Journal of Experimental Psychology: General

Copy of e-mail Notification zfr0389

Your article proofs from Journal of Experimental Psychology: General (Volume 133, Issue 4(ms#1)) are ready for your review
=====
Journal of Experimental Psychology: General Published by American Psychological Association

Dear Author,

The page proofs of your article (# 0389) are now ready for your final review before your article is published. Please access your proofs, proofread them carefully, and respond to the Production Editor within 48 hours. To access your proofs, please refer to this URL address
http://rapidproof.cadmus.com/RapidProof/retrieval/index.jsp

Login: your e-mail address
Password: ----

The site contains 1 file. You will need to have Adobe Acrobat? Reader software (Version 4.0 or higher) to read this file. This is free software and is available for user downloading at
http://www.adobe.com/products/acrobat/readstep.html.

If you have any problems with downloading your article from the Rapid Proof site, please contact rapidprooftech@cadmus.com. PLEASE INCLUDE YOUR ARTICLE NUMBER (0389) WITH ALL CORRESPONDENCE.

This file contains:

1. Proofreading Instructions
2. Subscriptions and Special Offers information
3. Reprint Order Form
4. A copy of the page proofs for your article. The proof contains 20 pages.

After printing the PDF file, and within 48 hours of receipt, please read the page proofs carefully against your copy of the copyedited manuscript and

1. indicate changes or corrections in the margin of the page proofs;
2. answer any and all queries that appear on the last page of the PDF proof;
3. proofread any tables carefully against your copy of the copyedited manuscript;
4. proofread any equations and all mathematical symbols;
5. proofread any figures and check figure and caption placement;
6. check that any non-English characters and symbols, especially ? (mu), have been typeset correctly.

Please respond to the Production Editor as follows:
Authors within the continental United States:
- If you have no changes, e-mail the Production Editor that you have no changes.
- If you have minimal changes, you may summarize them in an e-mail to the Production Editor. Please indicate the location of changes clearly. Example: "Page 2, left column, 3rd paragraph, in sentence 'Each niche . . . ,' infrared is misspelled."
- If you have several changes and would prefer not to summarize them in an e-mail, please send clearly marked proofs to the postal address given at the end of this message.

Authors outside the continental United States:

- If you have no changes, e-mail the Production Editor that you have no changes.
- If you have any changes, please list them in an e-mail to the Production Editor, or fax a clearly marked set of proofs to the Production Editor's attention. If you choose to e-mail the changes, please indicate the location of changes clearly. Example: "Page 2, left column, 3rd paragraph, in sentence 'Each niche . . . ,' infrared is misspelled."

If you are ordering reprints, please fill out the Reprint Order Form and return it with payment/purchase order to Cadmus Reprints, Reprint Account Manager, P.O. Box 751903, Charlotte, NC 28275-1903.

If you have questions or concerns about the editing of your proofs, please contact the Production Editor at APA.

Sincerely,

Production Editor
Journal of Experimental Psychology: General
APA Journals Office
750 First Street, NE
Washington, DC 20002-4242
Tel: 202-336-5540
E-mail: XGeneral@apa.org
FAX (for non-U.S. authors): 202-336-5549

E-Proofreading Instructions

Enclosed are typeset proofs of your article. **Please proofread the proofs word for word against your copy of the manuscript and return your changes to the Production Editor within 48 hours.** Options for returning your changes are provided in the e-mail message.

Author's Responsibility. Authors are expected to read their proofs word for word against the copyedited manuscript for accuracy of content. Production Editors read proofs only for grammatical sense and correctness, without reference to the manuscript. Therefore, read the proofs with great care. Follow the instructions provided in the e-mail notice for indicating changes. Proofreading marks are provided below.

• Be sure that the typesetter has followed the manuscript exactly as edited. Answer any questions and double-check tables, figures, and formulas.

•Mark corrections on the proofs in **a color other than black (e.g., red pencil or ink),** using the proofreading marks given below. Mark corrections in the margins as well as in the text, For detailed instructions on proofreading, see the *Publication Manual of the American Psychological Association*. (Do not make any marks on the manuscript.)

•Limit changes to correcting printer's errors and inserting data not previously available. Additional changes will be charged to you as author alterations. Such author alterations are charged at current printer's rates according to the number of lines and pages affected. Bear in mind that even a one-word change on a page proof can be costly.

Returning Your Proofs

Please retain a copy of your corrected proofs and return your changes within 48 hours to the Production Editor, as specified in the e-mail message. If proofs are not returned promptly, publication may be delayed to the next available issue.

Production Editor
(Title of Jurnal)
APA Journals, Second Floor
750 First Street, NE
Washington, DC 20002-4242

Phone: (202) 336-5540

Proofreading Marks

- Delete
- Close up (clo se up)
- Delete and close up (delete and and close uup)
- Insert something (His name Bill)
- Insert a space (thecat)
- Stet - let original stand
- Transpose (transpoes or change order the)
- Set farther to the left
- Set farther to the right
- Begin new paragraph
- Spell out (set 5 as five: set & as and)
- Set in capitals
- Set in small caps
- Set in lowercase
- Set in *italic* type: *cat*
- Delete italic; set in roman: cat
- Set in **boldface** type: **cat**
- Hyphen (self concept)
- En dash (1965 1972)
- Em dash (em or long dash)
- Superscript (1 3)
- Subscript (H 2 O)
- Centered (p · q)
- Comma
- Apostrophe
- Period
- Semicolon
- Colon

Inside

p. 2 Special offers
pp. 3-4 Reprint orders

Subscriptions and Special Offers

In addition to purchasing reprints of their articles (see p. 3), authors may purchase an annual subscription, purchase an individual issue of the journal (at a reduced rate), or request a single copy (at no cost) under special "hardship" circumstances.

To place your order fill out the order form below (including the mailing label). Send the completed form and your check made out to the **American Psychological Association** to the following address:

APA Order Department
750 First Street, NE
Washington, DC 20002-4242

For information about becoming a member of the American Psychological Association, call the Membership Office at 1-800-374-2721.

2004 EPF Journal Subscription Rates

Journal*	Individual Rate	Member/ Affiliate
American Journal of Orthopsychiatry	$ 90	$ 77
Cultural Diversity and Ethnic Minority Psych	$ 70	$ 50
Consulting Psychology Journal	$ 70	$ 50
Dreaming	$ 80	$ 45
Families, Systems, & Health	$ 110	$ 80
Group Dynamics	$ 70	$ 50
History of Psychology	$ 70	$ 50
International Journal of Stress Management	$ 70	$ 53
Jrnl Occupational Health Psych	$ 70	$ 50
Jrnl of Psychotherapy Integration	$ 70	$ 61
Psychoanalytic Psychology	$ 70	$ 51
Psychological Services	$ 70	$ 50
Psychology of Addictive Behaviors	$ 70	$ 62
Psychology of Men & Masculinity	$ 70	$ 50
Psychotherapy: T, R, P, T	$ 90	$ 55
Rehabilitation Psychology	$ 70	$ 50
Review of General Psychology	$ 70	$ 50

2004 APA Journal Subscription Rates

Journal*	Individual Rate	APA Member Rate
American Psychologist	$ 216	NA
Contemporary Psychology	$ 141	$ 56
Behavioral Neuroscience	$ 224	$ 127
Developmental Psychology	$ 195	$ 98
Emotion	$ 80	$ 45
Experimental & Clinical Psychopharm.	$ 104	$ 51
Health Psychology	$ 88	$ 56
Jrnl. of Abnormal Psychology	$ 120	$ 59
Jrnl. of Applied Psychology	$ 172	$ 84
Jrnl. of Comparative Psychology	$ 70	$ 45
Jrnl. of Consulting & Clinical Psychology	$ 207	$102
Jrnl. of Counseling Psychology	$ 85	$ 45
Jrnl. of Educational Psychology	$ 133	$ 65
Jrnl. of Family Psychology	$ 104	$ 51
Jrnl. of Personality & Social Psychology	$ 382	$ 190
JEP: Animal Behavior Processes	$ 90	$ 45
JEP: Applied	$ 70	$ 45
JEP: General	$ 70	$ 45
JEP: Human Perception & Performance	$ 274	$ 136
JEP: Learning, Memory, & Cognition	$ 274	$ 136
Neuropsychology	$ 104	$ 51
Professional Psych.: Research & Practice	$ 104	$ 51
Psychological Assessment	$ 104	$ 51
Psychological Bulletin	$ 172	$ 85
Psychological Methods	$ 70	$ 45
Psychological Review	$ 129	$ 63
Psychology & Aging	$ 119	$ 59
Psychology, Public Policy, & Law	$ 70	$ 45

* For journal descriptions, see APA's web site: http://www.apa.org/journals

CUT ALONG DASHED LINE - RETURN LOWER PORTION TO APA ORDER DEPARTMENT

Instructions: Check the appropriate box, enter journal title and price information, and complete the mailing label in the right column. Enclose a check made out to the American Psychological Association, and mail it with the form to the APA Order Department.

❑ Annual Subscription (available on January-December basis only). To subscribe, specify calendar year of the subscription. Refer to the Subscription Rates shown above.

Journal: ______________________

Calendar year of subscription: ______________ Price: ________

Special Offers! If you are an APA journal article author, you may take advantage of two Special Offers. (These offers do not apply to Educational Publishing Foundation journals.)

❑ **Individual Copy.** You may order individual copies of the entire issue in which your article appears. As an author, you receive a special reduced rate of $5 a copy for up to a maximum of 25 copies. We cannot take phone requests for single copies; please use this form.

Journal: ______________________

Vol. no.: ________ Issue no.: ________ Issue month: ________

_____ copies @ $5 a copy = $ _______ (order amount)
\+ _______ (handling; see below)
TOTAL cost of order: _______

Handling fees		
Order amount:	Handling fee:	International
< $15	$5	$15
$15 - $60	$6	$16
> $60	Order amount x .10	$20

TOTAL ENCLOSED: ______________________

❑ **Hardship Request.** If you do not have a personal subscription to the journal and you do not have access to an institutional or departmental subscription copy, you may obtain a single copy of the issue in which your article appears at no cost by filling out the information below.

Journal: ______________________

Vol. no.: ______________ Issue no.: ________

Issue month: ______________________

PRINT CLEARLY - THIS IS YOUR MAILING LABEL

Name: ______________________

Address: ______________________

____

____

Send the completed form and your check, made out to the **American Psychological Association**, to:

APA Order Department
750 First Street, NE
Washington, DC 20002-4242

All orders must be prepaid. Allow 4-6 weeks after the journal is published for delivery of a single copy or of the first copy of a subscription.

REPRINTS

Authors have two options for ordering reprints: Authors who need to use purchase orders may order reprints from the standard "*Purchase Order Service.*" For a substantially lower price, authors may use the "*Prepaid Service.*" The price schedules below give the prices for each service. All international prices include shipping via WWDS. All domestic shipments will be made via UPS. We request that you do not use Post Office box numbers; provide a full street address if possible. Authors may request expedited shipping - the additional cost will be billed. You are required to pay all duties if they apply. (See order form on reverse.)

- **Prepaid Service:** Authors have a lower priced option for ordering reprints. To take advantage of this lower price, submit your credit card information with your order. The prices given below include postage.

- **Purchase Order Service:** You must submit a purchase order with your reprint order. Orders will not be processed unless the purchase order accompanies the order form. Cadmus Reprints will bill you later for the cost of the reprints. Do **not** send remittance with the reprint order form and purchase order. Remember that the price you see below includes postage, so it is the exact amount you will be billed. (Exception: Authors requesting expedited shipping will be billed the additional cost.)

Complete the order form on the back of this page and return it to Cadmus Reprints (not to APA). Only one order form is provided - include your coauthors' orders on this form or make photocopies of the order form for your coauthors. Check the box for either the prepaid service or the purchase order service. Give explicit instructions for all authors receiving reprints, using the space at the bottom of the order form.

To determine the cost of the reprints, count the number of pages in the printed article and refer to the price schedules below. For example, if your article is 11 pages long, you want 100 reprints, you live in the United States, and you are using the prepaid service, your total cost would be $106.17.

If you are charging all or part of the reprint order to an institution (e.g., a university or government agency) and the institution cannot submit a check for payment with the order, then a purchase order is required. In this case, use the purchase order service price schedule and include the purchase order with the order form.

The order form should be sent to Cadmus Reprints at the same time that page proofs are returned to the production editor. Reprints will be mailed within two (2) weeks of the publication of the journal. Orders received after the issue goes to press will be processed with the next issue.

Where to Order Reprints

Send your order form with credit card information (**Personal checks must clear before reprints are processed. There is a $30.00 charge for returned checks.**) or a purchase order in the amount indicated on the purchase order service price schedule to:

Cadmus Reprints
P.O. Box 751903
Charlotte, NC 28275-1903
Phone: (410) 819-3966 FAX: (410) 820-9765

RATES EFFECTIVE 1/1/04 - 12/31/04

DOMESTIC

APA - DOMESTIC RATES - prepaid with postage

	No. of Pages in Article								
Copies	**1-4**	**5-8**	**9-12**	**13-16**	**17-20**	**21-24**	**25-28**	**29-32**	**Covers**
1-50	40.14	53.62	67.21	84.33	99.21	115.29	130.20	143.92	74.56
51-100	52.60	78.01	106.17	134.04	161.50	192.45	220.64	247.94	85.98
101-200	71.02	114.69	164.95	211.44	260.27	314.54	364.38	413.43	91.82
201-300	88.67	154.11	217.90	281.58	347.35	421.53	490.25	557.87	117.76

APA - DOMESTIC RATES - Purchase Order - with postage

	No. of Pages in Article								
Copies	**1-4**	**5-8**	**9-12**	**13-16**	**17-20**	**21-24**	**25-28**	**29-32**	**Covers**
1-50	42.92	57.37	71.91	90.24	106.17	124.60	139.30	155.55	79.79
51-100	56.29	83.49	113.60	143.41	172.81	205.92	236.10	265.27	86.81
101-200	75.98	122.70	176.52	226.24	278.51	325.26	389.90	442.35	98.26
201-300	94.89	164.92	226.37	301.30	371.66	451.02	524.56	596.93	126.01

INTERNATIONAL

APA - INTERNATIONAL RATES - prepaid with postage

	No. of Pages in Article								
Copies	**1-4**	**5-8**	**9-12**	**13-16**	**17-20**	**21-24**	**25-28**	**29-32**	**Covers**
1-50	42.32	55.82	73.60	90.95	108.59	126.31	143.99	161.55	74.56
51-100	55.89	81.58	111.76	141.84	172.81	202.22	210.37	262.52	80.32
101-200	77.60	133.09	188.36	243.59	298.78	354.00	409.29	464.50	91.82
201-300	103.01	183.75	265.29	345.69	426.67	508.03	588.99	672.75	117.76

APA - INTERNATIONAL RATES - Purchase Order - with postage

	No. of Pages in Article								
Copies	**1-4**	**5-8**	**9-12**	**13-16**	**17-20**	**21-24**	**25-28**	**29-32**	**Covers**
1-50	45.29	59.75	78.76	97.31	116.20	135.16	154.94	172.88	79.79
51-100	59.50	87.28	119.59	151.77	184.06	216.40	225.11	280.92	85.94
101-200	76.83	142.41	201.55	260.65	319.71	378.78	437.95	497.00	110.46
201-300	110.22	196.76	283.86	369.90	456.51	543.57	630.21	719.88	126.01

Additional Rates

Set Title Page, Each	$14.17
Each extra mailing	$ 5.90
Remake pages, each	$ 8.59

2004 REPRINT ORDER FORM

APA and EPF Journal Authors: To order reprints, complete all sections of this form. Please read the instructions on page 3.

