Psychonomic Bulletin & Review
2007, 14 (5), 908-912

A negative compatibility effect in priming of emotional faces

Jennifer D. Bennett
University of British Columbia, Vancouver, British Columbia, Canada

Alejandro Lleras
University of Illinois, Urbana-Champaign, Urbana, Illinois

Chris Oriet
University of Regina, Regina, Saskatchewan, Canada

and

James T. Enns
University of British Columbia, Vancouver, British Columbia, Canada

The negative compatibility effect (NCE) is the surprising result that low-visibility prime arrows facilitate responses to opposite-direction target arrows. Here we compare the priming obtained with simple arrows to the priming of emotions when categorizing human faces, which represents a more naturalistic set of stimuli and for which there are no preexisting response biases. When inverted faces with neutral expressions were presented alongside emotional prime and target faces, only strong positive priming occurred. However, when the neutral faces were made to resemble the target faces in geometry (upright orientation), time (flashing briefly), and space (appearing in the same location), positive priming gradually weakened and became negative priming. Implications for theories of the NCE are discussed.

Identifying an image for the second time is often faster and more accurate than the first time. Yet prior experience can also be detrimental, as in the negative compatibility effect (NCE; Eimer & Schlaghecken, 1998). In this case, a double-headed arrow (prime) is presented briefly, followed by a pattern (mask) that reduces prime visibility to near-chance levels. A clearly visible double-headed arrow (target) is then presented, with participants making a speeded response to its direction. This prime–mask–target sequence leads to the most rapid responses when the direction of the target is opposite that of the prime.

A current debate concerns whether negative priming points to mechanisms that are distinct from those involved in positive priming. Theoretical positions range from claims that subliminal primes result in the inhibition of a specific motor response (Eimer & Schlaghecken, 1998; Schlaghecken & Eimer, 2006), or even a more general response inhibition (Klapp, 2005; Klapp & Hinkley, 2002; Praamstra & Seiss, 2005), to the claim that there is no need for inhibitory mechanisms at all (Lleras & Enns, 2004, 2005, 2006; Verleger, Jaśkowski, Aydemir, van der Lubbe, & Groen, 2004), to those seeking multimechanism accounts (Jaśkowski & Przekoracka-Krawczyk, 2005; Klapp, 2005; Schlaghecken & Eimer, 2006). Here we do not resolve this debate but report new evidence of interest to all these perspectives.

One point of agreement in the debate is that if theories of the NCE are useful for understanding priming more generally, they should hold when displays are more naturalistic and when they do not involve the overlearned responses or involuntary orienting effects associated with arrows (Ristic & Kingstone, 2006; Sumner, 2007). Here we directly compare the pattern of results from a typical NCE experiment involving arrows (Experiment 1) with those from a new test of the NCE involving the categorization of emotions in human faces (Experiment 2). We chose the faces task because (1) emotions are conveyed in a configuration of features, implying that no simple feature is responsible for priming, (2) categorizing expressions across different faces means that participants must extract certain signals (i.e., emotion) while ignoring others (i.e., identity, gender, race), and (3) responding to emotions with arbitrary keypresses eliminates all ready-made response mappings.

EXPERIMENT 1
Arrow Priming Is Influenced by Target–Mask Similarity

The three conditions are illustrated in Figure 1A. For static flankers, a brief prime arrow was followed by a target arrow. Two other patterns flanked the center and were visible

