BR and b-CFS tasks was counterbalanced across participants. On each trial of the b-CFS task, a face or a house was shown to one eye and a rapidly changing Mondrian-like mask to the other eye. When the stimulus emerged from suppression, participants were asked to report whether it was a face or a house. Although our comparisons of interest were between the different affective knowledge conditions and the novel face condition, the houses were included to keep the b-CFS task as similar to the rivalry task as possible. We hypothesized that the faces associated with negative information as compared to those associated with neutral or positive information or novel faces would be prioritized in visual awareness during both BR and b-CFS. Specifically, we expected that faces associated with negative information would be perceived for longer durations during BR and that they would reach awareness more quickly during b-CFS.

In addition, although the present study was designed to test the effect of affective knowledge on visual awareness, it also allowed us to test whether any kind of face learning, independent of affective valence, would influence awareness in the two tasks. Because the duration of perceptual dominance did not differ between learned and novel faces in the study by Anderson and colleagues (2011), we expected no such general influence of face learning on BR. However, given the findings demonstrating that familiarity acquired through long-term learning influences sup-

pression times in b-CFS, we examined the possibility that short-term learning of faces (in a single experimental session) might also influence access to awareness in b-CFS.

Method

Participants

Over the course of one academic year, as many Oberlin College students were tested as possible, resulting in a total of 70 participants (50 female, 18–23 years, $M = 19.14$ years, $SD = 1.24$). We only tested participants who did not wear glasses and who said that they had normal or corrected-to-normal vision. Participants were naive to the research question. They participated for partial course credit or payment. Informed consent was obtained following a protocol approved by the Oberlin College Institutional Review Board.

One participant did not achieve stable perceptual fusion and thus did not complete the BR and b-CFS tasks. One participant completed only the BR task due to time constraints.

In the BR task, nine observers (13% of the sample) had extremely long dominance durations in many trials, with only one percept dominating the whole 10-s trial. Because these trials were excluded from the analysis (see below), results for these observers would have been computed based only on a small proportion of trials. For the main analysis of the BR task we therefore excluded those nine observers who had less than 20% of valid trials, such that the final sample for the BR task consisted of 60 participants (42 female, 18–23 years, $M = 19.12$ years, $SD = 1.19$). Results for the total sample of 69 participants were similar (see supplemental results).

For the b-CFS task four participants with response accuracies classifying as outliers (lower than the first quartile minus 1.5 interquartile range [IQR]) were removed from the analyses, resulting in a final sample of 64 participants (44 female, 18–23 years, $M = 19.13$ years, $SD = 1.20$). Screening of mean suppression durations yielded no additional outliers (no mean suppression durations lower than the first quartile minus 1.5 IQR or higher than the third quartile plus 1.5 IQR; similarly, no mean suppression durations shorter than mean minus 2.5 SD or longer than mean plus 2.5 SD).

Statistical Power

With the final sample of 60 participants in the BR task we had 80% power for detecting effect sizes of Cohen's $d \geq 0.37$. With the whole sample of 69 participants in the BR task (see supplemental results in the online supplemental material) we had 80% power for detecting effect sizes of Cohen's $d \geq 0.35$. With the final sample of 64 participants in the b-CFS task we had 80% power for detecting effect sizes of Cohen's $d \geq 0.36$. These power calculations are important given that part of the present study consisted of an attempt to replicate the influence of affective knowledge on BR reported by Anderson et al. (2011). In their Study 1, effect sizes for the key comparisons between dominance durations for faces paired with negative information and dominance durations for faces paired with non-negative (neutral, positive) information were $d = 0.28$ (for the comparison with neutral) and $d = 0.32$ (for the comparison with positive), respectively.