Journal of Experimental Psychology: General

SEND the reprint order and
(1) credit card number, or
(2) money order/certified check, or
(3) approved purchase order

TO:

Cadmus Reprints
P.O. Box 751903
Charlotte, NC 28275-1903

BILLING NAME ______________________

ORGANIZATION ______________________

ADDRESS (no p.o. box) ______________________

CITY ______________ STATE ________

PUBLICATION ______________________

VOLUME ________ ISSUE ________

ARTICLE TITLE ______________________

AUTHOR ______________________

DATE ______________

PHONE # ______________

FAX # ______________

ROOM # ______________

ZIP ______________

E-MAIL ______________

REPRINTS INCLUDE COLOR? ❑ YES ❑ NO

OF PAGES ________

OF REPRINTS ________

OF COVERS ________

PAYMENT METHOD: CHECK ONE

___CREDIT CARD   CARD NUMBER ______________
  ___ VISA   EXPIRATION DATE ______________
  ___ MASTERCARD   SIGNATURE ______________

___MONEY ORDER/CERT. CHECK (MAKE PAYABLE TO: **Cadmus Reprints**)

___APPROVED PURCHASE ORDER (ORIGINAL PO MUST BE ATTACHED)

___CHECK (shipment delayed until check clears)

COMPUTE COST OF ORDER

PRICE (per chart) $ ________

Add'l for Covers ________

SUBTOTAL $ ________

PA residents add 6% tax ________

TOTAL $ ________

COMPLETE SHIPPING LABEL below. No P.O. Boxes.
Include phone number on international shipments. INTERNATIONAL shipments can be made via AIR for additional charges, please indicate in Special Shipping Instructions if you desire.

(TYPE OR PRINT MAILING LABEL BELOW)

SHIP TO: Phone No. ______________

Name ______________________

Address ______________________

____

City ______________ State ______________ Zip ________

Journal of Experimental Psychology: General
2004, Vol. 133, No. 4, 000–000

0096-3445/04/$12.00 DOI: 10.1037/0096-3445.133.4.0

Negative Compatibility or Object Updating? A Cautionary Tale of Mask-Dependent Priming

Alejandro Lleras and James T. Enns
University Of British Columbia

The *negative compatibility effect* (NCE) is the surprising result that visual targets that follow a brief prime stimulus and a mask can be identified more rapidly when they are opposite rather than identical to the prime. In a recent article in this journal, S. T. Klapp and L. B. Hinkley (2002) proposed that this reflected a competition between inhibitory unconscious processes and excitatory conscious processes. The authors of the current article report 7 experiments with results countering this theory and propose an alternative account within the framework of object substitution masking. In this account, the NCE reflects the updating of perceptual objects, including their links to responses closely associated with those objects.

Visual priming refers to the influence of a previously viewed stimulus on the identification of a current stimulus. In many situations, prior experience with a stimulus results in an advantage for the subsequent identification of the same stimulus (e.g., Bar & Biederman, 1998; James, Humphrey, Gati, Menon, & Goodale, 2000; Leuthold & Kopp, 1998), one that is visually similar to it (e.g., Fiser & Biederman, 2001; Forster, Davis, Schoknecht, & Carter, 1987), or even one that is only semantically related to it (e.g., Marcel, 1983; O'Connor & Potter, 2002; Potter, 1999). However, prior experience with a stimulus can, under some circumstances, also have an apparently detrimental effect on target identification. This is the case in the so-called negative compatibility effect (NCE), which is the focus of the present article.

This NCE was first reported by Eimer and Schlaghecken (1998) and has since been the subject of extensive study (Eimer & Schlaghecken, 2001, 2002; Eimer, Schubo, & Schlaghecken, 2002; Klapp & Hinkley, 2002; Schlaghecken & Eimer, 2001, 2002). A typical sequence of events in an NCE study is as follows. First, a prime is presented very briefly, usually for no longer than 35 ms. A typical prime is a double-headed arrow that points to either the left or the right. Second, a visual pattern mask (typically, a composite of the two prime patterns) is presented over the prime location for about 100 ms. Finally, a target is presented and participants are asked to report its identity as quickly and accurately as possible. The target is a double-headed arrow as well, pointing either in the same direction as the prime (*compatible* condition) or in a direction opposite to the prime (*incompatible* condition). Visual priming is measured by comparing response time (RT) to the target on compatible trials, where prime and target indicated the same response, with RT to the target on incompatible trials, where prime and target indicated opposite responses.

As indicated by its name, the NCE is the surprising result that RT on incompatible trials is actually faster than RT on compatible trials, yielding a negative priming effect. Figure 1 illustrates a very similar procedure, used by Schlaghecken and Eimer (2002), which will be the basic procedure in this study and in which primes and masks are presented slightly above or below fixation. As will become clear, we did not present the entire prime–mask–target sequence at fixation, as in Klapp and Hinkley (2002), because we wanted to focus exclusively on possible perceptual interactions between prime and mask stimuli. F1

Prime visibility can be manipulated in several ways, including by reducing prime duration, prolonging mask duration, or shortening the prime–mask interval. In studies of the NCE, prime visibility is usually measured on a separate set of trials in which only prime and mask are presented (the target is omitted from the sequence) and the task is to identify the prime. It is interesting to note that the NCE has been observed even when prime visibility is severely reduced, such that the accuracy of participants in the prime identification task is only 60%, very close to chance levels of guessing at 50%.

Intrigued by the effects of barely visible primes on target identification, Klapp and Hinkley (2002) investigated the NCE in five experiments. In addition to replicating the basic NCE result, they reported five novel results: (a) Positive priming, not an NCE, was observed when the mask was omitted from the sequence of events so that prime visibility was high; (b) an NCE was observed for the visual prime–mask sequence even when the target was an auditory discrimination; (c) an NCE was observed when there were three rather than only two alternative responses (i.e., three primes and three targets); (d) an NCE was observed even when the standard trial sequence was preceded by a cue signaling the identity of the target with 100% reliability; and (e) when the target was omitted from the sequence of events and participants were forced to select a response, they tended to choose the response opposite to the one indicated by the prime.

Alejandro Lleras and James T. Enns, Department of Psychology, University of British Columbia, Vancouver, British Columbia, Canada.

This research was supported by grants from the Natural Science and Engineering Research Council of Canada and from Nissan Motor Corporation to James T. Enns and by a postdoctoral research award to Alejandro Lleras by the National Science Foundation under Grant 0309998.

Correspondence concerning this article should be addressed to Alejandro Lleras, who is now at the Department of Psychology, University of Illinois at Urbana-Champaign, 603 East Daniel Street, Champaign, IL 61820. E-mail: alleras@uiuc.edu

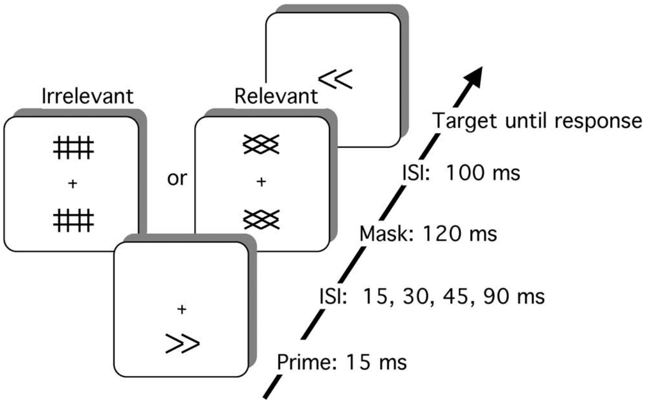

Figure 1. Temporal sequence and spatial layout of displays in Experiment 1. ISI = interstimulus interval.

From these results, Klapp and Hinkley (2002) concluded that the NCE reflects the unconscious processing of the prime, which leads to the inhibition of the response code associated with it. Under conditions of low prime visibility, unconscious processes that are generally inhibitory in nature win the competition over conscious processes that are excitatory, leading to the overall inhibition of the response code associated with the prime. In contrast, when no mask is used (e.g., in Klapp & Hinckley's Result a), conscious processes win the competition and positive priming is observed. Furthermore, these authors interpreted the cross-modal NCE (Result b) as evidence that the locus of this effect is at the response-selection stage rather than at a perceptual stage and the multiple-response NCE (Result c) as evidence of specific inhibition of the prime-related response rather than excitation of the alternative response. Finally, they also concluded that the NCE occurs automatically and without conscious awareness (Results d and e).

Although Klapp and Hinkley's (2002) proposal is consistent with the available data, we believe that these authors, along with Eimer and Schlaghecken (1998, 2002), have overlooked an important factor in the methodology of these experiments. This is the relation between the prime and the mask, which, when investigated in detail, suggests to us an entirely different understanding of the phenomenon. Figure 2 illustrates many of the primes and masks that have been used in studies of the NCE. Note that there is a very consistent relationship between the visual features present in the primes (and targets) and those present in the masks. In all cases, the visual features of the directional arrows used as primes (e.g., oblique lines and acute angles) are also present in the masks. In no case is the mask composed of visual features that are not in the primes. This is so even when the mask is a haphazard jumble of lines, as in Eimer and Schlaghecken (2002), or when it consists of the letters *WXXW* or *XWWX*, as in Klapp and Hinkley (2002, Experiments 1, 3–5). The critical features of arrows, intersections of oblique lines, are always present. To date, no one has tested a mask that consists of features entirely different from those that distinguish the two primes from each other.

In one respect, it is not surprising that masks were chosen to share the visual features of primes. This is because the effectiveness of a pattern mask generally increases with its similarity to the prime (Breitmeyer, 1984; Hellige, Walsh, Lawrence, & Prasse, 1979; Kinsbourne & Warrington, 1962), and one of the explicit goals of the researchers has been to reduce the visibility of the prime as much as possible. From this perspective, using masks that are composites of the prime stimuli is a very efficient way to reduce prime visibility while at the same time not appearing to bias the priming effects in any way. But herein lies the problem. Masks containing features of both prime stimuli will only be truly unbiased if they are processed by the visual system entirely independently of the primes. However, if the perceptual processing of the prime features interacts with those of the mask features, these seemingly neutral masks may, in fact, act as strong positive primes for the features that are not shared between prime and mask. In other words, these masks may yield positive priming effects based on the new features that are contained within them.

How might such positive priming from new features in the mask come about? One way is through the object updating process that occurs whenever the human visual system tracks a dynamic visual event over space and time. Object updating refers to the process whereby recently sampled information is integrated with an existing representation of a scene, resulting in an updated version (e.g., Lleras & Moore, 2003; Moore & Enns, in press). If the scene has not changed from one point in time to the next, then the original representation is simply reinforced by the process. However, if the scene has changed, then the updating process can lead to the replacement of the existing information with more recent information. In the context of backward visual masking, this updating process has been referred to as *object substitution* to reflect how the process of target identification is disrupted when a later arriving mask appears in the same spatiotemporal sequence as the target (Di Lollo, Enns, & Rensink, 2000; Enns, 2002; Enns & Di Lollo, 1997; Jiang & Chun, 2001a, 2001b; Lleras & Moore, 2003; Neill, Hutchison, & Graves, 2002).

The object substitution theory proposes that masking is a consequence of the ongoing recurrent communication between neurons at lower and higher levels of processing. Initial sensory input activates the spatially local and geometrically simple receptive fields of lower level units, which, in a feedforward sweep, activate units at higher levels (the object-representation level) that are sensitive over larger regions of the visual field and are tuned to more complex properties such as shapes and patterns. To resolve ambiguity between alternative object activations at the higher level and to bind patterns at the higher level to specific spatiotemporal locations, a feedback sweep of processing is required. Pattern

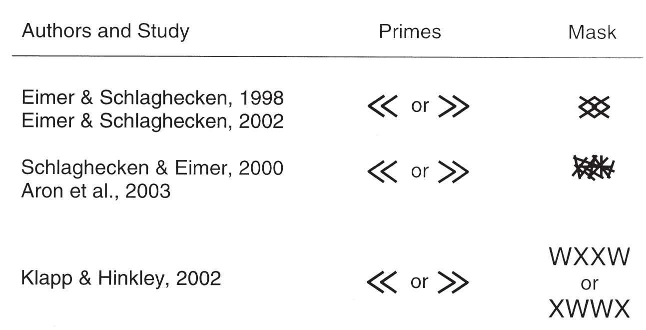

Figure 2. Examples of prime and mask stimuli in the literature on the negative compatibility effect.

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

hypotheses generated at the higher level are compared with the ongoing activity at the lower level. If the visual image remains stable over the iterations required to match the contents of these two levels to some criterion, the system will become stable in its representation of a given scene. However, if the input activity is altered before these iterations are complete, a mismatch will be detected and the iterative processes will begin again, this time based on the new sensory input that is currently activating the lower level neurons.

The NCE can arise in this view because of an updating process involving the prime–mask sequence. Because of the spatiotemporal proximity of the prime and mask, these two stimuli are interpreted as being different instantiations of a single object, whose object-level features will be updated as changes in the stimulus occur. Initial processing begins with the feedforward activation of one of the hypotheses regarding the prime (e.g., a right-pointing arrow). Soon after this initial hypothesis is tested by reentrant processing, a partial mismatch will be detected and iterative processing will begin anew, this time on the hypothesis that has been activated by the mask. Because prime and mask share common features (i.e., the right-pointing arrow), most of the object updating will entail updating features that are present in the mask but absent from the prime (i.e., the left-pointing arrow). Because this is the last updating of information before the presentation of the target, it can leave the system tuned for a pattern hypothesis that is the alternative to the prime (i.e., the left-pointing arrow). In this way, the rapid sequence of prime (e.g., a right-pointing arrow) and mask (i.e., the composite arrows) can lead to a perceptual state in which the new task-relevant features in the mask (i.e., the left-pointing arrow) govern the priming effects. Although this looks like negative priming when indexed with respect to the prime, it is actually positive priming because it is the new features in the mask that have most recently influenced the system. In addition, we show that this phenomenon generalizes to masks that contain response-related features, even when these features do not have a direct spatial correspondence with the features of prime or target, as was the case in four of the experiments presented by Klapp and Hinkley (2002).