J. T. Enns, jenns@psych.ubc.ca

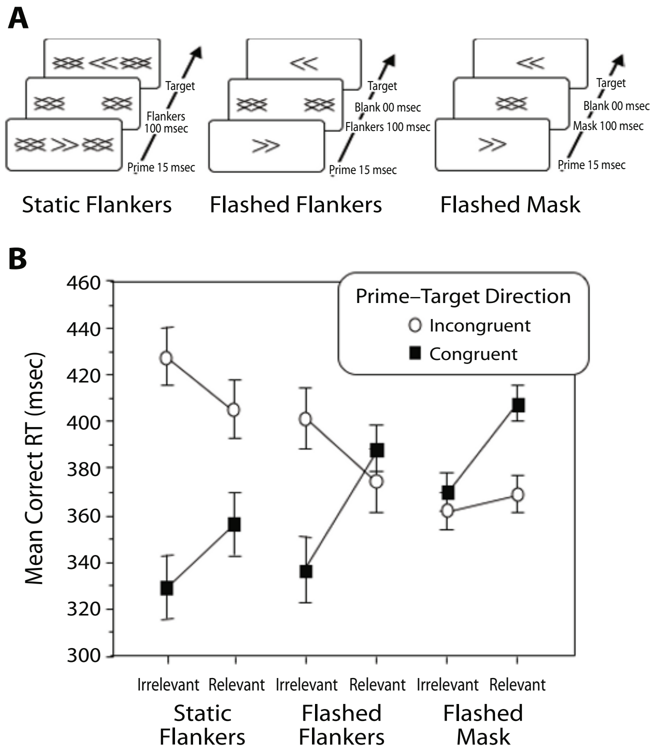

Figure 1. (A) Example display sequences in Experiment 1. The flankers and masks consisted of either relevant features (two superimposed double-headed arrows, as shown) or irrelevant features (only vertical and horizontal lines, not shown). (B) Mean correct RT in Experiment 1. *Congruent* refers to the same arrow direction in prime and target; *incongruent* to opposite arrow directions in prime and target. Error bar represents one standard error of the mean (*SE*).

throughout the display sequence. The features of these flanking patterns varied in their similarity to the target: Relevant flankers were two superimposed double-headed arrows, and irrelevant flankers had the same number of vertical and horizontal lines forming a square grid. Differences in priming between relevant and irrelevant flankers could thus be attributed to geometric similarity between flankers and targets.

For flashed flankers, the same flanking patterns were flashed only briefly following the prime, thereby resembling more closely the target arrow in its temporal properties. Yet these flankers still left the prime arrow completely visible, as shown by Jaśkowski (2007). Differences in priming between static and flashed flankers can thus be attributed to increased temporal similarity of the flankers to the target.

Flashed mask is a typical NCE sequence with three images in the same location and 100 msec or more elapsing between prime and target (Klapp & Hinkley, 2002). Here we compared priming with flashed flankers and masks in order to measure the influence of increased spatial similarity between mask and target.

Method

Participants. Thirty-five undergraduates at the University of British Columbia participated for extra credit in psychology courses. Ten were tested in the static flanker and flashed flanker conditions; 15, in the flashed mask condition. All were naive to the purpose and all reported vision corrected to 20/20.

Apparatus. Displays were presented on a 17-in. eMac computer (screen resolution 800 × 600 pixels, 67 Hz, 256 levels of gray). Each arrow spanned 0.5 degrees of visual angle, and the spatial gap between items in the flanker conditions was 0.1 degrees. The layout and duration of each display are shown in Figure 1A. Each prime, mask, and target stimulus occurred randomly and equally often. Half of the trials were incongruent (different arrow direction for prime and target) and half were congruent (same arrow direction in prime and target). Participants indicated the direction of the target arrow by pressing "z" for left and "/" (slash) for right. Response feedback was given by a plus (correct), minus (incorrect), or circle (no response) for 1.34 sec, which also served as the fixation point for the next trial. A message after each block warned participants to slow down if errors exceeded 5%.

Procedure. Participants in each condition completed 400 trials (8 blocks of 50 trials) of target discrimination. Participants in the flashed flanker and flashed mask conditions also performed 120 trials (3 blocks of 40 trials) of a prime discrimination task. Accuracy for this task was greater than 98% for both relevant and irrelevant flashed flankers. Accuracy was 80% for the irrelevant flashed mask and 44% for the relevant flashed mask, a significant difference [$t(14) = 19.91, p < .001$].

