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Attention, intention and domain-specific processing

Matthew Finkbeiner[1] and Kenneth I. Forster[2]

[1] Macquarie Centre for Cognitive Science, Macquarie University, Sydney, NSW 2109, Australia
[2] Department of Psychology, University of Arizona, Tucson, AZ, 85721, USA

Many researchers use subliminal priming to investigate domain-specific processing mechanisms, which have classically been defined in terms of their autonomy from other cognitive systems. Surprisingly, recent research has demonstrated that nonconsciously elicited cognitive processes are not independent of attention. By extension, these findings have been used to call into question the autonomy of domain-specific processing mechanisms. By contrast, we argue that the demonstrated modulation of nonconscious cognitive processes by attention occurs at a predomain-specific stage of processing. Thus, although we agree that attention might be a prerequisite of nonconscious processes, we suggest that there is no reason to think that higher-level cognitive systems directly modulate domain-specific processes.

Introduction

Cognitive scientists have long been interested in the nonconscious mind, and especially in establishing the depth of processing of nonconsciously perceived information [1–4]. The intrigue with nonconscious processing stems from the widely held assumption that nonconscious cognitive processes are elicited independently of higher-level cognitive systems or resources (e.g. attention, intention or consciously set strategies) [5,6]. Importantly for our purposes here, this assumption has provided the basis for using subliminal priming to investigate domain-specific processing mechanisms. Domain-specific processing mechanisms have classically been defined in terms of their automaticity (i.e. mandatory engagement by a single information type) and autonomy (i.e. impervious to top-down modulation; but see Coltheart [7]). Thus, it has been reasoned that subliminal priming provides an ideal window into domain-specific processing mechanisms. Surprisingly, several recent findings have called this line of reasoning into question by showing that masked priming effects, which serve to index nonconscious cognitive processes (Box 1), depend upon attention and, in some cases, are modulated by one's consciously set expectations. These recent findings are potentially devastating because they seem to undermine a long line of masked priming research that has been thought to reveal core properties of automatically elicited, domain-specific processing mechanisms.

Three stages of information processing

Before addressing these recent findings, it is important to consider the stages of information processing that are minimally required to observe masked priming effects. We suggest that there are at least three general stages of processing in a typical masked priming experiment: a 'pre-domain-specific' stage, a 'domain-specific' stage and a 'decision' stage (Box 2). Importantly, to undermine the assumption that domain-specific processes proceed autonomously, one would need to demonstrate that the computations carried out at the second (domain-specific) stage of processing are directly modulated by higher-level cognitive systems (e.g. attention). For example, if one found that the presence of spatial attention was a prerequisite of masked orthographic priming, but not masked morphological priming (Box 1), this would indicate that attention modulated domain-specific (i.e. orthographic) processes. By contrast, if spatial attention is found to be a prerequisite of masked priming effects across several different information domains, this would then suggest that attention operates at a domain-general level of information processing. Later, we argue that the recent findings that have been brought to bear on this issue suggest that top-down modulations of nonconscious cognitive processes are carried out at a general pre- or postdomain-specific level of processing. Table 1 summarizes experimental evidence bearing on top-down modulation of masked priming effects.

Masked priming effects depend upon attention

The first study to demonstrate the essential role of attention in nonconscious priming was reported by Naccache *et al.* [8]. These authors asked participants to categorize target numbers as either greater or less than 5 by pressing one of two buttons. As in all masked priming experiments (Box 1), the visible target was preceded by a masked prime that participants were unable to report. Somewhat different from other masked congruence priming experiments, however, the primes and targets were imbedded in an otherwise continuous stream of masks. Crucially, a masked congruence priming effect (faster response latencies on congruent trials) was only obtained on those trials in which a salient cue (green square; c.f. Experiment 2 in ref [8]) appeared in the stream of masks just before the prime-target pair of stimuli. Because the prime-target pair was always presented at fixation, and because the stimulus onset asynchrony (SOA) between prime and target was held constant, this finding demonstrated that temporal attention needs to be 'focused in time'

Corresponding author: Finkbeiner, M. (finkbeiner@maccs.mq.edu.au).