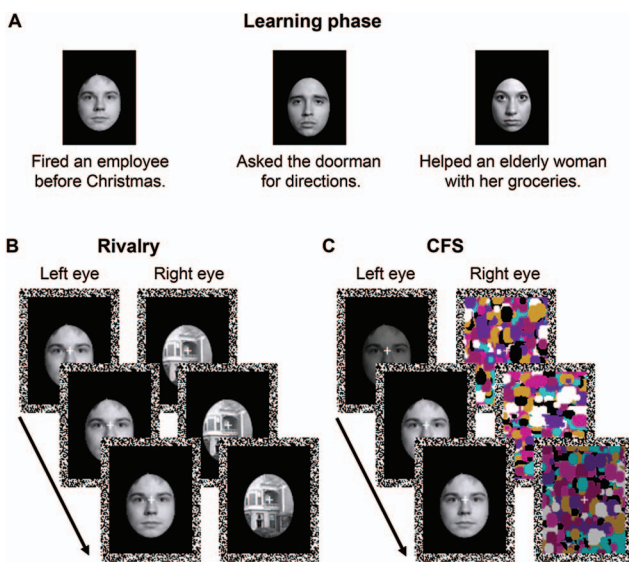


Figure 1. Illustration of the experimental procedure. A: In the learning phase, face photographs were paired with sentences describing socially negative, neutral, or positive behaviors. B: In the binocular rivalry experiment, these face photographs were presented to one eye while a house photograph was presented to the other eye. Participants continuously indicated their percept. C: In the continuous flash suppression (CFS) experiment, a face or a house was presented to one eye while Mondrian-like continuous flash suppression (CFS) masks were flashed at 10 Hz into the other eye. Participants made a speeded face-house discrimination as soon as the initially invisible image emerged from suppression. See the online article for the color version of this figure.

Thus, with the whole BR sample we had 63% and 75% power for detecting the respective effects.¹

Apparatus, Stimuli, and Procedure

Stimuli and instructions were presented on a 24-in LCD screen (1,920 × 1,080 pixels resolution) using Matlab and the Psychtoolbox functions (Brainard, 1997). Participants viewed the screen from a viewing distance of approximately 84 cm, with their heads stabilized by a chin-and-head rest. The screen was black. Stimuli (1.50° × 1.95°) were 40 structurally neutral faces and 40 houses. These were the same luminance- and contrast-matched stimuli used in Anderson et al. (2011, kindly provided by Eric Anderson²). Faces and houses were cropped into oval shapes, meaning that for faces the ears and (most of the) hairstyles were excluded, and for houses the roofs were excluded. In the learning phase, faces were paired with 30 sentences describing social behaviors (10 negative, 10 neutral, and 10 positive behaviors). The sentences were the same sentences used in Study 1 by Anderson and colleagues (the exact sentences are available in their supporting online material).

Learning phase. In the learning phase, participants viewed 30 neutral faces that were paired with a sentence describing a negative social behavior (e.g., “fired an employee before Christmas”), a neutral social behavior (e.g., “asked the instructor for a pencil”), or a positive social behavior (e.g., “gave up seat on the bus to a pregnant lady”). On each trial, one face was presented at the center of the screen and the sentence (in white Arial font) was centered just below the face. Participants were asked to form impressions of the people by imagining them actually performing the behavior described. Each face–sentence pair was shown for 5 s, followed by a 0.3-s intertrial interval. Each face–sentence pair was presented four times, for a total of 120 trials. Trial order was randomized, and the face–valence pairings were counterbalanced across three groups of participants, such that across participants each face was paired with negative, neutral, and positive sentences. There were breaks after 30, 60, and 90 trials.

Face-learning test. After the learning phase, participants were required to explicitly categorize each face as having been associated with a negative, neutral, or positive behavior (as in Anderson et al., 2011, Study 2), using the left, down, and right arrow keys. Faces were presented centrally until response. Each face was presented once, in randomized order. If categorization accuracy was at least 60% correct, participants proceeded to the BR task or to the b-CFS task. If they did not meet this criterion, they cycled through the learning phase and the face-learning test until they reached 60% correct.

BR task. After the face-learning test half of the participants first did the BR task and then the b-CFS task, and for the other half the order was reversed. In the BR task and in the b-CFS task participants viewed the screen dichoptically through a custom-built mirror stereoscope. The mirrors of the stereoscope were adjusted for each observer to promote stable binocular fusion. Two fusion contours (1.80° × 2.25°) consisting of random noise pixels (width 0.15°) were displayed side by side on the screen such that one frame was shown to each eye. A white fixation cross was displayed in the center of each frame.