Results

Target arrow discrimination. Participants had a mean accuracy above 95% in all three conditions. Mean correct response time (RT) is shown in Figure 1B. Two findings are noteworthy. First, as the condition changed from static flankers to flashed flankers to masks, RTs on incongruent trials decreased whereas RTs on congruent trials increased. Second, the RT difference between incongruent and congruent trials (the priming effect) was more strongly positive for irrelevant than for relevant flankers/masks. What began as large positive priming for static irrelevant flankers was transformed into negative priming as the flankers/masks increased in temporal and spatial similarity to the target.

These findings were supported by an ANOVA (all p values are Greenhouse–Geisser corrected). The interaction of congruence × condition [$F(2,32) = 25.98, p < .001, MS_e = 1,089.49$] indicated that priming was generally positive for static flankers, less positive for flashed flankers, and negative for flashed masks. RTs on incongruent trials decreased significantly ($p < .05$) with each step from static flankers to flashed masks [$F(2,32) = 6.16, p < .02, MS_e = 2,511.15$], and RTs on congruent trials increased significantly with each step between conditions [$F(2,32) = 5.24, p < .02, MS_e = 2,486.18$]. The interaction of congruence × relevance [$F(1,32) = 82.79, p < .001, MS_e = 282.23$] indicated that priming was more strongly positive for irrelevant than for relevant flanker/masks. The three-way interaction of congruence × relevance × condition [$F(2,32) = 6.06, p < .01, MS_e = 282.23$] reflected that the shape of the congruence × relevance interaction differed somewhat in each of the three conditions (e.g., incongruent RTs did not decline from irrelevant to relevant masks in the flashed mask condition like it did in the other two conditions).

We tested whether priming was more strongly positive for irrelevant than for relevant flankers/masks in each condition with a simple effects test focused on the congruence × relevance interaction: static flankers [$F(1,32) = 29.91$], flashed flankers ($F = 55.18$), and flashed masks ($F = 11.36$) (all p values $< .01$). Given the baseline differences in incongruent versus congruent RTs in each condition, this meant that relevant features reduced the magnitude of positive priming for static flankers, transformed positive priming to negative priming for flashed flankers, and increased the magnitude of negative priming for flashed masks.

EXPERIMENT 2
Priming of Facial Expression Is Influenced by the Same Factors

Face priming was tested in the same way, with a few important exceptions. First, 16 different faces were used as targets: half posing an angry expression and half a happy one. Second, flankers and masks consisted of 8 different faces posing neutral expressions, in order to create unbiased images akin to the superimposed double-headed arrows in Experiment 1. Half of these were shown upright—relevant, but unbiased with regard to emotion—and half inverted—irrelevant, since emotion is difficult to process in inverted faces (Murray, Yong, & Rhodes, 2000). Third, display timing differed slightly because of screen requirements for high-resolution images.

Method

Participants. Forty-five undergraduates at the University of British Columbia participated for extra credit in psychology courses.

Materials and Procedure. Images were selected from the JACFEE set (Matsumoto & Ekman, 1988) and presented with screen resolution 1,024 × 768 pixels, 89 Hz, 256 levels of gray: 245 pixels per side (approximately 7.5 × 7.5 cm) on an intermediate gray background (50% intensity). The 16 images used as primes and targets included 2 emotions (angry, happy) × 2 races (Asian, Caucasian) × 2 sexes (female, male) × 2 exemplars (Person 1, Person 2). The 8 neutral-emotion faces used as flankers or masks consisted of 2 races (Asian, Caucasian) × 2 sexes (female, male) × 2 orientations (upright, inverted). Each prime, mask, and target stimulus occurred randomly and equally often. Half of the trials were incongruent (different emotions in prime and target) and half were congruent (same emotion in prime and target). Timing of displays is indicated in Figure 2A, with slight variations from Experiment 1.