It is important to note that the NCE does not only involve visual processes, as described by object substitution theory, but it also involves motor priming. The motor priming occurs because the prime and target stimuli are visually very similar or even identical and because these stimuli are strongly associated with specific responses (i.e., the left arrow maps to a left response). Participants become attuned to extracting task-relevant features from the display (those that discriminate one possible target from the other), so when a prime arrow is presented, they involuntarily process the prime using the same system configuration that they use for the target. Consequently, if perceptual evidence in favor of one response is extracted from the display, it may be quickly linked to its corresponding motor program.

Overview of Experiments

We tested this hypothesis in several ways in the present study. We first conducted a typical NCE experiment using two types of masks in addition to a no-mask control condition. In one condition, we used relevant masks consisting of superimposed double arrows similar to those used by Klapp and Hinkley (2002, Experiment 2) and Eimer and Schlaghecken (1998, 2002). In the other condition, we used irrelevant masks consisting of the same number and density of lines but containing none of the features of the primes and targets. If Klapp and Hinkley's hypothesis of unconscious inhibition is correct, the NCE should be observed with both types of masks, provided they leave primes at equal levels of visibility. However, if prime–mask interactions are the key to this effect, then the NCE should be observed with relevant masks but not with irrelevant masks. To anticipate the outcome, a significant NCE was observed with relevant masks, whereas only positive priming was observed with either irrelevant masks or in the absence of any masks.

In Experiments 2, 3 and 4, we extended this finding of mask-dependent priming to a wider range of prime–mask patterns. In Experiment 2, we tested random line masks at two different line densities, similar to those used by Eimer and Schlaghecken (2002; Schlaghecken & Eimer, 2002). However, in the relevant-mask condition, the lines were all oblique, such that the features of right- and left-pointing arrows were present in a very abstract fashion, whereas in the irrelevant-mask condition, the same lines were used but only in vertical and horizontal orientations. In Experiment 3, the masks used in Experiment 2 were used once again, but this time, the compatibility effect was examined at shorter prime–mask intervals to reduce prime visibility even further. Finally, in Experiment 4, we tested for generality in the other extreme: Only a single arrow was used as a prime along with a single diamond shape as the relevant mask and a single pound sign as the irrelevant mask. In all of these cases, the NCE was obtained with relevant masks over a wide range of prime visibility. In contrast, positive priming was obtained when either no masks or irrelevant masks were used over an equivalent visibility range.

Experiment 5 and 6 were designed to test two central premises of the object updating hypothesis, namely, (a) that new features of the mask stimulus can induce positive priming of the target on their own and (b) that the strength of these new features in the mask is influenced by the nature of the immediately preceding prime. In Experiment 5, we tested a single task-relevant but unbiased prime (a diamond shape) followed by a mask that included the same prime plus a superimposed directional arrow. The results revealed positive priming from the new directional arrow in the mask, indicating that these new features could indeed prime target responses for the timing intervals ordinarily used in NCE experiments. In Experiment 6, we tested a sequence involving a task-relevant prime (a diamond shape) or a task-irrelevant prime (a pound sign) prior to the presentation of directional arrow masks. The results showed positive priming from the new mask features in both cases, but it is important to note that this priming was stronger in the case of the relevant prime. This finding is unique from previous NCE experiments in showing that prime–mask features interact in producing the priming effect on target identification.

In Experiment 7, we studied the temporal course of the prime–mask interactions in both relevant masks that produce the NCE and irrelevant masks that produce positive priming. This was done by varying the duration of the mask rather than the prime–mask interval, as in most previous studies. The results showed that positive priming was systematically diminished as the mask duration increased to 45 ms. When mask duration increased beyond this range, only the relevant mask resulted in the NCE. An irrelevant mask of longer duration consistently resulted in positive priming. Taken together, these results strong implicate a perceptual object updating process as the basis of the NCE rather than the inhibition of unconsciously activated responses from unseen prime stimuli.

General Method

Participants

In each of the seven experiments, 15 different undergraduate students at the University of British Columbia participated for extra credit in an introductory psychology course. All were naive to the purpose of the study and all had normal or corrected-to-normal vision.

Stimuli

F3 Figure 3 is a catalog of the prime and mask stimuli used in the experiments. Target stimuli were double arrows pointing either left or right, with each stimulus subtending about 0.5° of visual angle. Primes were identical in size and most often consisted of double-headed arrows, with the exceptions shown in Figure 3. Relevant masks were composed of oblique lines of the same orientation as the lines in the target stimuli. In contrast, irrelevant masks were composed of vertical and horizontal lines, not related in any way to either the target stimuli or any response. The energy of the masks in each comparison was equated because they always involved the same number of screen pixels displayed over an equivalent area and for the same duration. On each trial, the prime could appear 1.5° either above or below fixation. Masks were presented simultaneously at both possible prime locations. The target was always presented at fixation.

Equipment

All experiments were run on eMac computers, at a screen resolution of 640 × 480 ms, which allowed a screen refresh rate of 138 Hz. The experiments were programmed using VScope software (Enns & Rensink, 1992).

Procedure

In all but Experiment 5, testing was performed in two phases that took place within an hour. In the first phase, participants performed a two-alternative forced-choice discrimination of a left- or right-pointing prime arrow. The prime was presented for 15 ms either above or below fixation and was followed by one of four randomly chosen prime–mask intervals: 15 ms, 30 ms, 45 ms, and 90 ms. Masks were presented at both possible prime locations for 120 ms, equally often in a random order, and on one fifth of the trials, no mask was presented.

In the second phase, participants performed a two-alternative forced-choice discrimination of a left- or right-pointing target arrow. However, prior to the target presentation, a prime was presented for 15 ms either above or below fixation and was followed by one of the varying prime–mask intervals (anywhere from 15 ms to 90 ms, depending on the experiment); masks were then presented for 120 ms at both possible prime locations. The target was presented at fixation 100 ms after mask offset and remained visible until a response was made. On no-mask trials, the prime–target interval was 240 ms, the same as in masked trials. Unlike the study of Klapp and Hinkley (2002), where there was always an interstimulus interval (ISI) of 0 ms between prime and mask, we always used a nonzero ISI so as to avoid confounding prime–mask interval with prime energy (see Di Lollo, von Mühlenen, Enns, & Bridgeman, 2004, for a discussion of how masking is differentially affected by target energy and target–mask ISI).

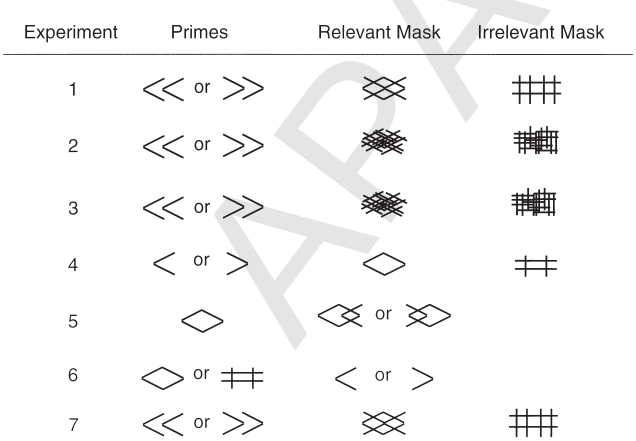

Figure 3. Examples of prime and mask stimuli used in Experiments 1–7. Targets were always double arrows, pointing right or left, and were identical to the primes used in Experiments 1, 2, and 7. Experiment 2 had two different levels of mask density and Experiment 3 had two levels of prime contrast (not illustrated here).

Data Analyses

The alpha level for significance chosen for all statistical tests was .05. When reporting significant results, we present the mean squared error and eta squared (estimated effect size) associated with the *F* value. When reporting *t* tests, we indicate the standard error of the mean. The *p* values of nonsignificant results are presented only when the corresponding *F* value exceeds 1.

Only mean correct RT was analyzed in speeded target-identification tasks. In addition, RT smaller than 150 ms or larger than 2,000 ms was discounted as error, which reduced the total number of observations by less than half of 1%.

Mean proportion errors for all experiments are shown in the tables. Participants generally had an error rate of less than 5% in target identification. This mirrored the RT data in all important respects: Positive RT priming was associated with fewer errors on compatible trials and negative RT priming was associated with fewer errors on incompatible trials.

Experiments 1–4: The NCE Is Mask Dependent

Experiment 1

The first experiment replicated a typical NCE experiment involving a task-relevant mask and extended the study of the priming effects to a task-irrelevant mask. In the relevant condition, the mask consisted of superimposed double arrows similar to those used by Klapp and Hinkley (2002, Experiment 2) and Eimer and Schlaghecken (1998, 2002). In the irrelevant condition, the masks contained the same number and density of lines but none of the features of the primes and targets (see Figure 1). We purposely chose to study slightly eccentric prime–mask sequences, as in Schlaghecken and Eimer (2002), rather than presenting these sequences at fixation, as in Klapp and Hinkley (2002), because we wanted to avoid any mask–target interactions that might occur over and above the prime–mask interactions that were the focus of our study.

Method

The relevant mask was a set of superimposed double arrows and the irrelevant mask was a set of two juxtaposed identical pound signs composed of strictly vertical and horizontal lines. In the prime identification phase, participants completed three blocks of 80 trials each. In the target identification phase, they completed seven blocks of 80 trials.

Results

Prime identification. Mean accuracy of prime identification is shown in Figure 4A. Accuracy increased with prime–mask interval, $F(3, 42) = 37.20$, $MSE = 0.007$, $\eta^2 = .73$, and mask type interacted with interval, $F(3, 42) = 5.75$, $MSE = 0.006$, $\eta^2 = .29$, reflecting a ceiling effect at the 90-ms ISI condition for both types of mask. In other words, relevant masks reduced the visibility of the prime more efficiently than did irrelevant masks at all but the longest interval: 15 ms, $t(14) = 3.54$, $SE = 0.04$; 30 ms, $t(14) = 4.67$, $SE = 0.03$; 45 ms, $t(14) = 5.74$, $SE = 0.03$; 90 ms, $t(14) < 1$.

F4

Target identification. Mean RT compatibility effects for target identification are shown in Figure 4B , with mean RTs and mean proportion errors for all conditions shown in Table 1. In the no-mask condition, RT was reliably 18 ms faster on compatible trials than on incompatible trials, $t(14) = 3.69$, $SE = 4.99$. The same pattern of positive priming held for the irrelevant-mask condition: Compatible trials were 20 ms faster than incompatible trials were, $t(14) = 5.62$, $SE = 3.64$. Only in the relevant-mask condition was the priming opposite in direction, with RT after incompatible trials 10 ms faster than after compatible primes, $t(14) = 2.26$, $SE = 4.24$.

T1

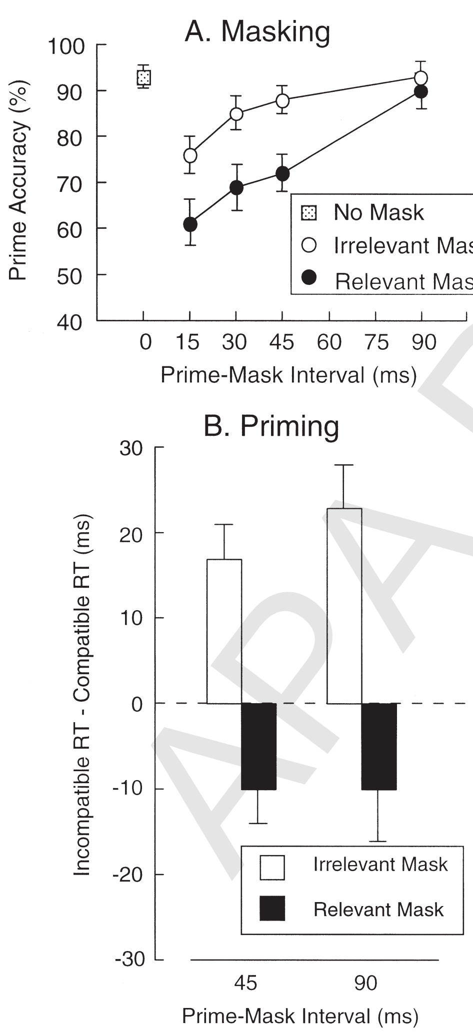

Figure 4. A: Mean prime accuracy in Experiment 1. B: Prime–target compatibility effects in Experiment 1. Standard error bars are ±1 standard error of the mean.

Table 1
Mean Correct Response Times (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask Type in Experiment 1 EQ: 1

Mask type and interval	Incompatible	Compatible	Priming
	Response time		
None			
240 ms	395 (11)	377 (9)	+18 (5)
Irrelevant			
45 ms	381 (11)	364 (10)	+17 (4)
90 ms	372 (7)	349 (9)	+23 (5)
Relevant			
45 ms	369 (10)	379 (10)	−10 (4)
90 ms	363 (10)	373 (10)	−10 (6)
	Errors		
None			
240 ms	0.039	0.057	−.018
Irrelevant			
45 ms	0.031	0.018	+.013
90 ms	0.036	0.033	+.003
Relevant			
45 ms	0.052	0.095	−.043
90 ms	0.052	0.035	+.017

Note. Interval is the time between the offset of the prime and the onset of the following stimuli (the masks in masked trials, the target in no-mask trials). Standard errors are in parentheses.

For more detailed analysis, RTs were submitted to a repeated-measures analysis of variance (ANOVA) with three factors: ISI (45 ms and 90 ms), prime–target compatibility (compatible and incompatible), and mask type (relevant and irrelevant). This confirmed the two-way interaction between Prime–Target Compatibility × Mask Type, $F(1, 14) = 37.12$, $MSE = 182.87$, $\eta^2 = .73$. In addition, participants were overall 9 ms faster in responding on the longer ISI trials (mean RT = 373 ms) than on the shorter ISI trials (mean RT = 364 ms), $F(1, 14) = 13.43$, $MSE = 184.80$, $\eta^2 = .49$. Participants were also overall 5 ms faster at responding to targets that followed irrelevant masks (mean RT = 366 ms) than targets that followed relevant masks (mean RT = 371 ms), $F(1, 14) = 6.23$, $MSE = 99.61$, $\eta^2 = .31$. The three-way interaction was not significant, $F(1, 14) < 1$.