On each trial of 10 s, a face was shown to one eye and a house to the other eye. The intertrial interval lasted 2.2 s. Participants were asked to fixate on the central cross and to press the left arrow

key when they saw mostly the face, the right arrow key when they saw mostly the house, and the down arrow key when they had a mixed percept. They were instructed to continuously indicate their percept by pressing one of these three keys throughout a trial.

Participants first completed four practice trials with stimulus exemplars that were not used in the experiment proper. Some participants went through the practice trials more than once if they had not fully understood the task yet. In the BR task proper, participants completed 80 trials, in which 40 faces (30 neutral faces previously paired with negative, neutral, or positive sentences, plus 10 novel neutral faces) were presented twice, once to the left eye and once to the right eye. Every face exemplar was paired with one of the 40 house exemplars. Trial order was randomized. There were breaks after 20, 40, and 60 trials.

Breaking continuous flash suppression task. The general setup was similar to the BR task. On every trial of the b-CFS task, a face or a house was gradually introduced to one eye by linearly decreasing its transparency from 100% to 0% over 1.8 s. At the same time, high-contrast Mondrian-like CFS masks flashing at 10 Hz were presented to the other eye. Starting 4 s after trial onset, the transparency of the CFS masks was linearly increased from 0% to 100% over a period of 8 s. Participants were asked to fixate on the central cross and to indicate whether a face (left arrow key) or a house (right arrow key) was emerging from suppression. They were required to respond as quickly and as accurately as possible, pressing the respective key as soon as they were able to discriminate between face and house. This face/house discrimination task differs from the localization and detection tasks most commonly used in b-CFS paradigms. Here, we used this task to keep response requirements between the BR and the b-CFS tasks similar, to maximize chances of replicating the BR findings by Anderson et al. (2011) in the b-CFS task. Because it is likely that the face/house discrimination task requires more visual information than a simple localization or detection task, the suppression times in the current task may be longer as a result. Trials lasted until response or for a maximum of 12 s. There was a 2.1-s intertrial interval.

Participants first completed eight practice trials with stimulus exemplars that were not used in the experiment proper. Some participants went through the practice trials more than once if they had not fully understood the task yet. In the b-CFS task proper there were 160 trials, in which 40 faces (30 neutral faces previously paired with negative, neutral, or positive sentences, plus 10 novel neutral faces) and 40 houses were presented twice, once to the left eye and once to the right eye. Trial order was randomized. There were breaks after 40, 80, and 120 trials.

¹ These power analyses assume two-tailed tests, because we used two-tailed *t* tests to assess differences between faces paired with negative and non-negative information. Assuming one-tailed tests that assess whether faces paired with negative information have longer dominance durations than faces paired with neutral or positive information, we had 74% and 84% power, respectively. Note that neither of these key comparisons would have become significant had the tests been one-tailed (see Results).

² Development of the Interdisciplinary Affective Science Laboratory (IASLab) Face Set was supported by the National Institutes of Health Director’s Pioneer Award (DP1OD003312) to Lisa Feldman Barrett.

Analysis

For the BR task, mean dominance durations were calculated for negative, neutral, positive, and novel faces, as well as for houses. All analyses followed the strategy by Anderson et al. (2011). Thus, percepts at the end of the 10-s trials were excluded as they were artificially shortened. We also computed the percentage of trials for which the face was the first percept and the alternation rates (mean number of percepts per trial), separately for the four conditions. For the b-CFS task, mean suppression times were calculated based on trials with correct responses only. Dependent variables were first analyzed using repeated-measures ANOVAs with the factor face condition (negative, neutral, positive, novel), which was followed up with paired *t* tests comparing the four levels.

In addition, for mean dominance durations from the BR task and for mean suppression times from the b-CFS task we conducted Bayesian analyses using JASP (JASP Team, 2016). Bayes factors (BFs) were calculated to quantify the evidence for the presence or the absence of a main effect of face condition in a Bayesian repeated-measures ANOVA, which was followed up with Bayesian paired *t* tests to compare the four levels, using the JASP default settings (Cauchy prior width 0.707). In assigning categorical labels to BFs, we followed Wetzels and Wagenmakers (2012), who suggest labeling BFs between 1 and 3 “anecdotal evidence,” BFs between 3 and 10 “substantial evidence,” BFs between 10 and 30 “strong evidence,” and BFs between 30 and 100 “very strong evidence.”