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Box 1. Masked priming paradigm

In the widely used 'sandwich' masking paradigm, a prime stimulus, which is undetectable to participants, is presented briefly between a forward and backward mask [32,35]. The target stimulus follows the prime, and response latencies are calculated from target onset. The experimental manipulation involves the prime-target relationship. Because priming effects are thought to reflect the overlap in processing of the prime and target stimuli, this technique can be used to investigate a wide range of cognitive processes. For example, the finding that the prime-target pair drive–DROVE produces the same amount of priming as drove–DROVE (relative to dribe–DROVE) suggests that morphological processes are engaged automatically [46]. Similarly, the finding that klip–CLIP produces priming relative to plip–CLIP suggests that phonological processes can be engaged directly [4,47]. Likewise, the finding that translation prime-target pairs (e.g. □–HAND) produce priming with bilingual participants suggests that the semantic properties of printed words are accessed automatically [24–27].

The masked priming paradigm has also been used with pictures. Figure I depicts a masked congruence priming task in which participants were asked to categorize the target stimulus as either a face or a tool [48]. In this case, reliably faster response latencies in the congruent condition (i.e. prime and target stimuli are exemplars of the same category) than in the incongruent condition (i.e. prime and target are from different categories) are taken as evidence that categorical information can be accessed directly, without visual awareness.

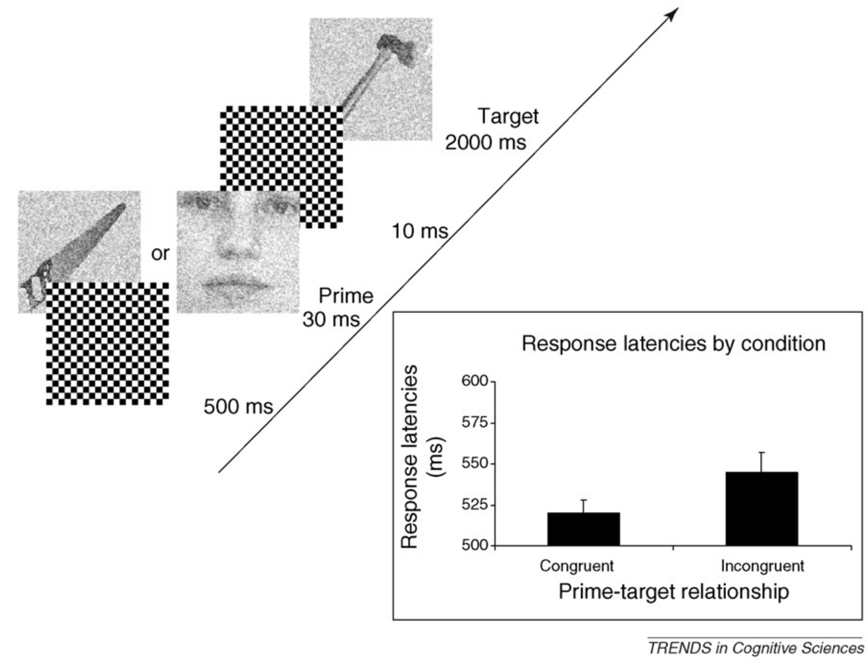

Figure I. Depiction of a masked congruence priming experiment, in which participants categorize the target stimulus as a face or a tool. Faster response latencies on congruent trials, where both prime and target belong to the same category, than on incongruent trials, where the prime and target stimuli belong to opposite categories, indicates a masked congruence priming effect. Based on experiments by Ref. [48].

for masked congruence priming effects to be obtained (see Kiefer and Brendel [9] for a replication and extension of this finding).

In a more stringent test of the role of attention in masked priming, Lachter *et al.* [10] manipulated transient spatial attention (i.e. attention was transiently directed towards or away from the prime stimulus). Manipulations of spatial attention are more stringent, insofar as it is possible to manipulate both voluntarily and involuntarily directed attention either towards or away from the prime stimulus, which is more difficult to accomplish in manipulations of temporal attention. Lachter *et al.* found that only spatially attended primes produced priming. In this study [10], they used the lexical decision task and 'identity' primes (e.g. table–TABLE versus shirt–TABLE). This finding has been replicated [11] and has recently been extended to include a letter-identification task [12].

Taken together, these findings are compelling in refuting the assumption that cognitive processes which are elicited independently of awareness are similarly elicited independently of attention. This long-standing assumption no longer holds. However, does the refutation of this assumption similarly entail the refutation of the long-standing and central assumption in cognitive science which holds that domain-specific processes proceed independently of higher-level cognitive systems, including attention? We presently find no compelling reason to think so.