Experiment 2

In this experiment, we tested random line masks that had two different line densities, similar to those used by Eimer and Schlaghecken (2002; Schlaghecken & Eimer, 2002). As shown in Figure 3, all lines in the relevant mask were oriented obliquely at the same angle as the lines in the arrow stimuli, so that at their

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

intersections they contained the visual features relevant to the primes and targets. For irrelevant masks, the same lines were rotated so that now they were either vertical or horizontal in orientation. The density of the masks was manipulated with two goals in mind: (a) to study the effect of mask energy on prime visibility (denser masks might be more effective at reducing prime visibility) and (b) to study the effect of feature density on the priming effect (one might expect that a denser relevant mask might yield a larger NCE).

Method

Relevant masks consisted of randomly superimposed oblique-oriented lines, whereas irrelevant masks consisted of the same lines rotated to horizontal and vertical alignments. The masks covered the same area as in Experiment 1, with the low-density masks containing 16 lines and the high-density masks 32 lines. There were five masking conditions in all (no mask, low-density irrelevant, high-density irrelevant, low-density relevant, high-density relevant). In the prime identification phase of the experiment, there were three blocks of 72 trials; in the target identification phase, there were eight blocks of 72 trials. One out of 9 trials was a no-mask trial in each phase.

Results

Prime identification. Mean accuracy of prime identification is
F5 shown in Figure 5A. Accuracy increased with prime–mask interval, $F(3, 42) = 27.59$, $MSE = 0.02$, $\eta^2 = .66$, and relevant masks generally reduced the visibility of the prime more efficiently than irrelevant masks did, $F(1, 14) = 78.33$, $MSE = 0.008$, $\eta^2 = .85$. There was also an interaction between mask type and prime–mask interval, $F(3, 42) = 2.84$, $MSE = 0.008$, $\eta^2 = .17$, indicating once again a ceiling effect at 90 ms for both types of masks. It is interesting that mask density had no influence on prime identification accuracy, either as a main effect, $F(1, 14) = 1.30$, $p = .27$, or in an interaction with any other factor, all Fs < 1.08.

Target identification. Mean RT compatibility effects for target identification are shown in Figure 5B, with mean RTs and mean
T2 proportion errors for all conditions shown in Table 2. Significant positive RT priming occurred in the no-mask condition (62 ms), $t(14) = 8.86$, $SE = 6.96$, and in the irrelevant-mask condition (14 ms), $t(14) = 2.92$, $SE = 4.87$, but negative RT priming was again observed only in the relevant-mask condition (−10 ms), $t(14) = 2.49$, $SE = 3.98$.

For more detail, a four-way ANOVA was conducted with variables ISI, mask type, mask density (low and high), and compatibility. This confirmed the significance of the two-way interaction between compatibility and mask type, $F(1, 14) = 27.93$, $MSE = 313$, $\eta^2 = .67$. There were no significant main effects—compatibility, $F < 1$; mask type, $F(1, 14) = 2.00$, $p = .18$—although mask density and ISI had marginal effects—$F(1, 14) = 4.18$, $p = .06$, and $F(1, 14) = 3.45$, $p = .084$, respectively—reflecting slightly shorter RTs with denser masks and with longer ISIs (2.5-ms advantage in both cases).

The Density × Mask Type interaction was significant, $F(1, 14) = 5.64$, $MSE = 184$, $\eta^2 = .29$, reflecting that participants were slightly slower to respond to targets that followed a low-density relevant mask (mean RT = 386 ms) than to targets that followed a high-density relevant mask (mean RT = 379 ms), a low-density irrelevant mask (mean RT = 379 ms), or a high-density irrelevant mask (mean RT = 380 ms). The three-way interaction Mask Type × Compatibility × ISI was not significant, $F(1, 14) < 1$. No other effects or interactions were significant: All other Fs < 1.2, except for the three-way interaction Density × ISI × Compatibility, $F(1, 14) = 1.88$.

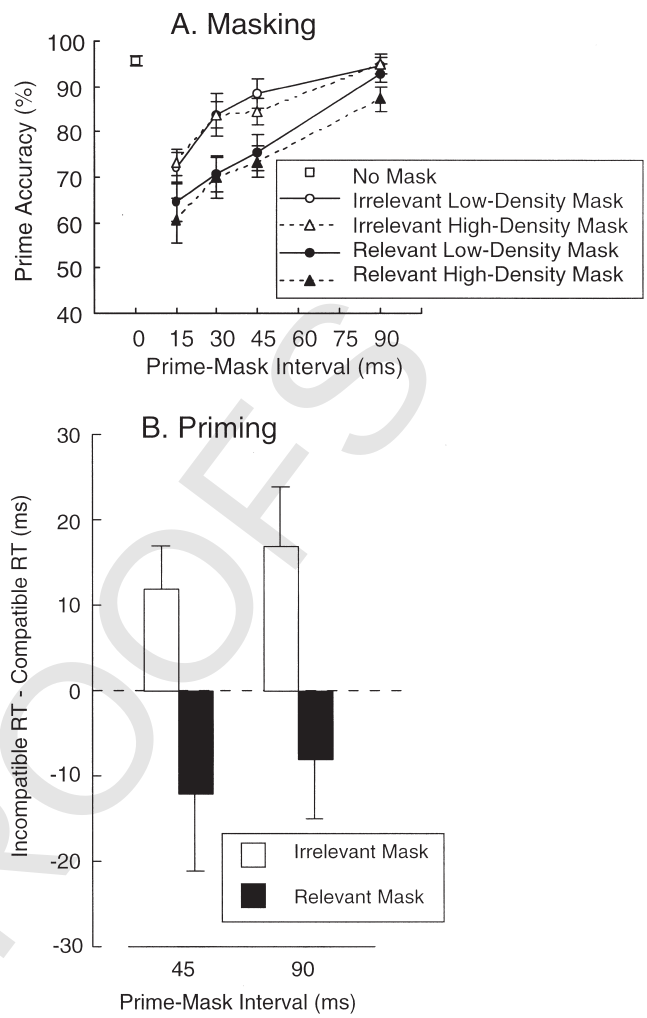

Figure 5. A: Mean prime accuracy in Experiment 2. B: Prime–target compatibility effects in Experiment 2. Standard error bars are ±1 standard error of the mean.

Participants were overall 51 ms slower in no-mask trials (mean RT = 432 ms) than in masked trials (mean RT = 381 ms), $t(14) = 14.83$, $SE = 3.43$, which might partially account for the larger priming effect in the no-mask condition compared with the irrelevant-mask condition.

Experiment 3

The goal of this experiment was to reduce prime visibility on irrelevant-mask trials as much as possible. Skeptics might argue that the positive priming observed with irrelevant masks in Experiments 1 and 2 was due to the relatively better visibility of the prime on those trials (see Figures 4A and 5A) rather than to the type of mask used. Furthermore, previous studies have examined

Table 2
Mean Correct Response Times (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask Type in Experiment 2

Mask type, interval, and density	Incompatible	Compatible	Priming
	Response time		
None			
240 ms	463 (18)	401 (14)	+62 (7)
Irrelevant			
45 ms			
Low	385 (15)	373 (13)	+12 (5)
High	389 (14)	378 (11)	+11 (7)
90 ms			
Low	385 (14)	373 (11)	+12 (8)
High	389 (15)	367 (14)	+22 (7)
Relevant			
45 ms			
Low	383 (16)	392 (12)	−9 (9)
High	373 (13)	388 (15)	−15 (6)
90 ms			
Low	380 (16)	389 (12)	−9 (8)
High	374 (14)	381 (16)	−7 (5)
	Errors		
None			
240 ms	0.046	0.054	−.008
Irrelevant			
45 ms			
Low	0.039	0.023	+.016
High	0.123	0.014	+.109
90 ms			
Low	0.062	0.035	+.027
High	0.029	0.019	+.010
Relevant			
45 ms			
Low	0.027	0.037	−.010
High	0.081	0.035	−.046
90 ms			
Low	0.052	0.046	−.006
High	0.029	0.037	−.008

Note. Interval is the time between the offset of the prime and the onset of the following stimuli (the masks in masked trials, the target in no-mask trials). Standard errors are in parentheses.

the NCE with visibility levels between 50% (chance performance) and 65% (relatively poor prime detection accuracy), so it could be argued that the priming effects obtained in this study reflect entirely different mechanisms than those at play in the NCE at very low visibility levels.

Method

Prime contrast and prime–mask ISI were manipulated to reduce prime visibility. Prime contrast was either high (black against the monitor's white background) or low (gray level with 40% of the saturation of the high-contrast primes). Prime–mask intervals were shorter (15 ms and 30 ms instead of the 45 ms and 90 ms used in Experiments 1 and 2). Masks were otherwise the low-density relevant and irrelevant masks of Experiment 2. In the prime identification phase of the experiment, there were three blocks of 72 trials; in the target identification phase, there were eight blocks of 72 trials. One out of 9 trials was a no-mask trial in each phase.

Results

Prime identification. Mean accuracy of prime identification is shown in Figure 6A. Accuracy increased with prime–mask interval, $F(3, 42) = 72.91$, $MSE = 0.01$, $\eta^2 = .84$, and relevant masks were overall 5% more effective in reducing the visibility of the prime than irrelevant masks were, $F(1, 14) = 7.70$, $MSE = 0.02$, $\eta^2 = .35$. There was also an interaction between mask type and prime–mask interval, $F(3, 42) = 4.40$, $MSE = 0.008$, $\eta^2 = .24$, indicating that prime visibility, although initially equal (61.1% with irrelevant masks and 61.9% with relevant masks at an ISI of 15 ms), improved at a faster rate with irrelevant masks than with relevant masks. F6

Although prime contrast did not have a main effect on overall prime visibility, $F(1, 14) = 2.07$, $p = .17$, it did have a significant interaction with mask type, $F(1, 14) = 5.68$, $MSE = 0.009$, $\eta^2 = .29$. This interaction reflected that prime contrast had no overall impact on prime accuracy for irrelevant masks (80.8% and 79.9%

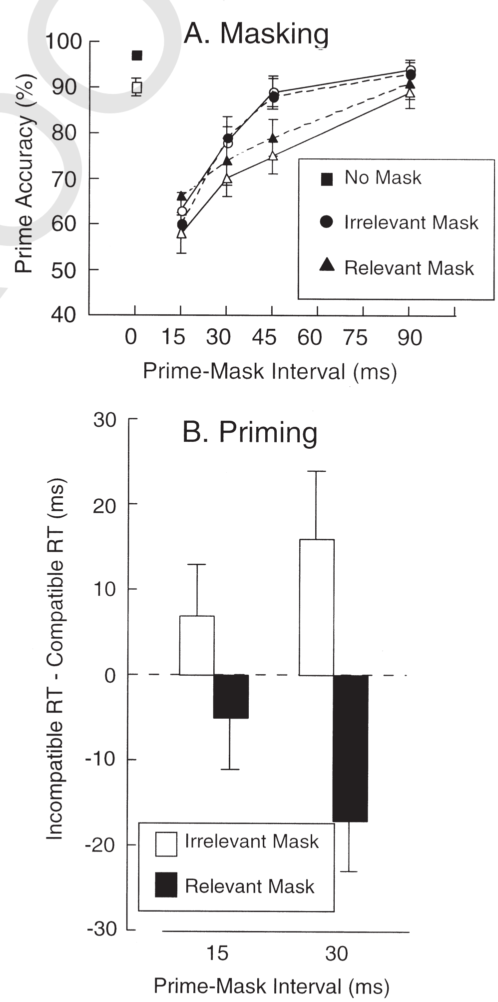

Figure 6. A: Mean prime accuracy in Experiment 3. B: Prime–target compatibility effects in Experiment 3. Standard error bars are ±1 standard error of the mean. In Panel A, open symbols represent data in the low-contrast prime condition, whereas filled symbols represent data in the high-contrast prime condition.

for low- and high-contrast primes, respectively), although it did for relevant masks (72.9% and 77.9% for low- and high-contrast primes, respectively). No other effects were significant (all Fs < 1).

Target identification. Mean RT compatibility effects for target identification are shown in Figure 6B, with mean RTs and mean proportion errors for all conditions shown in Table 3. Overall, there was significant positive RT priming in the no-mask condition (77 ms), $t(14) = 5.81$, $SE = 13.18$, and in the irrelevant-mask condition (12 ms), $t(14) = 2.75$, $SE = 4.20$, but negative RT priming was again only observed in the relevant-mask condition (−11 ms), $t(14) = 2.80$, $SE = 3.77$.

The main goal of this experiment was to see whether irrelevant masks would yield positive priming at low prime-visibility levels.

Table 3
Mean Correct Response Times (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask Type in Experiment 3

Mask type, interval, and contrast	Incompatible	Compatible	Priming
Response time			
None			
240 ms			
Low	444 (18)	380 (16)	+64 (11)
High	454 (22)	365 (16)	+89 (17)
Irrelevant			
15 ms			
Low	368 (12)	367 (13)	+1 (6)
High	372 (11)	359 (13)	+13 (7)
30 ms			
Low	377 (14)	356 (11)	+21 (9)
High	367 (12)	355 (11)	+12 (7)
Relevant			
15 ms			
Low	360 (12)	362 (10)	−2 (5)
High	361 (11)	368 (11)	−7 (7)
30 ms			
Low	358 (11)	370 (7)	−12 (6)
High	352 (9)	374 (12)	−22 (6)
Errors			
None			
240 ms			
Low	0.112	0.019	+.093
High	0.149	0.005	+.144
Irrelevant			
15 ms			
Low	0.023	0.014	+.009
High	0.025	0.005	+.020
30 ms			
Low	0.037	0.037	.00
High	0.042	0.028	+.014
Relevant			
15 ms			
Low	0.019	0.025	−.006
High	0.005	0.037	−.032
30 ms			
Low	0.030	0.042	−.012
High	0.016	0.044	−.028

Note. Interval is the time between the offset of the prime and the onset of the following stimuli (the masks in the masked trials, the target in no-mask trials). Standard errors are in parentheses.

A direct answer to this question is given in the High-Contrast Prime × 15-ms ISI condition: with irrelevant masks, prime identification was at only 59%, and still a positive priming effect of 13 ms was obtained (see Table 3). In contrast, with identical prime contrast and prime–mask ISI, relevant masks yielded a prime-visibility level of 66%—if anything, better visibility than with irrelevant masks, $t(14) = -1.82$, $SE = 0.03$, $p = .09$— and a negative 7-ms priming effect, which missed being significantly different from the 13-ms positive priming with irrelevant masks by .001, $t(14) = 2.14$, $SE = 9.12$, $p = .051$.