The 45 participants (15 per condition) classified the emotion of the target face as rapidly as possible by pressing “z” for angry and “/” for happy. After completing 10 practice trials, participants were tested on 540 trials (six blocks of 90 trials). Participants in the flashed flanker and flashed mask conditions then completed 360 trials of a prime categorization task (four blocks of 90 trials). Accuracy in the flashed flanker condition was greater than 93% for both upright and inverted faces. Accuracy in the flashed mask condition was significantly lower [mean = 58%; $F(1,28) = 369.71$, $p < .001$, $MS_e = 0.011$], with 59% for inverted masks and 57% for upright masks, a nonsignificant difference [$F(1,14) = 2.18$, $p > .17$].

Results

Participants were very accurate in target face categorization (static flankers = 98.2%, flashed flankers = 97.6%, flashed mask = 97.9%). Mean correct RT is shown in Figure 2B. These findings are very similar to those for arrows: What began as large positive priming for inverted static flankers was diminished and became negative priming as mask–target similarity increased temporally (static to flashed flankers), spatially (flashed flankers to flashed masks), and geometrically (inverted to upright flankers/masks).

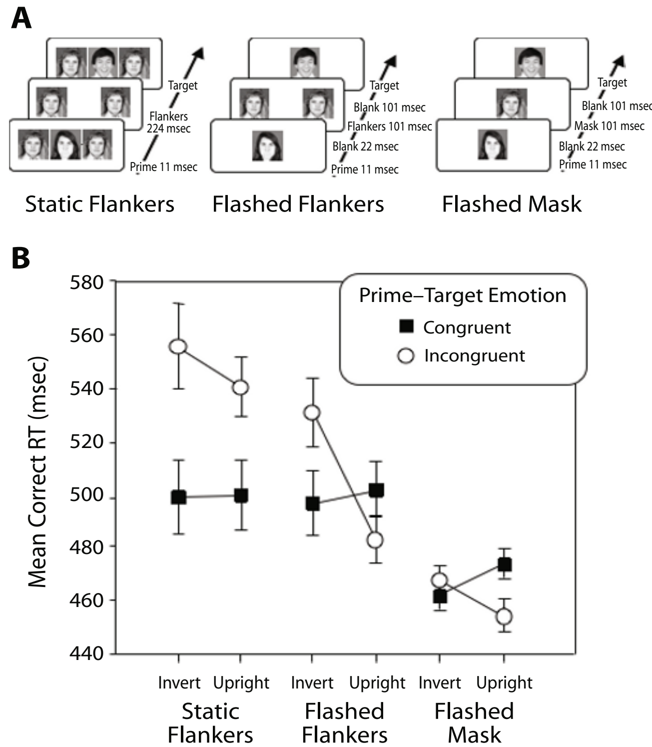

Figure 2. (A) Example display sequences in Experiment 2. The flankers and masks were either upright (as shown) or inverted (not shown). (B) Mean correct RTs in Experiment 2. *Congruent* refers to the same emotion in prime and target; *incongruent* to different emotions in prime and target. Error bars represent one standard error of the mean (*SE*).

This interpretation was supported by ANOVA. The interaction of congruence × condition [$F(2,42) = 16.87$, $p < .001$, $MS_e = 734.61$] indicated that priming was generally positive for static flankers, less positive for flashed flankers, and negative for flashed masks. RTs on incongruent trials decreased ($p < .05$) at each step between conditions [$F(2,42) = 4.72$, $p < .02$, $MS_e = 734.61$, $MS_e = 11{,}921.28$], whereas RTs on congruent trials did not differ significantly with condition [$F(2,42) < 1$, $MS_e = 12{,}777.59$]. The interaction of congruence × relevance [$F(1,42) = 15.97$, $p < .001$, $MS_e = 680.01$] indicated that priming was more strongly positive for inverted than upright flanker/masks. The three-way interaction of congruence × relevance × condition was not significant [$F(2,42) = 1.94$, $MS_e = 680.01$]. Simple effects tests examining the interaction of congruence × flanker/mask orientation in each condition indicated it was significant in the flashed flankers [$F(1,42) = 9.76$, $p < .01$] and the flashed masks ($F = 6.70$, $p < .03$), but not in the static flankers ($F = 1.51$, $p > .20$).