First, the finding that transient attention is a prerequisite for masked priming effects across two distinct information domains (i.e. Arabic numerals [8] and letters [12], in addition to printed words [10,11]) is important because it suggests that transient attention is operating at a domain-general level of processing. Second, there is a large body of literature which convincingly demonstrates that transient attention primarily affects basic visual dimensions, such as contrast sensitivity, orientation discrimination, spatial resolution and temporal resolution [13–16], all of which can reasonably be subsumed within the earliest, predomain-specific stage of processing.

On the basis of these observations, we suggest, following Broadbent [17] and others [10], that transient attention

Box 2. Stages of processing

It is possible to specify three general stages of information processing that are required in a typical masked priming experiment. The first stage of processing involves extracting low-level features from the physical stimulus such as position, orientation, scale and contrast. Processing at this initial stage corresponds roughly to Marr's primal sketch [49] and is invariant across different types of information (e.g. letters versus numbers). Thus, processing at this stage precedes, for example, the processing of numbers *qua* numbers or letters *qua* letters. We refer to this first stage of processing as 'predomain-specific' processing.

The second stage of processing begins with an assembly of low-level features and ends with the selection of the specific mental representation that corresponds to the physical stimulus. The second stage of processing (which encompasses several sublevels of representation and processing, depending upon one's particular theory) is 'domain specific', insofar as this stage of processing is 'lexical' or 'numerical', or whatever else the case might be.

The third and last stage of processing is the level at which decisions and inferences are made. Because it is generally thought that information at this 'postdomain-specific' level of processing is available for conscious report, one would expect higher-level cognitive systems to interact here and, hence, it is unlikely that any processes at this stage are autonomous. Thus, this stage of processing is not generally thought to be relevant in discussions of automatic (autonomous) processes.

might function as a 'window' in the earliest stage of information processing. Essentially, if this window is positioned appropriately in space and time, then subsequent stages of information processing can become engaged and can proceed autonomously. If this attentional window is not positioned correctly, subsequent stages of processing do not become engaged to a sufficient degree to modulate response latencies (i.e. produce priming). Thus, although we agree that transient attention might be essential to observe nonconscious priming effects, we suggest that the locus of these attentional effects is at an early, predomain-specific stage of processing. Note that we do not include learning effects in this discussion because the assumption of autonomy of domain-specific processes only applies to online processes. It must be the case that learning modifies the structural and dynamical properties of processing mechanisms at the second (or later) stages of information processing [18].

Consciously set expectations and nonconscious processing

A second line of findings that potentially challenges the assumed autonomy of domain-specific processes involves an interaction between consciously set expectations and masked priming effects. In one well-known example, Greenwald *et al.* [19] asked participants to categorize two-digit target numbers as larger or smaller than 55. Although these authors did not use overlapping prime and target stimulus sets, the prime stimuli (e.g. 27 and 91) were constructed with the same digits as the target stimuli (e.g. 72 and 19), but in reverse order (c.f. Experiment 3 in ref [19]). The pattern of masked congruence priming effects revealed that participants had learned specific stimulus-response (S-R) mappings for each pair of digits in the target stimuli but, importantly, the S-R mappings had not encoded the order of the digits. For example, Greenwald *et al.* [19] found that the prime 27 facilitated 'larger than 55' responses and the prime 91 facilitated 'less than 55' responses. These paradoxical results indicate that participants were able to apply