For more detail, a four-way ANOVA was conducted with variables ISI, mask type, prime contrast (low and high), and compatibility. This confirmed the significance of the two-way interaction between compatibility and mask type, $F(1, 14) = 19.21$, $MSE = 381$, $\eta^2 = .58$. There were no significant main effects (all Fs < 1). The interaction Mask Type × Prime Contrast did not reach significance, $F(1, 14) = 2.73$, $p = .12$. No other two-way interaction approached significance (all Fs < 1).

The three-way interaction Mask Type × Compatibility × ISI was also very near significance, $F(1, 14) = 4.56$, $p = .51$. This interaction reflects the finding that priming effects (whether positive with irrelevant masks or negative with relevant masks) increased in magnitude with increasing ISIs (see Figure 6B). The three-way interaction Prime Contrast × ISI × Compatibility was not significant, $F(1, 14) = 2.50$, $p = .14$. No other interactions approached significance (all Fs < 1.3).

A post hoc analysis of the RT data was performed to evaluate the significance of the priming effects in each of the cells of the design. This analysis showed (a) in the no-mask condition, both the low- and high-contrast primes produced significant priming, $t(14) = 5.54$, $SE = 11.50$, and $t(14) = 5.13$, $SE = 17.43$, respectively; (b) in the irrelevant-mask condition, the low-contrast prime failed to produce any significant priming effect at the 15-ms ISI condition, $t(14) < 1$, but did so at the 30-ms ISI condition, $t(14) = 2.40$, $SE = 8.62$, whereas the high-contrast prime produced marginal priming effects at the 15-ms ISI condition, $t(14) = 1.95$, $SE = 6.52$, $p = .07$, and at the 30-ms ISI condition, $t(14) = 1.79$, $SE = 6.52$, $p = .09$; (c) similarly, in the relevant-mask condition, the low-contrast prime failed to produce any significant priming effect at the 15-ms ISI condition, $t(14) < 1$, but produced a marginal priming effect at the 30-ms ISI condition, $t(14) = 2.01$, $SE = 5.72$, $p = .06$, and the high-contrast prime failed to produce any significant priming at the 15-ms ISI condition, $t(14) < 1$, but did so at the 30-ms ISI condition, $t(14) = 3.81$, $SE = 5.76$.

Similar to participants in Experiment 2, participants in this experiment were overall 46 ms slower in no-mask trials (mean RT = 411 ms) than in masked trials (mean RT = 365 ms), $t(14) = 6.03$, $SE = 7.68$, which may partially account for the larger priming effect in the no-mask condition compared with the irrelevant-mask condition.

Experiment 4

This experiment tested the generality of mask-dependent priming at the other extreme: Only a single arrow was used as a prime, along with a single diamond shape as the relevant mask and a single pound sign as the irrelevant mask (see Figure 3).

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

Method

Primes were single-headed arrows, pointing either right or left. The relevant mask was a diamond obtained by attaching both primes by their tails. The irrelevant mask was a pound sign (two vertical and two horizontal lines) consisting of the same number of screen pixels as the diamond mask. Targets were still double-headed arrows as in previous experiments. In other words, unlike in previous experiments, in Experiment 4, the target was not identical to one of the primes. Similarly, Klapp and Hinkley (2002, Experiment 2) found an NCE in an experiment where the masks contained response-relevant features but the target did not correspond to either of the primes. It is important that we show such generality as well, except that we predict positive priming when irrelevant masks are used and negative priming when relevant masks are used.

In the prime identification phase, participants completed three blocks of 80 trials each. In the target identification phase, they completed seven blocks of 80 trials.

Results

Prime identification. Mean accuracy of prime identification is F7 shown in Figure 7A. As in the previous three experiments, accuracy increased with prime–mask interval, $F(3, 42) = 23.54$, $MSE = 0.01$, $\eta^2 = .63$, but unlike those experiments, this time the strength of masking did not differ significantly between relevant and irrelevant masks, $F(1, 14) = 2.81$, $p = .12$, perhaps due to a bad datum at 30 ms (a Type B error). The interaction of Mask Type × Prime–Mask Interval was not significant either, $F(3, 42) < 1$.

Target identification. Mean RT compatibility effects for target identification are shown in Figure 7B, with mean RTs and mean T4 proportion errors for all conditions shown in Table 4. There was significant positive RT priming in the no-mask condition, $t(14) = 4.53$, $SE = 8.88$, and a small amount of positive priming (4 ms, not significantly different from 0), in the irrelevant-mask condition, $t(14) < 1$. The negative 6-ms priming in the relevant-mask condition also failed to reach significance on its own, $t(14) = 1.26$, $p = .23$. However, a direct comparison of these two different priming effects was significant, $t(14) = 2.40$, $SE = 4.30$. In sum, even for this simplified stimuli, relevant and irrelevant masks yielded different compatibility effects.

For more detail, we used a repeated-measures ANOVA to examine three factors: ISI (45 ms and 90 ms), compatibility (compatible and incompatible), and mask type (relevant and irrelevant). This confirmed the two-way interaction of Compatibility × Mask Type, $F(1, 14) = 5.75$, $MSE = 138.96$, $\eta^2 = .29$. In addition, participants were overall 8 ms faster in responding on the irrelevant-mask trials (mean RT = 331 ms) than on relevant-mask trials (mean RT = 339 ms), $F(1, 14) = 26.76$, $MSE = 77.84$, $\eta^2 = .66$. ISI failed to reach significance, $F(1, 14) = 2.54$, $p = .13$. The three-way interaction Mask Type × Compatibility × ISI was not significant, $F(1, 14) < 1$. No other effects were significant either, all Fs < 1.

Similar to participants in Experiments 2 and 3, participants in Experiment 4 were overall 31 ms slower in no-mask trials (mean RT = 366 ms) than in masked trials (mean RT = 335 ms), $t(14) = 8.40$, $SE = 3.73$.

Discussion of Experiments 1–4

These first four experiments replicated the essential aspects of the NCE that have been reported previously (Eimer & Schlaghecken, 1998, 2002; Klapp & Hinckley, 2002). A briefly presented prime consisting of a directional arrow, followed by a mask consisting of a composite of the visual features contained in the two versions of the prime (whether exact replicas of the primes or only loosely assembled response-related features), results in the faster identification of a subsequent target resembling the prime that was not presented. In addition, the NCE was obtained under a variety of mask types, ranging from very simple masks presented in the identical spatial locations of the primes (Experiments 1 and 4) to masks that only resemble the features of the primes in quite abstract ways (they contain many line intersections) and that do not correspond directly to the spatial locations of the primes (Experiments 2 and 3).

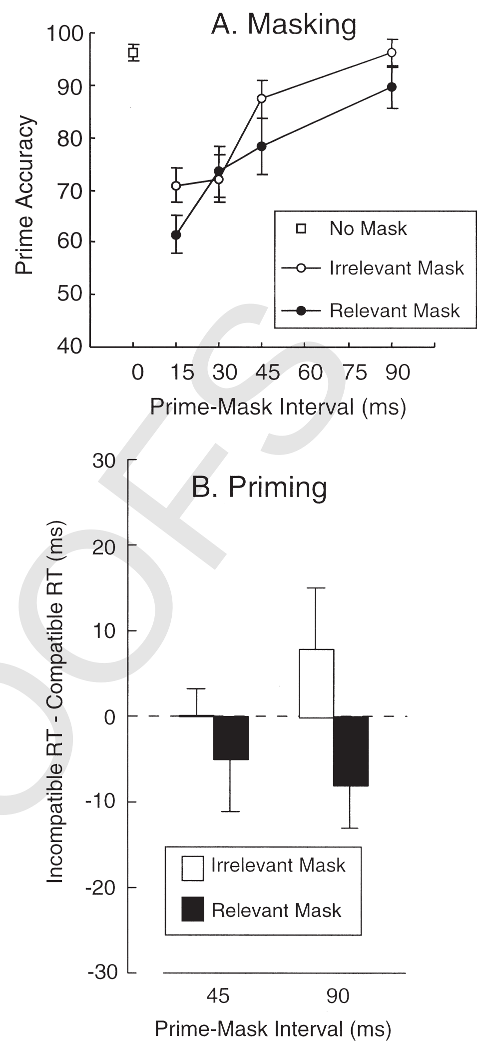

Figure 7. A: Mean prime accuracy in Experiment 4. B: Prime–target compatibility effects in Experiment 4. Standard error bars are ±1 standard error of the mean.

The finding that is not anticipated by existing accounts of the NCE, including Klapp and Hinckley's (2002) account based on the unconscious inhibition of response activation, is that the NCE is not obtained when the masks do not contain the visual features needed to distinguish the primes. In all of the conditions containing

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

Table 4
Mean Correct Response Time (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask Type in Experiment 4

Mask type and interval	Incompatible	Compatible	Priming
	Response time		
None			
240 ms	387 (9)	347 (9)	+40 (9)
Irrelevant			
45 ms	333 (7)	333 (8)	0 (4)
90 ms	333 (7)	325 (7)	+8 (7)
Relevant			
45 ms	338 (8)	343 (7)	−5 (6)
90 ms	334 (7)	342 (9)	−8 (5)
	Errors		
None			
240 ms	0.078	0.028	+.050
Irrelevant			
45 ms	0.025	0.037	−.012
90 ms	0.056	0.066	−.010
Relevant			
45 ms	0.028	0.049	−.021
90 ms	0.045	0.061	−.016

Note. Interval is the time between the offset of the prime and the onset of the following stimuli (the masks in masked trials, the target in no-mask trials). Standard errors are in parentheses.

irrelevant masks that we tested, the direction of influence between prime and target was positive, just as it was when no mask was presented at all (as is confirmed with a quick glance at Tables 1–4). It is important to note that the direction of the prime–target influence was constant across a large range of visibility levels for both types of mask: always negative in the case of relevant masks (with prime-visibility levels ranging from 58% in Experiment 3 to 92% in Experiment 2) and always positive in the case of irrelevant masks (with prime-visibility levels ranging from 59% in Experiment 3 to 96% in Experiment 4). This is consistent with our object updating hypothesis but not with the account based on unconscious inhibition.

To recap the unconscious inhibition account, it predicts that the NCE should be observed only in situations where unconscious processes are likely to win the competition over conscious processes, and this should occur most readily when the visibility of the prime is low. However, the present data speak against this proposal in three important ways. First, it is clear that a negative priming effect was always obtained when relevant masks were used, that is, both when prime visibility was relatively low (i.e., in the 15-, 30-, and 45-ms intervals) and when prime visibility was high (i.e., in the 90-ms interval). There were no significant differences in the size of this negative priming as a function of visibility in any of the four experiments. The one exception was Experiment 3, where the magnitude of the NCE actually increased with increased prime visibility, a relation that directly refutes Klapp and Hinkley's (2002) hypothesis that a larger NCE is to be expected with decreasing (not increasing) prime visibility. Reduced visibility of the prime is clearly not a necessary condition for the NCE.

Second, the design of all four experiments allowed the effects of the two masks to be compared at similar levels of prime visibility. Consider, for example, the data of Experiment 1. At the relevant-mask, 90-ms-ISI condition, Figure 4A, shows that the prime is highly visible and indeed comparable to the visibility of the prime in the absence of a mask, $t(14) = 1.67$. Yet, Figure 4B shows that there was negative RT priming in that condition, whereas positive RT priming was found in the no-mask condition. A similar comparison can be made in Figure 5 for the priming associated with a high-density relevant mask at 90 ms and an irrelevant mask of either low or high density at 45 ms; prime identification accuracy does not differ, $t(14) < 1.0$. Relevant and irrelevant masks lead to opposite priming effects at comparable levels of prime visibility.

The same relationship holds at low levels of prime visibility. Figure 6A shows that at the short prime–mask ISI, relevant and irrelevant masks yielded comparable levels of visibility. Yet, Figure 6B once again shows that there was positive priming in the irrelevant-mask condition and negative priming in the relevant-mask condition. Despite prime visibility being equated in all of the comparisons above, relevant masks were consistently associated with negative RT priming and irrelevant masks were consistently associated with positive RT priming. Surely some factor other than prime visibility is involved.

Third, the temporal interval is also not the predictive variable, as might be expected if unconscious inhibition depended on some specific prime–mask temporal relations. For example, at the same prime–mask intervals of 45 ms, in three experiments, negative priming was observed for relevant masks and either positive priming (Experiment 1–2) or no priming (Experiment 4) was observed for irrelevant masks. Interesting to note is that in the three experiments that used the same prime–mask ISI (Experiments 1, 2, and 4), ISI did not affect the magnitude of the priming effects (all three Fs < 1). Yet we still found the same pattern of negative priming with relevant masks and positive priming with irrelevant masks.

As a final check on the generality of this finding, we combined the data from these three experiments (collapsing across mask density in Experiment 2) and tested once again for the Mask Type × Compatibility interaction and the three-way Mask Type × Compatibility × ISI, in an attempt to detect any effect of ISI on the magnitude of the observed priming effects. The results were clear. The two-way interaction Mask Type × Compatibility was significant, $F(1, 42) = 65.33$, $\eta^2 = .61$, reflecting the different priming effects observed with the two types of masks. However, the three-way interaction with ISI was not significant, $F(1, 42) = 1.53$, $p = .22$. The between-subject variable of experiment did not modulate this three-way interaction, $F(2, 42) < 1$, although it did modulate the two-way interaction Mask Type × Compatibility, $F(2, 42) = 4.84$, $\eta^2 = .18$. This reflected the different magnitude of the priming effect across the three experiments in question. In sum, we are confident that ISI played no role in determining the direction of the priming effects in Experiments 1, 2, and 4. The finding of negative priming with relevant masks and positive priming with irrelevant masks generalizes to a wide range of visibility, prime–mask intervals, mask densities, and mask complexities.

Now reinspect Figure 2, which shows the masks used in previous studies of the NCE. Experiment 1 in our study directly addresses the studies where two superimposed primes were used as the mask (Eimer & Schlaghecken, 1998, 2002). Our Experiments

2 and 3 tested masks with scrambled oriented lines (relevant masks) or scrambled vertical and horizontal lines (irrelevant masks). Their results help us make sense of data from previous experiments where randomly oriented lines were used as masks (e.g., Aron et al., 2003; Schlaghecken & Eimer, 2000). We argue that the randomly oriented line masks in those studies behave just like our relevant masks in Experiments 2–4, simply because of the high likelihood of such masks containing relevant features on a large proportion of the trials.