Results

Face Learning Test

Participants were required to reach a criterion of 60% correct before proceeding to the BR or to the b-CFS task (following Anderson et al., 2011, Study 2). Of the 60 participants included in the final sample of the BR task, 38 needed only one round of face learning to reach the criterion, 21 needed two rounds, and one participant needed four rounds ($M = 1.37$ rounds, $SD = 0.49$). Of the 64 participants representing the final sample of the b-CFS task, 41 needed only one round of face learning to reach the criterion, 22 needed two rounds, and one participant needed three rounds ($M = 1.38$ rounds, $SD = 0.49$).

For the final sample included in the BR task, mean accuracy in the face-learning test was 77.2% correct ($SD = 9.8$). Performance did not differ significantly between faces associated with negative ($M = 77.0\%$ correct, $SD = 12.8$), neutral ($M = 79.2\%$ correct, $SD = 14.2$), and positive sentences ($M = 75.3\%$ correct, $SD = 14.2$), $F(2, 118) = 1.60$, $p = .206$, $\eta_p^2 = .03$. Similarly, for the final sample included in the b-CFS task (largely overlapping with the BR task sample), mean accuracy in the face-learning test was 77.5% correct ($SD = 9.6$). Performance did not differ significantly between faces associated with negative ($M = 78.1\%$ correct, $SD = 12.3$), neutral ($M = 78.0\%$ correct, $SD = 15.2$), and positive sentences ($M = 76.3\%$ correct, $SD = 13.9$), $F(2, 126) = 0.46$, $p = .632$, $\eta_p^2 = .01$.

BR Task

Mean dominance durations were 2.24 s ($SD = 1.03$) for faces and 1.55 s ($SD = 0.62$) for houses. The mean duration of mixed percepts

was 1.63 s ($SD = 0.93$). Thus, the total mean duration of any percept (faces, houses, or mixed) was 4.58 s ($SD = 1.75$), reflecting the shortening of the effective trial duration by excluding the last percept. The percentage of mixed percepts was 29.9% ($SD = 14.4$). This proportion was somewhat lower than that reported in Anderson et al. (2011; Study 1: 38.4%, Study 2: 46.4%). In the supplemental results in the online supplemental material, we therefore report additional analyses on mixed percepts and from a subset of participants whose proportion of mixed percepts was better matched to that of Anderson and colleagues' study.

To test whether affective knowledge associated with structurally neutral faces would be prioritized for awareness, we assessed whether pairing faces with sentences describing negative, neutral, or positive social behaviors influenced dominance durations during BR. Mean dominance durations were 2.32 s ($SD = 1.14$) for negative faces, 2.27 s ($SD = 1.14$) for neutral faces, 2.34 s ($SD = 1.17$) for positive faces, and 2.02 s ($SD = 0.96$) for novel faces (see Figure 2a). A repeated-measures ANOVA revealed a significant main effect of face condition, $F(3, 177) = 6.04$, $p = .001$, $\eta_p^2 = .09$. Planned follow-up *t* tests showed that this was due to novel faces being perceptually dominant for significantly shorter times than negative, neutral, and positive faces, all $t(59) > 3.12$, all $p < .003$, all $d > 0.40$. There were no significant differences between the other conditions, all $t(59) < 0.95$, all $p > .343$, all $d < 0.12$. Thus, although faces that had been presented previously in the learning phase dominated consciousness for longer than novel faces, there were no differences between affective learning conditions. This result is different from the study by Anderson et al. (2011) who did not find overall shorter dominance durations for novel faces, but longer dominance durations for faces previously paired with negative information. Our results do not replicate this valence-specific effect on conscious perception during BR.

The Bayesian analysis confirmed these conclusions: The Bayesian repeated-measures ANOVA revealed very strong evidence for an effect of face condition on dominance durations (BF = 34.32). However, when novel faces were excluded from the analysis and the factor face condition was reduced to three levels (negative, neutral, positive), the Bayesian ANOVA revealed strong evidence for the absence of an effect of face condition (BF = 12.81). Thus, as in the results from the standard analysis, the effect of face condition on dominance durations was due to novel faces differing from learned faces. This was confirmed by follow-up Bayesian *t* tests yielding strong evidence for the presence of differences in dominance durations between novel and learned faces (all BF > 10.71), and substantial evidence for the absence of differences between negative, neutral, and positive faces (all BF > 4.59).