Table 1. Top-down modulation of masked priming effects

Findings demonstrating top-down modulation of nonconscious processing	
Top-down mechanism	
Temporal attention	**Task and findings**
Naccache *et al.* (2002) [8]	Arabic numerals produce masked congruence priming only when temporally attended
Kiefer and Brendel (2006) [9]	Semantic priming, as indexed by the N400 component, is modulated by temporal attention
Fabre *et al.* (2007) [50]	Priming by categorical, but not physically identical, prime stimuli is modulated by temporal attention
Spatial attention	
Lachter *et al.* (2004) [10]	Only spatially attended letters [12] and letter strings [10,11] produce priming
Besner *et al.* (2005) [11]	
Marzouki *et al.* (2007) [12]	
Task-induced strategies	
Nakamura *et al.* (2006) [30]	Priming is mediated by distinct neural circuits, depending upon the task
Finkbeiner and Caramazza (in press) [48]	The polarity of the masked congruence priming effect shifts as a function of the response modality
Stimulus-induced strategies	
Abrams and Greenwald (2000) [51]	Positive targets (e.g. tulip, humor) led participants to treat masked negative primes (e.g. tumor) as being positive
Greenwald *et al.* (2003) [19]	Consciously perceived targets (e.g. 72) cause masked primes (e.g. 27) to facilitate 'larger than 55' responses
Damian (2001) [20]	In a size-judgment task, only primes in the target set produced masked priming effects
Findings needed to demonstrate top-down modulation of domain-specific processing	
Top-down mechanism	
Spatial attention	**Task and findings**
	In a masked priming experiment designed to index domain-specific processes (i.e. avoids stimulus-induced strategies) and that manipulates spatial attention and stimulus quality (of the prime), a main effect of stimulus quality would need to be obtained, with no modulation of the interaction between attention and priming
Task-induced strategies	
	Combine neuroimaging with the TMS study reported by Nakamura *et al.* [30]. First, use TMS to determine which neural regions are crucial to observe masked priming in reading aloud and lexical decision. Then use neuroimaging to show that repetition suppression (i.e. priming) is restricted to the task-relevant regions (i.e. L-STG but not L-IPL in the lexical decision task)

learned S-R mappings (e.g. the juxtaposition of the stimuli '7' and '2' corresponded to a 'larger than 55 response') to the processing of nonconsciously perceived information. Findings similar to these have now been reported by several researchers [20–23].

Although it is impressive that individuals are able to apply learned S-R mappings to the processing of nonconsciously perceived information, these findings do not necessarily challenge the assumption that domain-specific processes are carried out autonomously (i.e. independently of consciously set expectations). For example, Kunde *et al.* [21] posit that findings such as these can be attributed to learned or anticipated associations between low-level sensory codes (e.g. visual features) and motor responses (i.e. the second, domain-specific stage of processing is bypassed). If this interpretation is correct, then it is important to note that masked priming effects do not index domain-specific processes in experiments that enable learned S-R mappings, or that enable participants to anticipate the prime stimuli on the basis of the encountered target stimuli. This is an important constraint to keep in mind when designing masked priming experiments to investigate domain-specific processes, but it is easily circumvented.

In fact, the large majority of masked priming experiments that have been reported in the literature do not violate this constraint. Perhaps the most convincing in this respect are the translation-priming experiments with bilingual participants [24–27]. In these experiments, participants are asked to perform a task (e.g. lexical decision or semantic categorization) over target words presented in one of their languages, and where the masked primes are words from their other language. Because participants are unaware of the bilingual nature of the experiment, it is unlikely that they are able to anticipate the prime stimuli, or even the language of the prime stimuli. Yet masked translation-priming effects are robust and have been influential in informing theories of bilingual lexical representation and processing [27–29].

Can task demands modulate domain-specific processes?

Given that domain-specific processing mechanisms have classically been defined in terms of their autonomy (but see Coltheart [7]), it follows that task demands should not modulate processes at the second, domain-specific stage of processing. Thus, for example, the mechanism that is dedicated to the processing of printed text should become engaged whenever printed text is encountered, regardless of the particular experimental contexts. Evidence to the contrary would stand in sharp contrast to the definitional properties of domain-specific processing mechanisms, and yet a recent report by Nakamura *et al.* [30] has been taken to provide such evidence.

Nakamura *et al.* [30] used transcranial magnetic stimulation (TMS) in a masked repetition priming experiment in which participants either performed a lexical decision or a reading aloud task. The primary finding from this study was that TMS applied to the left superior temporal gyrus (L-STG), but not to the left inferior parietal lobe (L-IPL), disrupted masked repetition priming in the lexical decision task. By contrast, TMS applied to the L-IPL, but not the L-STG, eliminated masked repetition priming in the reading aloud task. This double dissociation is striking because it indicates that different neural circuits mediate masked repetition priming depending upon the task at hand. Importantly for our purposes here, it has been suggested on the basis of these findings that individuals are able to use the task instructions to control which processing mechanisms become engaged by nonconsciously perceived prime stimuli [31].