DISCUSSION

This study shows that the NCE, previously studied using simple arrows and habitual responses, also occurs when categorizing emotions in human faces using arbitrary keypresses. Moreover, the factors that determine the strength and direction of priming apply both to arrows and faces. In both cases, increasing the similarity between an intervening mask and the target reduces the positive priming that is otherwise observed. One of the unexpected results was that flashing flankers or a mask between the prime and target facilitates (i.e., speeds) the target task relative to static flankers, especially for targets that are incongruent with the preceding prime. In what follows, we will briefly point to some implications of these findings for two classes of theory already in the NCE debate and for one theory not yet in the fray.

Motor Inhibition Theories

The account originally proposed by Eimer & Schlaghecken (1998) claimed the NCE was a behavioral consequence of a motor mechanism that quickly activates in response to sensory evidence but then self-inhibits when the activation is not sustained (i.e., when the prime is masked), allowing the participant to maintain volitional control over their actions (Schlaghecken & Eimer, 2006). A closely related account proposes reciprocal inhibition between competing responses (Klapp, 2005; Klapp & Hinkley, 2002; Praamstra & Seiss, 2005). It is difficult to devise tests to distinguish between these two theories and so here we consider them together.

One aspect of the present data favoring a motor component is that priming with arrows (both positive and negative) was about twice the magnitude of priming with faces. This is consistent with larger priming being associated with stronger preexisting response mappings. But other aspects of the data challenge these theories. For instance, to account for the shift from positive to negative priming in faces, "motor activation" must be defined broadly enough to include rather abstract, categorical information mapped to arbitrary responses. This would not require a large modification, as the direct parameter specification theory (Neumann, 1990) for visually guided actions already does this.

A more difficult finding for these theories is that an NCE occurred with flashed flankers, where the prime was perfectly visible. These theories also do not explain why only upright face flankers/masks resulted in an NCE, especially when the inverted faces were equally effective in reducing prime visibility. Finally, the finding that flashing flankers and masks tended to speed rather than slow RT to the target, especially when their features resembled the target, does not easily fit the idea of an inhibitory mechanism. These considerations may limit motor inhibition to a restricted set of subliminal priming conditions, leaving the remaining findings for other theories, a position advocated by Klapp (2005) and Schlaghecken and Eimer (2006).

Object Updating

An alternative to motor theories denies the importance of inhibition and subliminal priming (Lleras & Enns, 2004; Verleger et al., 2004). If one begins with the assumption that vision is biased to interpret a rapid sequence as an object evolving over time (Lleras & Enns, 2004), then an important factor in predicting the direction of priming is the similarity of the mask and the target. A mask containing features relevant to the target task (i.e., evidence for a right or left arrow, or an angry or happy expression) leads to updating of the prime representation with the "new" features. Critically, the NCE occurs in this view not because of inhibition induced by the prime, but because of more recent activation from the newest features in the mask.

Consider the NCE for faces in Experiment 2. The prime face first activates a representation associated with its emotion. When the mask appears, this emerging representation is updated, and so an upright mask with a neutral expression will activate a response opposite to the initial prime face, just as double-headed arrows bias a response opposite in direction to the earlier directional prime arrow. This occurs because the new, updated features of the mask resemble the opposite target most closely. A similar effect has been reported in studies of face adaptation (Jiang, Blanz, & O'Toole, 2006).

The present results are consistent with this theory, provided one extends the concept of mask–target similarity beyond its original focus on the mask's geometric features (Lleras & Enns, 2004). In the present study, positive priming for congruent trials was systematically reduced by increases in geometrical, temporal, and spatial similarity. This theory places no special emphasis on the point at which positive priming crosses over to become negative priming, but interprets all priming as the net sum of multiple factors (Lingnau & Vorberg, 2005).