Finally, consistent with Anderson et al. (2011) there were no significant effects of face condition on the first percept, $F(3, 177) = 2.00$, $p = .115$, $\eta_p^2 = .03$, on face suppression durations (i.e., house dominance durations), $F(3, 177) = 2.16$, $p = .095$, $\eta_p^2 = .04$, or on alternation rates, $F(3, 177) = 1.78$, $p = .153$, $\eta_p^2 = .03$.

Potential order effects. One possible reason why the present results differed from those obtained by Anderson et al. (2011) is that in the present study participants completed not only a BR task but also a b-CFS task. It is thus possible that order effects contributed to the different pattern of results. The order of the BR and b-CFS blocks was counterbalanced across observers. Of the subset of 60 observers included in the previous analyses, 29 first did the BR task, and 31 first did the b-CFS task. To test for potential order

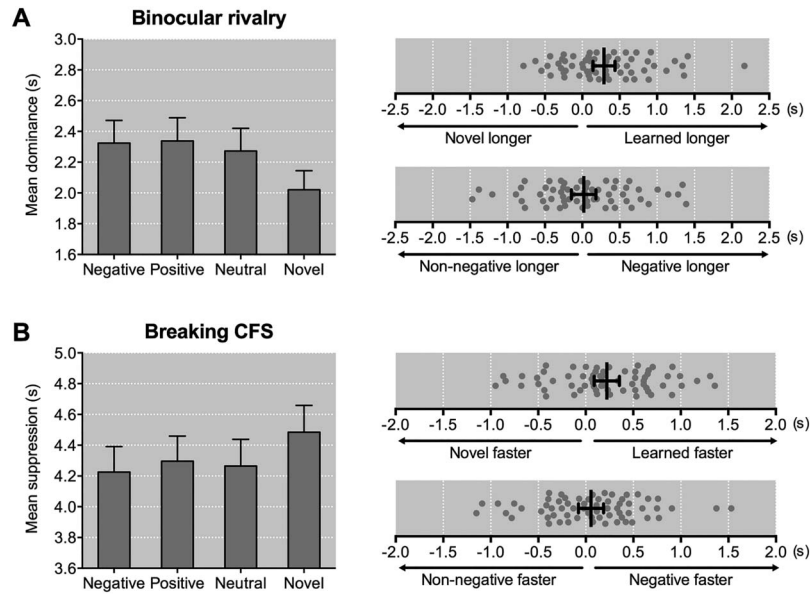


Figure 2. Results from the (A) binocular rivalry (BR) task and from the (B) breaking continuous flash suppression (b-CFS) task. The left bar graph panels show overall mean dominance durations for the BR task and overall mean suppression times for the b-CFS task, separately for the face conditions, together with the between-subjects *SE*. The right panels show difference scores. Every dot represents a participant, the vertical bars represent the mean and the horizontal error bars 95% CIs. For the BR task, the top panel shows the difference between dominance durations of learned faces (averaged across negative, neutral, positive) and novel faces. Positive values thus reflect longer dominance durations for learned faces, while negative values reflect longer dominance durations for novel faces. The bottom panel shows the difference between dominance durations of faces associated with negative behaviors and faces associated with non-negative behaviors (averaged across neutral and positive). Positive values thus reflect longer dominance durations for negative faces, while negative values reflect longer dominance durations for non-negative faces. For the b-CFS task, the top panel shows the difference between suppression times of novel faces and learned faces (averaged across negative, neutral, positive). Positive values thus reflect faster access to awareness for learned faces, while negative values reflect faster access to awareness for novel faces. The bottom panel shows the difference in suppression times of faces associated with negative behaviors and faces associated with non-negative behaviors (averaged across neutral and positive). Positive values thus reflect faster access to awareness for negative faces, while negative values reflect faster access to awareness for non-negative faces. In both the BR task and the b-CFS task there was an advantage for learned over novel faces, whereas learned negative and non-negative faces did not differ significantly.