We offer a different account of these findings. First, it is important to note that Nakamura *et al.* [30] observed masked priming effects in the reading aloud task for both words and non-words but only for words in the lexical decision task. This pattern of priming across these two tasks has often been observed and has been taken to mean that priming in the reading aloud task is mediated by a non-lexical route [32–34], whereas priming in the lexical decision task is mediated by a lexical route [35,36]. Second, the notion that distinct neural circuits mediate lexical and non-lexical processing routes is uncontroversial in the cognitive neuropsychology literature [37–41]. Thus, we suggest that the masked primes in the Nakamura *et al.* study engaged both the lexical and non-lexical routes simultaneously, regardless of the task demands. On this possibility, task demands do not modulate the engagement of domain-specific processing mechanisms but, rather, determine whether subsequent response formulation processes make use of the 'outputs' of those mechanisms. The Nakamura *et al.* study is inconclusive with respect to the possibility that their masked primes engaged behaviorally relevant and nonrelevant processes because TMS only reveals behaviorally relevant neural activity.

Can the autonomy of domain-specific processes be falsified?

Although it is now clear that nonconsciously elicited processes are modulated by top-down cognitive systems at some stage of information processing, we have argued that there is no compelling evidence (presently) to suggest that this is also true of domain-specific processes. A concern with our proposal is that it might be difficult to refute, and so we offer here two straightforward tests.

First, in a behavioral priming experiment, say a letter identification task in which the prime and target stimuli always differ in case and visual similarity, one could manipulate three factors: relatedness between prime and target (e.g. a–A versus s–A), location of spatial attention and visual properties of the prime stimulus (e.g. its size or contrast). Appealing to additive-factors logic [42], if the interaction between transient attention and priming is modulated by the stimulus quality, then it would follow that the effect of transient attention arises at the earliest 'pre-domain-specific' stage of processing. If, however, the interaction between transient attention and letter priming is not modulated by stimulus quality, then it would be reasonable to conclude that transient attention operates at a later domain-specific level of processing.

Second, if it is found with neuroimaging techniques (e.g. functional magnetic resonance imaging) that the manipulation of transient attention modulates activity in brain regions known to subserve domain-specific processes (e.g. the anterior regions of the 'visual word form area' [43,44] or the 'fusiform face area' [45]), but not early retinotopic regions, then this would seem to demonstrate top-down modulation of domain-specific processes.

Conclusion

Recent findings in the masked priming literature have revealed a surprisingly rich interplay between higher-level cognitive systems (i.e. attention) and the processing of nonconsciously perceived information. These findings are important in cognitive science because they refute the long-standing assumption that nonconscious processes are elicited independently of higher-level cognitive systems [5,6]. Because domain-specific processes and nonconscious processes share overlapping definitional properties (e.g. automatic and autonomous), these recent findings have similarly been thought to refute the presumed autonomy of domain-specific processes. We have suggested that the evidence to date does not support this conclusion. To preserve the autonomy of domain-specific processes, we have suggested that the top-down modulatory effects on nonconscious processing arise either early in visual processing, which we have termed 'predomain specific', or relatively late in information processing (e.g. at a decision stage), which we have termed 'postdomain specific'. In terms of attention, our suggestion is consistent with a large body of research that has localized the effects of transient attention in the earliest stages of visual processing [13–16]. With respect to the demonstrated effects of stimulus-induced strategies on nonconscious processing, our suggestion is consistent with a growing consensus in the literature which holds that these effects represent learned associations between sensory codes and responses which effectively bypass domain-specific processing [19–23].