Object updating also has no difficulty with the finding that negative priming can occur with both low and high visibility primes. This is because object updating occurs very early in visual processing; well before conscious access to these objects is possible (Enns & Di Lollo, 2001; Lleras & Enns, 2006). As such, these processes are as relevant to responses made to objects before conscious awareness is possible, as they are for objects that are consciously perceived. It therefore seems a moot question to ask whether the stimuli that gave rise to priming in this study also eventually resulted in conscious percepts. Conscious awareness of the display sequence is something that occurs after the responses we are measuring here are complete and thus is unable to influence the results.

These results also go beyond strictly object updating (Lleras & Enns, 2004, 2005, 2006). First, they show that even static flankers not in the same location as the prime have an influence on priming. This seems more like a simple failure of spatial attention than a by-product of object updating. The influence of flashed flankers, on the other hand, can be understood as a by-product of a "splitting motion" percept that sometimes occurs for moving objects (Mitroff, Scholl, & Wynn, 2004). Second, the finding that a categorization task follows the same rules as simple discrimination suggests that priming is indexing mental processes at many levels, possibly including responses, visual features, objects, scenes, and even scene classes. This is an aspect of priming that was not anticipated by the original description of object updating theory and so will need further development.

Source Confusion and Discounting

Another theoretical alternative comes from the ROUSE (responding optimally with unknown sources of evidence) model, originally developed for the masked priming of words (Huber, Shiffrin, Lyle, & Ruys, 2001). This theory claims that priming occurs when task-relevant features are activated, but only if that activation cannot be attributed to a perceptual event distinct from the target. Two factors are critical: (1) source confusion, in which prime and target features become confused into one percept, and (2) discounting, in which activation is reduced to the extent that a distinct prime event can be linked to the activation. Source confusion is increased with effective masking of the prime whereas discounting is increased when the prime is extended in duration or explicitly attended. With sufficient discounting, even negative priming can occur.

ROUSE could be applied to the NCE by focusing on how the intervening visible mask influences source confusion and discounting. When the mask is effective in reducing prime visibility, source confusion should be high. At the same time, if the mask resembles the target and yet is distinct from it, discounting should be high (Weidemann, Huber, & Shiffrin, 2005). These are the conditions that lead to negative priming in the ROUSE model and also to the NCE (e.g., flashed masks with relevant features). At the other extreme, when a prime activates a response and the mask does not resemble the target, source confusion is high and discounting is low. These are the conditions that lead to positive priming in the ROUSE model and in the present study (e.g., static flankers with irrelevant features). Future tests should examine whether the roles of the prime and the mask can really be disentangled in this way.

In conclusion, the similar pattern of results obtained with simple arrows and more naturalistic faces shows that the NCE is not limited to a small set of stimuli with strong response mappings; these results apply to diverse perceptual stimuli and tasks. Further, our demonstration of the NCE with both subliminal and highly visible primes demonstrates that the NCE is not dependent on reduced prime visibility. Future theory development should aim to encompass priming over the full range of conditions and levels of processing that are at play in the NCE.

AUTHOR NOTE

This research was supported by a Discovery Grant to J.T.E. and an Undergraduate Student Research Award to J.D.B., both from the Natural Science and Engineering Research Council of Canada. Correspondence concerning this article should be addressed to J. T. Enns, Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, BC, V6T 1Z4 Canada (e-mail: jenns@psych.ubc.ca).

REFERENCES

Eimer, M., & Schlaghecken, F. (1998). Effects of masked stimuli on motor activation: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception & Performance*, **24**, 1737-1747.

Enns, J. T., & Di Lollo, V. (2001). Origins of substitution: Reply to Bachmann. *Trends in Cognitive Sciences*, **5**, 54.