effects, we repeated the analysis of the mean dominance durations with the within-subject factor face condition (negative, neutral, positive, novel) and the between-subjects factor order (BR first, b-CFS first). This mixed ANOVA revealed a significant main effect of condition $F(3, 174) = 5.98, p = .001, \eta_p^2 = .09$, and a significant main effect of order, $F(1, 58) = 4.53, p = .037, \eta_p^2 = .07$, reflecting longer overall dominance durations for those observers who did b-CFS first ($M = 2.50$ s, $SD = 0.99$) than for those who did BR first ($M = 1.95$ s, $SD = 1.01$), but, importantly, no significant interaction, $F(3, 174) = 1.15, p = .329, \eta_p^2 = .02$ (for additional analyses on potential order effects, see supplemental results in the online supplemental material). Thus, the ordering of the experiments had no significant effect on the influence of face conditions on dominance durations.

Breaking Continuous Flash Suppression Task

Overall response accuracy was 96.8% correct ($SD = 3.0$). Mean suppression times were 4.32 s ($SD = 1.30$) for faces and 5.06 s ($SD = 1.40$) for houses.

Our main research question was whether pairing faces with negative, neutral, or positive social behaviors would influence the time they needed to overcome b-CFS and break into awareness. Mean suppression times were 4.23 s ($SD = 1.33$) for negative faces, 4.26 s ($SD = 1.39$) for neutral faces, 4.30 s ($SD = 1.31$) for positive faces, and 4.49 s ($SD = 1.39$) for novel faces (see Figure 2b). A repeated-measures ANOVA revealed a significant main effect of face condition, $F(3, 189) = 4.29, p = .006, \eta_p^2 = .06$. Planned follow-up *t* tests showed that this reflected longer suppression times for novel faces than for negative, neutral, and positive faces, all $t(63) > 2.27$, all $p < .027$, all $d > 0.28$. There were no significant differences between the other conditions, all $t(63) < 0.92$, all $p > .361$, all $d < 0.12$. Thus, similar to the results from the BR task, there was a general advantage for faces that had previously been presented in the learning phase relative to novel faces. However, as with the BR task there was no evidence that the particular valence associated with faces influenced access to awareness under b-CFS.

An additional repeated-measures ANOVA on the log-transformed suppression times (accounting for the positive skew of

the suppression times) confirmed these findings: The main effect of face condition was significant, $F(3, 189) = 4.77, p = .003, \eta_p^2 = .07$, reflecting longer suppression times for novel faces than for negative, neutral, and positive faces, all $t(63) > 2.52$, all $p < .014$, all $d > 0.31$. Again, there were no significant differences between the other conditions, all $t(63) < 0.66$, all $p > .509$, all $d < 0.09$.

The Bayesian repeated-measures ANOVA on these log-transformed suppression times revealed substantial evidence for an effect of face condition ($BF = 7.15$). However, when excluding novel faces from the analysis, reducing the factor face condition to three levels (negative, neutral, positive), the Bayesian ANOVA revealed strong evidence for the absence of an effect of face condition ($BF = 15.23$). Thus, as in the BR task, the effect of face condition was due to novel faces. This was confirmed by follow-up Bayesian t tests yielding (a) strong evidence for differences in suppression times between novel faces and neutral/negative faces ($BFs > 11.42$); (b) anecdotal evidence for differences between novel and positive faces ($BF = 2.57$); and, most importantly, (c) substantial evidence for the *absence* of differences between negative, neutral, and positive faces (all $BF > 5.91$).

Potential order effects. Thirty-three of the 64 observers included in the analyses of the b-CFS task first did the b-CFS block and 31 observers first did the BR block. Repeating the analysis of mean suppression times with the within-subject factor face condition (negative, neutral, positive, novel) and the between-subjects factor order (b-CFS first, BR first) revealed only a significant main effect of condition $F(3, 186) = 4.27, p = .006, \eta_p^2 = .06$, but no significant main effect of order, $F(1, 62) = 0.18, p = .674, \eta_p^2 < .01$, and no significant interaction, $F(3, 186) = 0.30, p = .825, \eta_p^2 < .01$, meaning that experimental order did not influence the effect of face condition on suppression times.