We must also address the experiments in Klapp and Hinkley (2002) in which the letter masks *WXXW* and *XWWX* were used equally often. It is easy to see that the *WXXW* mask contains relevant features; in fact, the two juxtaposed *X*s contain exactly the same set of features as the two double-arrow primes together (an *X* is the juxtaposition of two single-headed arrows). The *XWWX* mask contains the same features, although in this case, they do not appear in the same spatial location as the prime features. But exact spatial overlap of relevant features in the prime and mask is not critical, as we have seen. The present Experiments 2–4 showed that updating could occur when features did not have precise spatial correspondence, provided that the prime and mask are interpreted as being the same perceptual object changing over time (see Lleras & Moore, 2003, for an extended discussion of this point). Thus, if the mask *XWWX* is interpreted as the next installment of the prime stimulus, because they both occur at the same general location and they are temporally contiguous, then object updating should occur and a negative priming effect should ensue. Finally, it is also worth noting that even if the relevant features in the *XWWX* mask were too distant in the Klapp and Hinkley study for effective updating to occur, the *XWWX* and *WXXW* masks were randomly intermixed in those experiments. As such, the NCE measured in Klapp and Hinkley's studies may actually be the average of a greater NCE from trials when the *WXXW* mask was used and a smaller one from the *XWWX* trials.

Another criticism that may be raised concerns our presentation of the primes and masks 1.5° eccentric from fixation. Perhaps this produced different prime–mask interactions than are produced by primes and masks that occur directly at fixation, where spatial acuity is greater. In support of this possibility, Schlaghecken and Eimer (2000, Experiment 1) failed to find an NCE when they presented participants with primes and masks 2.8° away from fixation, but they did find an NCE when the same stimuli were presented at fixation. This issue was the focus of a recent study by Vorberg and Lingnau (2004), who found that all differences in masked priming between central and parafoveal prime locations disappeared when the stimuli were cortically magnified to equate their visibility. Stimulus sequences that produced negative priming did so equally at both locations, as did stimulus sequences that produced positive priming. Also notable was the direction of the effects: Eccentric stimulus sequences tended to produce less (not more) negative priming. This suggests that there is likely little difference in the negative priming effects we observed when primes and masks were presented 1.5° away from fixation and those that would be observed at fixation. If anything, those at fixation would only be stronger.

One aspect of the results of Experiment 2 is worth noting before we continue. Some readers may be surprised that the density manipulation in Experiment 2 failed to influence prime visibility. But this is not unusual for pattern masking (e.g., Enns, 2003; Hellige et al., 1979; Schiller, 1965; Spencer & Shuntich, 1970). The effectiveness of a backward pattern mask does not lie in its energy relative to the prime stimulus but rather in its confusability at a feature and object level with the stimulus that it follows.

Experiments 5–6: New Features in the Mask Influence Target Identification

In the next two experiments, we tested the validity of two central premises of the object updating account of the NCE. These are (a) that new features of the mask stimulus can induce positive priming of the target under the stimulus and timing conditions used in typical NCE experiments and (b) that the strength of the priming influence of the new features in the mask is affected by the nature of the immediately preceding prime.

It is important to establish the validity of these two premises, because otherwise it might still be tempting to argue, in keeping with the unconscious inhibition account (Klapp & Hinkley, 2002), that although the prime is indeed responsible for the NCE in Experiments 1–4, it only has an influence under a more restricted set of conditions than was previously envisaged. From the perspective of the object updating account, this argument will become increasingly difficult to defend if it can be shown that primes and masks do indeed interact in the proposed way, even when there is no possibility of any direct target priming from the prime stimulus itself.

Experiment 5

This experiment tested a single task-relevant (but response-neutral) prime, consisting of a diamond shape, followed by a mask that included a composite of the prime with a superimposed directional arrow. These stimuli are shown in Figure 3. If target RT priming occurred under these conditions, it would clearly be tied to the influence of the new features in the mask rather than to any features in the prime.

Method

The prime was the same diamond that was used as a mask in Experiment 4. Mask stimuli were obtained by superimposing a single-headed arrow on top of the diamond prime. Two masks were created in this way: one containing a diamond with a superimposed arrow pointing left and one containing a diamond with a superimposed arrow pointing right, as shown in Figure 3. The targets were identical to those used in previous experiments and again appeared 100 ms after mask offset. The experiment consisted only of the target identification phase, which took approximately 35 min to complete (prime identification was unnecessary because only one prime was used). There were seven blocks of 80 trials.

Results

Mean RT compatibility effects for target identification are shown in Figure 8, with mean RTs and mean proportion errors for all conditions shown in Table 5. An ANOVA including mask–target compatibility and prime–mask interval revealed a Mask–Target Compatibility × Prime–Mask Interval interaction, $F(1, 14) = 18.51$, $MSE = 61.81$, $\eta^2 = .57$. This reflected that in addition to significant positive RT priming at both intervals, $F(1, 14) = 70.30$, $MSE = 413.77$, $\eta^2 = .83$, the priming was signifi- F8 T5

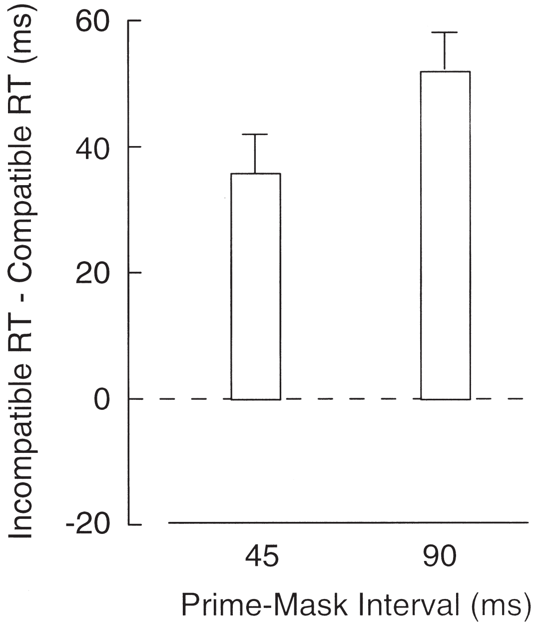

Figure 8. Mask–target compatibility effects in Experiment 5. Standard error bars are ±1 standard error of the mean.

cantly larger at the 90-ms than at the 45-ms interval. The main effect of prime–mask interval was marginal, $F(1, 14) = 4.31$, $p = .057$, with a shorter RT of 4 ms at the longer ISI.

Discussion

These results demonstrate an important proof of concept for the object updating hypothesis. New task-relevant visual features in the mask stimulus can result in positive priming for the target identification task under the same stimulus and timing conditions that normally produce the NCE when prime–target compatibility is being manipulated.

Experiment 6

In this experiment, participants viewed a sequence involving a task-relevant prime (a diamond shape) or a task-irrelevant prime (a pound sign) prior to the presentation of directional arrow masks. As in Experiment 5, any priming effects generated by this prime–mask sequence would have to be attributed to the mask, because the primes were both completely neutral with respect to any response to the target. However, because the primes now varied in task relevance (rather than the masks as in Experiments 1–4), if the mask-dependent priming was influenced by the nature of the prime stimulus, it would be additional support for the view that perceptual interactions among the prime and mask visual features were responsible for target priming in this paradigm.

These interactions might take the following form according to the object updating account. The appearance of one of the two primes would initiate iterative visual processing for the object at that location. However, the subsequent presentation of the mask, prior to the completion of the prime processing, would influence processing in different ways depending on the relation between the prime and the mask. Object updating should be easier to accomplish if the mismatch between the prime and mask stimulus is low, as in the relevant-prime condition. In contrast, the irrelevant-prime condition should result in a larger mismatch and a slower and more difficult object updating process (Moore & Lleras, in press). This account would therefore predict greater positive priming from the mask when it is preceded by the task-relevant prime stimulus.

Method

The primes were the diamond shape and pound sign shown in Figure 3. One fifth of trials contained no prime at all as a control condition. The masks were single-headed arrows, pointing either right or left, identical to the primes used in Experiment 4. RT compatibility was assessed by the relationship between masks and targets. The experiment consisted only of the target identification phase, seven blocks of 80 trials, which took approximately 35 min to complete.

Results

Mean RT compatibility effects for target identification are shown in Figure 9, with mean RTs and mean proportion errors for F9
all conditions shown in Table 6. ANOVAs including mask–target T6
compatibility, prime type, and prime–mask interval revealed a significant interaction of Prime Type × Mask–Target Compatibility, $F(1, 14) = 5.21$, $MSE = 118.40$, $\eta^2 = .27$, indicating that the generally significant positive mask–target priming, $F(1, 14) = 8.11$, $MSE = 1659.76$, $\eta^2 = .37$, was strongest when the response-neutral prime preceding the mask contained task-relevant visual features (mean RT priming of 26 ms) than when it did not (mean RT priming of 17 ms).

In addition to this main findings, the ANOVA revealed generally larger priming effects at prime–mask intervals of 90 ms (mean RT priming of 28 ms) than at 45 ms (mean RT priming of 14 ms), $F(1, 14) = 4.69$, $MSE= 280.92$, $\eta^2 = .25$. Prime type had a marginal effect on performance, $F(1, 14) = 3.90$, $p = .07$, reflecting a 4-ms tendency for faster responses following irrelevant primes. Last, the three-way interaction Mask–Target Compatibil-

Table 5
Mean Correct Response Time (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask-Target Relation in Experiment 5

	Mask–target relation		
Interval	Incompatible	Compatible	Priming
	Response time		
45 ms	397 (9)	362 (9)	+35 (6)
90 ms	402 (8)	349 (10)	+53 (6)
	Errors		
45 ms	0.031	0.009	+.022
90 ms	0.033	0.009	+.024

Note. Interval is the time between the offset of the prime and the onset of the mask. Standard errors are in parentheses.

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

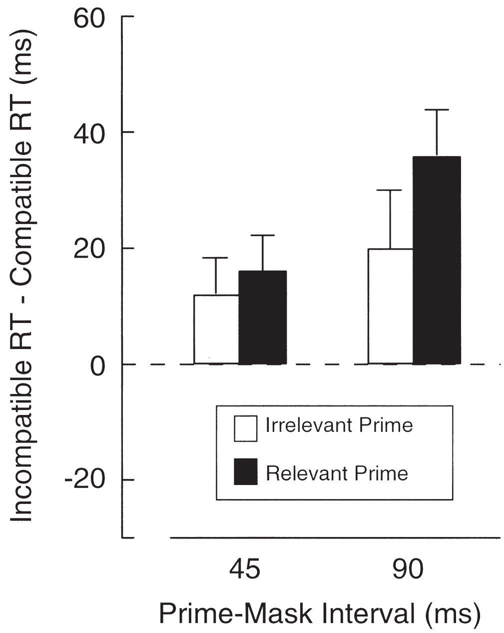

Figure 9. Mask–target compatibility effects in Experiment 6. Standard error bars are ±1 standard error of the mean.

ity × Prime Type × Prime–Mask Interval did not reach significance either, $F(1, 14) = 2.07$, $p = .17$.

Discussion

These results revealed positive priming from the new mask features, just as in Experiment 5. However, their unique contribution was that priming was stronger when the mask was preceded by a very brief prime containing task-relevant features, as predicted by the object updating hypothesis. In contrast to previous NCE experiments, including the present Experiments 1–4, this result shows that prime–mask features do interact in producing the priming effect on target identification. This is because there is no possible explanation of the priming in this experiment arising from the prime itself.

Note that primes in this experiment, as well as in previous experiments, were only present at a single location and then for only 15 ms. This is in contrast to the mask, which was presented in two locations and then remained on the screen for 120 ms. Yet mask–target compatibility effects were still influenced by the nature of the visual features in the prime. This result provides definitive evidence that prime–mask interactions play a role in target identification in this paradigm.

The finding that mask–target RT priming is greater following relevant primes as compared with irrelevant primes fits well with Moore and Lleras (in press). Because relevant primes contain the features of both possible masks, when the arrow mask is presented, very little updating of the object at that location is required. This effectively means that the relevant primes provide a head start in the processing of the directional masks even though, when considered on their own, they appear to be unable to bias target processing.

Experiment 7: Time Course of the Prime–Mask Interaction

In this experiment, we studied the temporal course of prime–mask interactions by systematically varying the duration of the mask rather than the blank prime–mask interval that researchers in most previous studies of the NCE have investigated. The rationale follows directly from the object updating hypothesis: If the perception of an object involves a time-consuming, iterative updating process, then the influence of the mask on target identification should be increasingly evident as more time can be devoted to the processing of the mask.

Previous studies of backward masking in which the duration of the mask has been systematically varied have shown that masking is indeed monotonically related to mask duration (e.g., Di Lollo et al., 2000; Enns, 2002; Turvey, 1973). In particular, the mask becomes increasingly effective as its duration is increased. According to the object updating hypothesis, this comes about because the iterative processes involved in object identification are increasingly likely to converge on the mask as the object of perception rather than any preceding stimulus, as more opportunity is given for the mask object to be processed. In the present experiment, we were interested in finding out for how long the process of mask identification was vulnerable to the influences of the preceding prime stimulus. We were also interested in whether the time course of interactions would be different for relevant or irrelevant masks.

Table 6
Mean Correct Response Times (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Prime Type in Experiment 6

Prime type and interval	Incompatible	Compatible	Priming
	Response time		
None			
270 ms	381 (12)	362 (9)	+19 (8)
Irrelevant			
45 ms	361 (12)	348 (9)	+13 (7)
90 ms	364 (13)	344 (10)	+20 (11)
Relevant			
45 ms	368 (11)	352 (10)	+16 (7)
90 ms	374 (13)	339 (8)	+35 (9)
	Errors		
None			
240 ms	0.017	0.016	+.001
Irrelevant			
45 ms	0.033	0.029	+.004
90 ms	0.063	0.031	+.032
Relevant			
45 ms	0.036	0.029	+.007
90 ms	0.076	0.027	−.049

Note. Interval is the time between the offset of the prime and the onset of the following stimuli (the masks in masked trials, the target in no-mask trials). Standard errors are in parentheses.

Method

A total of 30 undergraduate students participated in the experiment, 15 randomly assigned to each of two groups: a relevant-mask group and an irrelevant-mask group. This was done to keep the testing session under 1 hr while still getting sufficient observations per data point. The interval between prime and mask was fixed at 30 ms. Mask duration was chosen randomly on each trial and could be 0 ms (no mask), 8 ms, 45 ms, 83 ms, or 120 ms. The interval between mask and target was fixed at 100 ms. Testing consisted of six blocks of 40 trials in prime identification and 12 blocks of 40 trials in target identification.