Huber, D. E., Shiffrin, R. M., Lyle, K. B., & Ruys, K. I. (2001). Perception and preference in short-term word priming. *Psychological Review,* **108**, 149-182.

Jaśkowski, P. (2007). The effect of nonmasking distractors on the priming of motor events. *Journal of Experimental Psychology: Human Perception & Performance*, **33**, 456-468.

Jaśkowski, P., & Przekoracka-Krawczyk, A. (2005). On the role of mask structure in subliminal priming. *Acta Neurobiologiae Experimentalis*, **65**, 409-417.

Jiang, F., Blanz, V., & O'Toole, A. J. (2006). Probing the visual representation of faces with adaptation: A view from the other side of the mean. *Psychological Science*, **17**, 493-500.

Klapp, S. T. (2005). Two versions of the negative compatibility effect: A reply to Lleras and Enns (2004). *Journal of Experimental Psychology: General*, **134**, 431-435.

Klapp, S. T., & Hinkley, L. B. (2002). The negative compatibility effect: Unconscious inhibition influences reaction time and response selection. *Journal of Experimental Psychology: General*, **131**, 255-269.

Lingnau, A., & Vorberg, D. (2005). The time course of response inhibition in masked priming. *Perception & Psychophysics*, **67**, 545-557.

Lleras, A., & Enns, J. T. (2004). Negative compatibility or object updating? A cautionary tale of mask-dependent priming. *Journal of Experimental Psychology: General*, **133**, 475-493.

Lleras, A., & Enns, J. T. (2005). Updating a cautionary tale of masked priming: A reply to Klapp (2005). *Journal of Experimental Psychology: General*, **134**, 436-440.

Lleras, A., & Enns, J. T. (2006). How much like a target can a mask be? Geometric, spatial, and temporal similarity in priming. A reply to Schlaghecken and Eimer (2006). *Journal of Experimental Psychology: General*, **135**, 495-500.

Matsumoto, D., & Ekman, P. (1988). Japanese and Caucasian facial expressions of emotion (JACFEE) [Slides]. San Francisco: San Francisco State University.

Mitroff, S., Scholl, B., & Wynn, K. (2004). Divide and conquer: How object files adapt when a persisting object splits into two. *Psychological Science*, **15**, 420-425.

Murray, J. E., Yong, E., & Rhodes, G. (2000). Revisiting the perception of upside-down faces. *Psychological Science*, **6**, 492-496.

Neumann, O. (1990). Direct parameter specification and the concept of perception. *Psychological Research*, **52**, 207-215.

Praamstra, P., & Seiss, E. (2005). The neurophysiology of response competition: Motor cortex activation and inhibition following subliminal response priming. *Journal of Cognitive Neuroscience*, **17**, 483-493.

Ristic, J., & Kingstone, A. (2006). Attention to arrows: Pointing to a new direction. *Quarterly Journal of Experimental Psychology*, **59**, 1921-1930.

Schlaghecken, F., & Eimer, M. (2006). Active masks and active inhibition: A comment on Lleras and Enns (2004) and on Verleger, Jaśkowski, Aydemir, van der Lubbe, and Groen (2004). *Journal of Experimental Psychology: General*, **135**, 484-494.

Sumner, P. (2007). Negative and positive masked-priming—Implications for motor inhibition. *Advances in Cognitive Psychology*, **3**, 317-326.

Verleger, R., Jaśkowski, P., Aydemir, A., van der Lubbe, R., & Groen, M. (2004). Qualitative differences between conscious and nonconscious processing? On inverse priming induced by masked arrows. *Journal of Experimental Psychology: General*, **133**, 494-515.

Weidemann, C. T., Huber, D. E., & Shiffrin, R. M. (2005). Confusion and compensation in visual perception: Effects of spatiotemporal proximity and selective attention. *Journal of Experimental Psychology: Human Perception & Performance*, **31**, 40-61.

(Manuscript received July 7, 2006;
revision accepted for publication December 18, 2006.)