Discussion

The current experiment investigated the hypothesis that faces associated with negative behaviors are prioritized in visual awareness, but this was not found to be the case. In two tasks measuring different aspects of access to and dominance in visual awareness, faces associated with negative behaviors were not prioritized over faces associated with neutral or positive behaviors. However, even though the type of knowledge associated with a face did not change visual awareness of the face, faces associated with any type of behavior were prioritized over novel faces. In the BR task, where participants viewed a face with one eye and a house with the other, faces associated with behaviors dominated visual awareness as compared to novel faces. In the b-CFS task, where participants reported whether a stimulus emerging from suppression was a face or a house, faces associated with behaviors reached awareness more quickly than novel faces.

Our failure to find an influence of the type of affective knowledge associated with faces in the BR task came as a surprise. Anderson and colleagues (2011) previously used BR to demonstrate that faces associated with negative behaviors dominate visual awareness longer than faces associated with neutral or positive behaviors or novel faces. The goal of the present experiments was to investigate whether this finding would extend to b-CFS and we simply included the BR task in the current experiment to help us interpret a possible null effect. However, despite designing our BR task to be as similar to Anderson and colleagues' task as

possible, we did not reproduce their results. Instead, we found a different pattern of results, where faces associated with any type of information were prioritized over novel faces. Interestingly, this pattern was consistent across both the BR and b-CFS tasks.

The failure to find an influence of the type of affective knowledge associated with a face is unlikely to be due to a failure to learn the relevant associations with the faces. Like participants in Anderson and colleagues' (2011) second study, participants in our study were required to learn the associations to a threshold of 60% correct before continuing on to the BR and b-CFS portions of the experiment. Moreover, the order in which participants completed the two visual awareness tasks did not influence the results, suggesting that the lack of a difference between the affective knowledge conditions was not due to a weakening of the learned associations over the course of the second task.

Instead, the differences between our study and Anderson and colleagues' (2011) study may be due to contextual factors that decreased the perceived importance of the knowledge associated with the faces. For example, although we mentioned to participants that they would see faces from the learning task in the subsequent tasks, we carefully avoided any further description of the tasks as related. Perhaps subtle clues that the learning continued to be important or even an explicit description of the tasks as related would have led to a greater carryover of affective knowledge. Alternatively, it is also possible that subtle procedural differences could account for the differences between studies. Although we kept our BR task as similar to Anderson and colleagues' task as possible, one place where the studies might have differed is in how participants were instructed to report percepts. Specifically, to reduce the number of mixed percepts, we asked participants to indicate when they perceived an image that was mostly a face or a house, instead of entirely a face or house. As the proportion of mixed percepts in the present study was indeed lower than in Anderson and colleagues' experiments, it is possible that participants in our study adopted a more liberal criterion for reporting faces and houses. Although it is not clear what accounted for the difference between studies, our failure to find an influence of the type of knowledge associated with faces does suggest that the visual prioritization of faces associated with negative behaviors may be more circumscribed than previously thought.

Not only did the type of affective knowledge associated with faces fail to influence dominance durations in the BR task, it also failed to influence how quickly faces reached awareness in the b-CFS task. This finding fits with Rabovsky and colleagues' (2016) failure to find an effect of the type of affective biographical knowledge associated with faces on b-CFS. However, it stands in contrast to Gayet and colleagues' (2016) finding that colored annuli associated with shocks break suppression more readily than annuli that are not associated with shocks. Differences in the stimuli and learning are likely to account for the differences between studies.

Participants in Gayet and colleagues' (2016) study versus our study and Rabovsky and colleagues' (2016) study learned about colored annuli or faces, respectively. While the colored annuli were paired with a direct negative outcome for participants, the faces were not. Perhaps more importantly, learning to associate annuli with electric shock does not require semantic processing, but learning to associate faces with descriptions of behaviors does, at least initially. Although a handful of b-CFS studies seem to find semantic processing under

suppression. Gayet and colleagues (2014) argued that many of these studies lack proper controls and that the accumulated evidence for such effects is not convincing. Therefore, it is possible to interpret the lack of influence of type of affective knowledge in both our study and Rabovsky and colleagues' study as a failure to find semantic processing without awareness.