Results

Prime identification. Mean accuracy of prime identification is
F10 shown in Figure 10A. Accuracy decreased with mask duration, $F(4, 112) = 73.95$, $MSE = 0.004$, $\eta^2 = .72$, and mask type interacted with duration, $F(4, 112) = 25.78$, $MSE = 0.004$, $\eta^2 = .48$. Specifically, relevant masks reduced the visibility of the prime more efficiently than irrelevant masks did at all durations: 0 ms, $t(28) = 3.20$, $SE = 0.02$; 8 ms, $t(28) = 2.60$, $SE = 0.03$; 45 ms, $t(28) = 9.41$, $SE = 0.03$; 83 ms, $t(28) = 8.98$, $SE = 0.03$; and 120 ms, $t(28) = 9.19$, $SE = 0.03$.

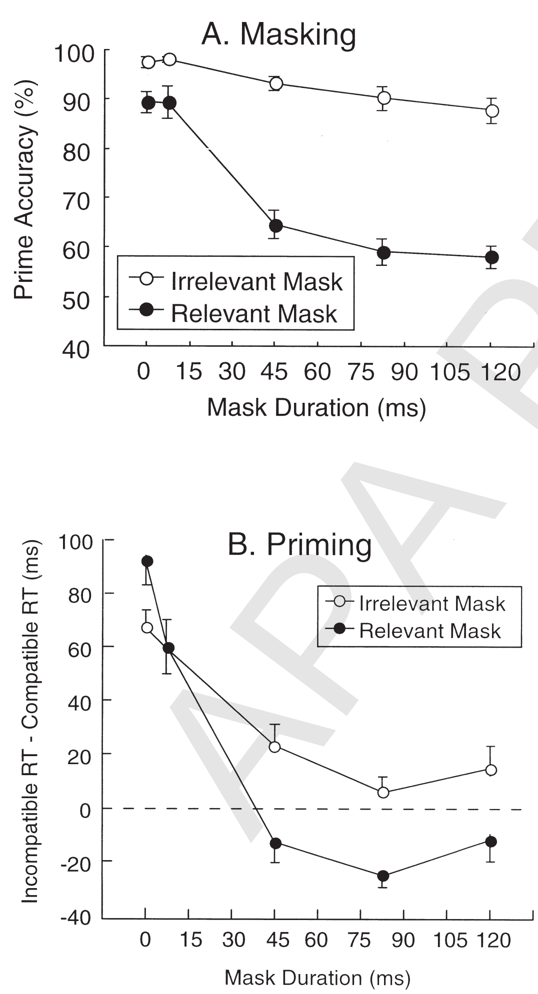

Figure 10. A: Mean prime accuracy in Experiment 7. B: Prime–target compatibility effects in Experiment 7. Standard error bars are ±1 standard error of the mean.

Target identification. Mean RT compatibility effects for target identification are shown in Figure 10B, with mean RTs and mean proportion errors for all conditions shown in Table 7. ANOVAs T7
included mask duration and prime–target compatibility as within-subjects factors and mask type as a between-subjects factor. This revealed a significant interaction of mask duration and prime–target compatibility, $F(4, 112) = 81.01$, $MSE = 288.18$, $\eta^2 = .74$, reflecting the expected finding that prime–target priming effects decreased in size as the duration of the intervening mask was increased. However, there was also a three-way interaction of Mask Type × Mask Duration × Prime–Target Compatibility, $F(4, 112) = 8.24$, $MSE = 288.18$, $\eta^2 = .23$, which reflected that mask duration had a different effect on target priming, depending on whether the mask was relevant or irrelevant. We explored this interaction with a comparison of the priming effects at several different mask durations.

When no masks were presented at all (0-ms duration), large positive priming effects occurred for both relevant masks, $t(14) = 10.78$, $SE = 8.67$, and irrelevant masks, $t(14) = 8.14$, $SE = 8.34$. In addition, there was a significant difference favoring greater priming in the relevant-mask condition, $t(28) = 2.12$, $SE = 12.04$. Because this difference could not be attributed to the mask appearing on that trial (there was none), it had to arise from the context of seeing relevant versus irrelevant masks on the other trials. Apparently, for those participants in the relevant-mask group, simply being in the context of seeing many relevant masks boosted the positive prime–target influence observed in the no-mask condition. Perhaps participants in the relevant-mask group took better advantage of the prime information in the no-mask trials because on masked trials they had a much harder time seeing the prime than did participants in the irrelevant-mask group (see Figure 10A).

At the shortest mask duration of 8 ms, relevant- and irrelevant-mask conditions produced the same high degree of positive priming between prime and target, $t(14) = 6.52$, $SE = 9.2$, and $t(14) = 6.74$, $SE = 8.88$, respectively, which did not differ with mask type, $t(28) < 1$. At the three longer mask durations (45, 83, and 120 ms), the two mask types resulted in qualitatively different priming effects once again. The irrelevant-mask condition resulted in significant positive masking at these mask durations, $t(14) = 5.54$, $SE = 2.77$, which did not differ significantly from one another, $F(2, 28) = 2.01$, $p = .15$. In contrast, the relevant-mask condition yielded significant negative priming at these mask durations, $t(14) = 4.05$, $SE = 3.55$, which also did not differ significantly from each other, $F(2, 28) = 2.22$, $p = .13$.

Discussion

On the one hand, this experiment showed that the positive priming associated with a briefly presented prime was systematically diminished as evidence for the mask accumulated in the visual system over a period of 40–50 ms. This is exactly what would be expected on an object updating account, as the perceptual strength of the emerging prime object slowly gave way to a relatively stronger mask object. When the mask duration was increased beyond 40 ms, positive priming was still evident in the irrelevant-mask condition, presumably because no other task-

Table 7
Mean Correct Response Times (in Milliseconds), Mean Proportion Errors, and Mean Priming (Incompatible − Compatible) as a Function of Mask Type and Mask Duration in Experiment 7

Mask type and duration	Incompatible	Compatible	Priming
	Response time		
Irrelevant			
0 ms	572 (13)	504 (16)	+68 (8)
7.5 ms	532 (11)	472 (15)	+60 (9)
45 ms	535 (12)	512 (13)	+23 (6)
82 ms	562 (12)	556 (13)	+6 (4)
120 ms	607 (15)	589 (16)	+18 (7)
Relevant			
0 ms	556 (13)	462 (16)	+94 (9)
7.5 ms	510 (11)	450 (15)	+60 (9)
45 ms	503 (12)	513 (13)	−10 (6)
82 ms	521 (12)	544 (13)	−23 (4)
120 ms	563 (15)	573 (16)	−10 (7)
	Errors		
Irrelevant			
0 ms	0.194	0.008	+.186
7.5 ms	0.161	0.015	+.146
45 ms	0.085	0.037	+.048
82 ms	0.064	0.047	+.027
120 ms	0.050	0.047	+.003
Relevant			
0 ms	0.218	0.006	+.212
7.5 ms	0.190	0.019	+.171
45 ms	0.037	0.063	−.026
82 ms	0.043	0.099	−.056
120 ms	0.053	0.065	−.012

Note. Standard errors are in parentheses.

relevant features had been perceived since the prime was presented. Prime features were spared from object updating by the irrelevant mask, in our view, because of the dissimilarity between the prime and mask.

On the other hand, at these same durations, the relevant mask was able to produce what appeared to be a negative priming relationship between primes and targets. However, given the evidence presented in Experiments 1–6, this is more readily interpreted as positive priming based on the new features present in the task-relevant mask. The fact that it takes these features more than 40 ms to emerge as effective priming stimuli is completely consistent with the iterative nature proposed to be underlying object formation and updating (Di Lollo et al., 2000; Enns, 2002; Enns & Di Lollo, 1997).

The results of Experiment 7 are also informative, as they address a possible alternative account regarding the prime–mask interactions in our experiments, namely, that of forward masking. Is it possible that the NCE reflects a forward masking effect of the prime stimulus on the mask, thereby reducing the visibility of some aspects of the mask? For example, a left-pointing arrow prime might reduce the visibility of the left-pointing part of the subsequent mask, biasing a perception of the right-pointing features in the mask. Although this may seem plausible at first glance, several aspects of our data speak against it. First of all, the pattern of results in Experiment 7 contradicts what would be expected if forward masking were at play. Indeed, one would expect that forward masking would be most effective at relatively short mask durations (because the prime would then be more likely to interfere with the processing of the mask) and least effective at longer mask durations (where the mask representation would be more robust). One would therefore expect the most negative priming at short mask durations (where forward masking is most effective) and most positive priming at longer masks durations (where forward masking is least effective). But Experiment 7 shows the reverse: There is positive priming at short mask durations and only negative priming once mask duration extends beyond 45 ms.

Second, forward masking has been shown to be very short-lived, extending only to an ISI of 50 ms between what we here call prime and mask (see Breitmeyer, 1984, for an extensive review). In contrast, the present Experiments 1, 2, and 4 showed identical or even larger NCE effects with an ISI of 90 ms (where forward masking should not be an issue) and an ISI of 45 ms (where it would be predicted to be much stronger).

Finally, it is difficult to understand how forward masking could account for the results we obtained with more abstract masks in Experiments 2 and 3. In those experiments, (a) there was no direct spatial correspondence of prime and mask contours, which are necessary for forward masking to be effective, and (b) the masks contained many more visual features than the primes did. In sum, after seriously considering the possibility of forward masking, we decided it seems unlikely that it played an important role in these priming effects.

General Discussion

The NCE refers to the finding that a visual target that follows a brief prime–mask stimulus sequence can be identified more rapidly when it is opposite rather than identical to the prime. In the present study, we examined this effect from the perspective of the updating process that normally accompanies the perception of dynamic objects (Di Lollo et al., 2000; Lleras & Moore, 2003; Moore & Enns, in press; Moore & Lleras, in press).

A critical prediction that follows from this perspective is that the NCE should only be observed when the masks that are used contain features relevant to the target identification task. This is because the primary task of target identification prepares the observer's visual input and motor response systems to distinguish stimuli on the basis of their distinctive features (i.e., the features of right- and left-pointing arrows in the present experiments). When the prime–mask sequence of stimuli is presented immediately before the target, the iterative perceptual processes that have been engaged for target identification inadvertently begin processing this sequence. This results in an initial activation of the features presented in the prime, followed by an updating of the task-relevant features present in the mask. If these most recently updated features are opposite to those in the prime, as they surely are when the mask is a composite of both primes, then the system is best prepared to process the target containing features opposite to those in the prime.

The prediction that the NCE would only be observed when the masks were composed of task-relevant features was consistently confirmed in this study under a wide range of masking conditions

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | Art: 1

(Experiments 1–4). Two experiments then demonstrated the validity of two central premises of the object updating hypothesis (Experiments 5–6). The first premise was that the new task-relevant features contained in a mask could induce positive priming of the target, even when the prime itself contained no biasing features. The second premise was that mask features do not prime the target identification task in isolation but that they interact with the features in the prime in their ultimate influence.

Finally, results were presented to document the temporal course of prime–mask interactions in the NCE (Experiment 7). When a prime stimulus was presented in isolation, the features contained in the prime governed the influence on the target identification task. As the prime was followed by a mask stimulus of graduated duration from 0 to 45 ms, the influence of the prime began to wane accordingly. When the mask consisted of task-irrelevant features, only a weak influence of the prime could be measured beyond 40 ms of mask duration. However, when the mask contained task-relevant features, these features were able to influence target identification, provided they had been on view for a period of more than 40 ms. Taken together, these results point to a coherent account of the NCE that is based on the rather ordinary mechanisms of perceptual updating rather than on the inhibition of unconsciously activated responses.

Object Updating and Previous Findings

In addition to arguing strongly against the NCE being based on unconscious inhibition, we must reconcile the object updating account with other notable features of the NCE outlined in previous articles. For example, one of the most striking findings of Klapp and Hinckley (2002) was the observation that an NCE could be obtained in a task involving both visual targets (arrows) and auditory targets (tones) that were presented unpredictably from trial to trial. From the perspective of object updating, it is important to note that a relevant mask still always followed each prime. This means that the updating process we propose could still occur in this experiment, because until the target arrived (either visual or auditory), the observer had to be prepared for a visual target. This preparation would lead to the processing of the prime–mask features as carriers of task-relevant information, which in turn would activate the corresponding motor responses associated with those features.

In a similar vein, it is not surprising that even when no target was presented at the end of some stimulus sequences, as in Klapp and Hinkley's (2002) Experiment 5, participants showed a tendency to select a response that was opposite to the prime. This follows because it is this opposite-to-prime tendency, coming from the new features in the mask, that yields the NCE on trials when targets are presented. It is our prediction that these same experiments, if conducted with irrelevant masks, would now produce positive priming results, just as the irrelevant masks did in the present study.

Finally, it is important to note that the object updating account is able to explain priming without any masks at all, priming with irrelevant masks, and priming with relevant masks using the same small set of principles. These include the ideas that preparation for a visual task involves configuring the visual system to process certain features and to link these features to the potential responses and that perceptual processing involves iterative updating of object representations as new information becomes available.

Object Updating and Response Links

Understood in this way, the priming effects explored in this study also point to a novel implication for the understanding of the object updating process as it concerns visually guided action. Research to date has focused primarily on how the updating process affects the perception of masked targets. In particular, the results have pointed to a process in which the perceptual attributes of the object-level representation of a target have been updated with features that actually belong to the mask, thereby resulting in low accuracy in target identification (e.g., Di Lollo et al., 2000; Enns, 2002). The experiments presented here suggest yet another aspect of object updating. In addition to updating the visual attributes of an object representation, the same process also updates any links that have been established between an object representation and its associated motor responses.

Furthermore, the present findings suggest that motor-response updating occurs in an ongoing way. It does not occur only after a stable object representation has been formed. If it did, no priming would be observed in the case of irrelevant masks, because these contain no response-relevant features, and no priming would be observed in the case of relevant masks either, because the stable representation of these objects contains equally strong links to the two responses. Instead, the data suggest that perceptual and motor updating occur together, with each kind of update being based on the new features that have been detected most recently in the display.

The findings from Experiment 7 are especially telling in this regard. When a prime was presented in isolation, the features of the prime governed the influence on target identification, suggesting that a link between the prime features and one of the responses was established on the basis of that brief event. As conditions were tested in which the prime was followed by masks of longer duration, the influence of the prime began to wane. This is either because the features of the irrelevant mask were replacing the previously acquired feature information and weakening the previously acquired response link or because the new features of the relevant mask had updated the representation and these features were then linked to the alternative response.