Although our findings differ from those of Anderson and colleagues (2011), they are broadly consistent with the conclusions from a recent meta-analysis on preconscious processing of threatening and negative visual information. In this study, Hedger and colleagues (2016) found that neutral stimuli, including faces, that had been aversively conditioned did not have a statistically significant influence on BR. Robust and consistent influences on both BR and b-CFS were only obtained for fearful faces, while results for other emotional stimuli, such as affective pictures or angry faces, were highly variable or not statistically significant. Together with the present study, this suggests that the "standard hypothesis" (cf. Hedger et al., 2016), according to which threatening and negative visual information is prioritized at early, preconscious processing levels, may not be as wide-ranging as previously thought. Some preconscious processing biases may rather be limited to certain stimuli, such as fearful faces. However, rather than reflecting genuine emotional effects, this fear advantage may be better explained by low-level stimulus properties (Gray et al., 2013; Hedger et al., 2015; Stein, End, & Sterzer, 2014).

A unique aspect of our b-CFS task was the comparison of newly learned faces to novel faces. By including novel faces in our design, we were able to demonstrate a main effect of learning, where faces associated with any type of information reached awareness more quickly than novel faces. Similarly, learned faces dominated visual awareness longer than novel faces in the BR task. One caveat to this finding is that while we counterbalanced the faces associated with each type of behavior across participants, we used the same set of novel faces for all participants. Thus, the differences between learned and novel faces in the b-CFS task could, in principle, be due to the physical differences between the groups of faces (for additional linear-mixed effects analyses testing whether these learning effects were robust across face exemplars, see supplemental results).

Although previous b-CFS studies have demonstrated that familiarity influences how readily stimuli reach awareness, the learning in these studies took place over relatively long periods of time (Geng et al., 2012; Gobbini et al., 2013; Stein, End, & Sterzer, 2014; Stein, Reeder, & Peelen, 2016). For example, participants in Gobbini and colleagues' study viewed photographs of personally familiar others whom they had known for at least a year. In contrast, the learning in the current study took place during a single laboratory session. It is unclear whether learning over such a short period of time affects perceptual mechanisms in similar ways to long-term learning, and whether such learning is supported by familiarity. There is, however, evidence that people can encode and retain many details about a large number of stimuli even when having seen these stimuli only once and for a brief amount of time (Brady, Konkle, Alvarez, & Oliva, 2008). It is also possible that the detection of learned faces, compared to novel faces, involves brain areas beyond visual cortex that support recognition of familiar individuals (Gobbini & Haxby, 2006). This distributed neural network involved in person knowledge may be activated without

awareness (Gobbini et al., 2013) and thus lower the threshold to conscious awareness for familiar faces.

Because all of the learned faces in the current study were associated with (negative, neutral, or positive) behaviors in the learning phase, it is possible that either the mere perceptual experience with the faces (i.e., mere exposure) or the semantic information associated with them led them to break into awareness more quickly. However, both the ongoing debate about whether semantic processing can occur without awareness and the fact that the familiar stimuli in previous studies are not all associated with detailed semantic knowledge suggest that perceptual experience may be the important factor. If simple perceptual experience is responsible for the difference between learned and novel faces, this raises a set of additional questions about what types of perceptual experience are most effective and how this experience generalizes to novel stimuli. For example, do stimuli need to be learned in some (affective) context, or is mere exposure sufficient for perceptual prioritization? Would there be a learning effect with even less exposure to the learned faces? Does prioritization reflect a feeling of familiarity or actual recollection? How long after learning does prioritization persist? Finally, does the learning effect generalize to novel views of a face?

In summary, we found that faces associated with negative behaviors were not prioritized in visual awareness relative to faces associated with neutral or positive behaviors. However, faces associated with any type of information were prioritized over novel faces. Although we found the same pattern of results across both the BR and b-CFS tasks, the BR results were more surprising because Anderson and colleagues (2011) had previously found that faces associated with negative behaviors dominate visual awareness during BR. Our results show that the influence of negative affective knowledge associated with faces is more limited than previously thought. This is consistent with the more general notion of limited semantic, high-level effects on access to awareness and conscious perception (Gayet et al., 2014; Stein, Siebold, & van Zoest, 2016). Given that there is evidence that fear conditioning can influence access to awareness (Gayet et al., 2016), one important challenge for future studies will be to determine the extent and boundary conditions of learning effects on visual awareness.

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