It is of interest to us that electrophysiological data recorded by Eimer and Schlaghecken (1998) can be interpreted as direct support for this hypothesis. These authors measured the lateralized readiness potential (LRP), which is widely regarded as a reliable index of response preparation, while participants performed essentially the same task as in our Experiment 1 (but only with relevant masks). An example figure from their study is shown in Figure 11. F11
A notable feature of these data is that, on presentation of the prime and mask to participants, the LRP showed an initial tendency to prepare the response indicated by the prime. That is, compatible primes led to an early burst of response-related preparation of the correct response, whereas incompatible primes led to an early burst of response-related preparation of the incorrect response (see LRP activity between 200 and 300 ms in Figure 11). After this initial burst of activity that lasted about 100 ms, the LRP signal reversed and began to show activity consistent with the response opposite to the prime (i.e., compatible prime trials showed preparation of

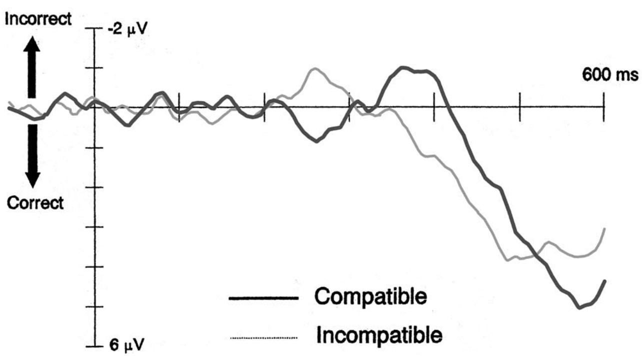

Figure 11. Lateralized readiness potentials for compatible and incompatible trials from Experiment 2 of Eimer and Schlaghecken (1998). Reprinted from "Effects of Masked Stimuli on Motor Activation: Behavioral and Electrophysiological Evidence" by M. Eimer and F. Schlaghecken, 1998, *Journal of Experimental Psychology: Human Perception and Performance, 24,* p. 1743. Copyright 1998 by the American Psychological Association.

incorrect responses and incompatible prime trials showed preparation of correct responses). With enough time, participants were able to correctly respond on most trials, but they were faster to reach the response threshold when the trial began with a prime opposite to the target because of this late reversal in response preparation.

The fact that these LRP data show two distinct phases of response preparation, with the first being a same-as-prime tendency followed shortly thereafter by an opposite-to-prime tendency, is in complete agreement with our account of response links being updated in an ongoing way. Furthermore, the presence of these two response activations is in direct contradiction to Klapp and Hinkley's (2002) account based on unconscious inhibition. Response inhibition would be exhibited in LRP signals by a reduction or by a delay in the onset of motor-preparation activity rather than by the preparation of one specific response that is opposite to the "suppressed" response.

It is important to acknowledge that we are not the first to think of masked priming in terms of perceptual information in a masked stimulus leading to updating of motor response preparation. According to the direct parameter specification model (Neuman, 1990a, 1990b; Scharlau & Ansorge, 2003; Scharlau & Neumann, 2003), once a particular stimulus–response mapping has been established, based on the intention of the observer, new features and objects that are relevant to this mapping are rapidly and continuously updated without conscious awareness. As in the object substitution theory, the updating involves overwriting earlier information that shares a spatial location and other critical information (e.g., similar contours and colors). However, unlike the object substitution theory, which is aimed at explaining what observers are aware of, the direct parameter specification model is aimed at explaining how observers are able to act rapidly on the basis of stimuli they are unable to see or see only dimly.

An interesting prediction that follows from the direct parameter specification model is that response priming based on continuous updating will only occur once a strong stimulus–response mapping (specific visual features mapped to specific responses) has been established. Strongly compatible stimuli and responses have been a feature of all previous NCE studies, including this one, where the preexisting and overlearned mapping between arrows and spatially corresponding responses have been exploited. We have begun pilot experiments in our lab to examine this question. For example, in one experiment, portions of the pound sign were used as primes and targets so that the previously relevant masks (oblique lines) and irrelevant masks (vertical and horizontal lines) could be reversed in their roles. However, we observed little priming of any kind (positive or negative) and RT was generally slower, suggesting that the priming effects under study in the NCE require well-established links between visual features and their associated responses. This issue clearly deserves more careful consideration than it has been given it so far.

In summary, two different aspects of vision seem to be at play in the NCE, consistent with the now widely held distinction between vision for conscious perception and vision for action (Goodale & Humphreys, 1998; Milner & Goodale, 1995). When considering the results in the prime identification task (i.e., low prime visibility), one must appeal to a theory that deals with the conscious perception of stimuli. Object updating, as understood within the framework of object substitution masking, is such a theory. Its main goal is to explain how a briefly perceived and then masked stimulus is processed by the visual system and to determine whether this processing will lead to awareness of the stimulus. However, when considering the results in the target identification task, one must appeal to a theory that deals with the relationship between briefly presented stimuli and response selection. Here we have shown that object updating can be such a theory when it is extended to include aspects of response selection within its scope. However, extending it in this way does mean that some simple assumptions about the roles of task set, feature relevance, and stimulus–response mapping must be added to what has been proposed so far regarding conscious perception (Di Lollo et al., 2000; Lleras & Moore, 2003).

Explanatory Limits of the Object Updating Account

It is important to be specific about what we believe are the explanatory limits of our object updating account. Although we provide it as a direct challenge to the unconscious inhibition account of the NCE by Klapp and Hinkley (2002), it is not meant to challenge all claims of unconscious inhibition nor to challenge the notion of unconscious processes in general. Myriad studies have documented aspects of unconscious perception (e.g., Goldiamond, 1958; Marcel, 1983; for reviews see Merikle & Daneman, 1998; Ortells, Daza, & Noguera, 2002), and those studies have been challenged and scrutinized elsewhere (e.g., Merikle & Reingold,1998; Snodgrass, 2002).

We also do not claim that all negative priming effects can be accounted for in terms of object updating. In the well-known negative priming paradigm, for example, two overlapping objects are presented simultaneously in two different colors (say green and blue), and the participants' task is to report the identity of one of the two objects on the basis of its color (e.g., report the green object) while ignoring the second object. Negative priming in this context is the finding that reporting the identity of a target shape takes longer when that shape had been ignored in a preceding trial than when it had not been previously ignored (e.g., Fox, 1995; Moore, 1994; Tipper, 1985). Under such circumstances, object updating likely plays little, if any, role in the determination of priming.

Conclusion

The present results are not consistent with the view that the NCE reflects the operation of automatic unconscious inhibitory processes in competition with controlled conscious excitatory processes (Klapp & Hinkley, 2002). Instead of proposing a competition between two mechanisms to account for positive and negative priming results, we have proposed that these two seemingly opposite results can be explained by a single process that constantly reviews and updates visual representations and their associated response links in order to reflect the changing nature of the environment.

As a cautionary note, we point out that although visual masking is a rich and powerful tool, one should not use it without properly considering the effects that masks have on visual processes. Although a backward mask can indeed lower the visibility of a preceding stimulus, such as the prime stimulus in NCE experiments, it will do so in predictable ways. One of these ways is through the rapid updating of information that appears to derive from the same object, which in this case is the prime–mask sequence.

References

Aron, A. R., Schlaghecken, F., Fletcher, P. C., Bullmore, E. T., Eimer, M., Barker, R., et al. (2003). Inhibition of subliminally primed responses is mediated by the caudate and thalamus: Evidence from functional MRI and Huntington's disease. *Brain, 126,* 713–723.

Bar, M., & Biederman, I. (1998). Subliminal visual priming. *Psychological Science, 9,* 464–469.

Breitmeyer, B. G. (1984). *Visual masking: An integrative approach*. New York: Oxford University Press.

Di Lollo, V., Enns, J. T., & Rensink, R. A. (2000). Competition for consciousness among visual events: The psychophysics of reentrant visual processes. *Journal of Experimental Psychology: General, 129,* 481–507.

Di Lollo, V., von Mühlenen, A., Enns, J. T., & Bridgeman, B. (2004). Decoupling stimulus duration from brightness in metacontrast masking: Data and models. *Journal of Experimental Psychology: Human Perception and Performance, 30,* 733–745.

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

Eimer, M., & Schlaghecken, F. (2001). Response facilitation and inhibition in manual, vocal, and oculomotor performance: Evidence for a modality-unspecific mechanism. *Journal of Motor Behavior, 33,* 16–26.

Eimer, M., & Shlaghecken, F. (2002). Links between conscious awareness and response inhibition: Evidence from masked priming. *Psychonomic Bulletin & Review, 9,* 514–520.

Eimer, M., Schubo, A., & Schlaghecken, F. (2002). Locus of inhibition in the masked priming of response alternatives. *Journal of Motor Behavior, 34,* 3–10.

Enns, J. T. (2002). Visual binding in the standing wave illusion. *Psychonomic Bulletin & Review, 9,* 489–496.

Enns, J. T. (2003). Object substitution and its relation to other forms of visual masking. *Vision Research, 44,* 1321–1331.

Enns, J. T., & Di Lollo, V. (1997). Object substitution: A new form of masking in unattended visual locations. *Psychological Science, 8,* 135–139.

Enns, J. T., & Di Lollo, V. (2000). What's new in visual masking? *Trends in Cognitive Sciences, 4,* 345–352.

Enns, J. T., & Rensink, R. A. (1992). VScope: Vision testing software for the Macintosh [Computer software]. Vancouver, British Columbia, Canada: Micropsych Software.

Fiser, J., & Biederman, I. (2001). Invariance of long-term visual priming to scale, reflection, translation, and hemisphere. *Vision Research, 41,* 221–234.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 39A,* 211–251.

Fox, E. (1995). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review, 2,* 145–173.

Goldiamond, I. (1958). Indicators of perception: I. Subliminal perception, subception, unconscious perception: An analysis in terms of psychophysical indicator methodology. *Psychological Bulletin, 55,* 373–411.

Goodale, M. A., & Humphreys, G. K. (1998). The objects of perception and action. *Cognition, 67,* 181–207.

Hellige, J. B., Walsh, D. A., Lawrence, V. W., & Prasse, M. (1979). Figural relationship effects and mechanisms of visual masking. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 88–100.

James, T. W., Humphrey, G. K., Gati, J. S., Menon, R. S., & Goodale, M. A. (2000). The effects of visual object priming on brain activation before and after recognition. *Current Biology, 10,* 1017–1024.

Jiang, Y., & Chun, M. M. (2001a). Asymmetric object substitution masking. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 895–918.

Jiang, Y., & Chun, M. M. (2001b). The spatial gradient of visual masking by object substitution. *Vision Research, 41,* 3121–3131.

Kinsbourne, M., & Warrington, E. K. (1962). Further studies on the masking of brief visual stimuli by a random pattern. *Quarterly Journal of Experimental Psychology, 14,* 235–245.

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.

Leuthold, H., & Kopp, B. (1998). Mechanisms of priming by masked stimuli: Inferences from event-related potentials. *Psychological Science, 9,* 263–269.

Lleras, A., & Moore, C. M. (2003). When the target becomes the mask: Using apparent motion to isolate the object-level component of object substitution masking. *Journal of Experimental Psychology: Human Perception and Performance, 29,* 106–120.

Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and recognition. *Cognitive Psychology, 15,* 197–237.

Merikle, P. M., & Daneman, M. (1998). Psychological investigations of unconscious perception. *Journal of Consciousness Studies, 5,* 5–18.

Merikle, P. M., & Reingold, E. M. (1998). On demonstrating unconscious perception: Comment on Draine and Greenwald (1998). *Journal of Experimental Psychology: General, 127,* 304–310.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.

Moore, C. M. (1994). Negative priming depends on probe-trial conflict: Where has all the inhibition gone? *Perception & Psychophysics, 56,* 133–147.

Moore, C. M., & Enns, J. T. (in press). Object substitution and the flash-lag effect. *Psychological Science*.

Moore, C. M., & Lleras, A. (in press). On the role of object representations in substitution masking. *Journal of Experimental Psychology: Human Perception and Performance.*

Neill, W. T., Hutchison, K. A., & Graves, D. F. (2002). Masking by object substitution: Dissociation of masking and cuing effects. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 682–694.

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

Neumann, O. (1990b). Visual attention and action. In O. Neumann & W. Prinz (Eds.), *Relationships between perception and action: Current approaches* (pp. 227–267). New York: Springer.

O'Connor, K. J., & Potter, M. C. (2002). Constrained formation of object representations. *Psychological Science, 13,* 106–111.

Ortells, J. J., Daza, M. T., & Noguera, C. (2002). Perception without awareness: The qualitative differences approach. In S. P. Shohov (Ed.), *Advances in psychology research* (Vol. 16, pp. 3–26). New York: Nova Science.

Potter, M. C. (1999). Understanding sentences and scenes: The role of conceptual short-term memory. In V. Coltheart (Ed.), *Fleeting memories: Cognition of brief visual stimuli* (pp. 13–46). Cambridge, MA: MIT Press.

Scharlau, I., & Ansorge, U. (2003). Direct parameter specification of an attention shift: Evidence from perceptual latency priming. *Vision Research, 43,* 1351–1363.

Scharlau, I., & Neumann, O. (2003). Perceptual latency priming by masked and unmasked stimuli: Evidence for an attentional interpretation. *Psychological Research, 67,* 184–196.

Schiller, P. H. (1965). Monoptic and dichoptic visual masking by patterns and flashes. *Journal of Experimental Psychology, 69,* 193–199.

Schlaghecken, F., & Eimer, M. (2000). A central–peripheral asymmetry in masked priming. *Perception & Psychophysics, 62,* 1367–1382.

Schlaghecken, F., & Eimer, M. (2001). Partial response activation to masked primes is not dependent on response readiness. *Perceptual Motor Skills, 92,* 208–222.

Schlaghecken, F., & Eimer, M. (2002). Motor activation with and without inhibition: Evidence for a threshold mechanism in motor control. *Perception & Psychophysics, 64,* 148–162.

Snodgrass, M. (2002). Disambiguating conscious and unconscious influences: Do exclusion paradigms demonstrate unconscious perception? *American Journal of Psychology, 115,* 545–579.

Spencer, T. J., & Shuntich, R. (1970). Evidence for an interruption theory of backward masking. *Journal of Experimental Psychology, 85,* 198–203.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 37A,* 571–590.

Turvey, M. T. (1973). On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with patterned stimuli. *Psychological Review, 81,* 1–52.

Vorberg, D., & Lingnau, A. (2004). *The time-course of response priming and inhibition: Cortical magnification accounts for central–peripheral asymmetries in masked priming*. Manuscript submitted for publication.

Received October 20, 2003
Revision received April 15, 2004
Accepted April 21, 2004 ■

tapraid1/zfr-xge/zfr-xge/zfr00404/zfr0389d04g | yodert | S=6 | 9/16/04 | 8:26 | 4/Color Figure(s): | Art: 1

EQ1—Ed: Milliseconds okay as set cap and lowercase? See thruout tables.