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References

1 Dehaene, S. *et al.* (1998) Imaging unconscious semantic priming. *Nature* 395, 597–600
2 Finkbeiner, M. *et al.* (2008) Engaging the motor system with masked orthographic primes: a kinematic analysis. *Vis. Cogn.* 16, 11–22
3 Pessiglione, M. *et al.* (2007) How the brain translates money into force: a neuroimaging study of subliminal motivation. *Science* 316, 904–906
4 Grainger, J. *et al.* (2003) Masked repetition and phonological priming within and across modalities. *J. Exp. Psychol. Learn. Mem. Cogn.* 29, 1256–1269
5 Posner, M.I. and Snyder, C.R.R. (1975) Attention and cognitive control. In *Information Processing and Cognition: The Loyola Symposium* (Solso, R.L., ed.), pp. 55–85, Erlbaum
6 Schneider, W. and Shiffrin, R.M. (1977) Controlled and automatic human information processing: 1. Detection, search and attention. *Psychol. Rev.* 84, 1–66
7 Coltheart, M. (1999) Modularity and cognition. *Trends Cogn. Sci.* 3, 115–120
8 Naccache, L. *et al.* (2002) Unconscious masked priming depends on temporal attention. *Psychol. Sci.* 13, 416–424
9 Kiefer, M. and Brendel, D. (2006) Attentional modulation of unconscious 'automatic' processes: evidence from event-related potentials in a masked priming paradigm. *J. Cogn. Neurosci.* 18, 184–198
10 Lachter, J. *et al.* (2004) Forty-five years after Broadbent (1958): still no identification without attention. *Psychol. Rev.* 111, 880–913
11 Besner, D. *et al.* (2005) Spatial attention as a necessary preliminary to early processes in reading. *Can. J. Exp. Psychol.* 59, 99–108
12 Marzouki, Y. *et al.* (2007) Exogenous spatial cueing modulates subliminal masked priming.. *Acta Psychol. (Amst.)* 126, 34–45
13 Pashler, H. (1998) *The Psychology of Attention,* MIT Press
14 Nakayama, K. and Mackeben, M. (1989) Sustained and transient components of focal visual attention. *Vision Res.* 29, 1631–1647
15 Carrasco, M. *et al.* (2004) Attention alters appearance. *Nat. Neurosci.* 7, 308–313
16 Carrasco, M. and McElree, B. (2001) Covert attention accelerates the rate of visual information processing. *Proc. Natl. Acad. Sci. U. S. A.* 98, 5363–5367
17 Broadbent, D.E. (1958) *Perception and Communication,* Oxford University Press
18 Ahissar, M. and Hochstein, S. (2004) The reverse hierarchy theory of visual perceptual learning. *Trends Cogn. Sci.* 8, 457–464
19 Greenwald, A.G. *et al.* (2003) Long-term semantic memory versus contextual memory in unconscious number processing. *J. Exp. Psychol. Learn. Mem. Cogn.* 29, 235–247
20 Damian, M.F. (2001) Congruity effects evoked by subliminally presented primes: automaticity rather than semantic processing. *J. Exp. Psychol. Hum. Percept. Perform.* 27, 154–165
21 Kunde, W. *et al.* (2003) Conscious control over the content of unconscious cognition. *Cognition* 88, 223–242
22 Klinger, M.R. *et al.* (2000) Mechanisms of unconscious priming: I. Response competition, not spreading activation. *J. Exp. Psychol. Learn. Mem. Cogn.* 26, 441–455
23 Eckstein, D. and Perrig, W. (2007) The influence of intention on masked priming: a study with semantic classification of words. *Cognition* 104, 345–376
24 Gollan, T.H. *et al.* (1997) Translation priming with different scripts: masked priming with cognates and noncognates in Hebrew–English bilinguals. *J. Exp. Psychol. Learn. Mem. Cogn.* 23, 1122–1139
25 Grainger, J. and Frenck-Mestre, C. (1998) Masked priming by translation equivalents in proficient bilinguals. *Lang. Cogn. Proc.* 13, 601–623
26 Jiang, N. and Forster, K.I. (2001) Cross-language priming asymmetries in lexical decision and episodic recognition. *J. Mem. Lang.* 44, 32–51
27 Finkbeiner, M. *et al.* (2004) The role of polysemy in masked semantic and translation priming. *J. Mem. Lang.* 51, 1–22
28 Davis, C.W. *et al.* (2003) Masked priming across languages: an insight into bilingual lexical processing. In *Masked Priming: State of the Art* (Kinoshita, S. and Lupker, S.J., eds), pp. 309–322, Psychology Press
29 Dijkstra, T. and van Heuven, W.J.B. (2002) The architecture of the bilingual word recognition system: from identification to decision. *Biling. Lang. Cogn.* 5, 175–197
30 Nakamura, K. *et al.* (2006) Task-guided selection of the dual neural pathways for reading. *Neuron* 52, 557–564
31 Dehaene, S. and Naccache, L. (2006) Can one suppress subliminal words? *Neuron* 52, 397–399
32 Forster, K.I. and Davis, C. (1991) The density constraint on form-priming in the naming task: interference effects from a masked prime. *J. Mem. Lang.* 30, 1–25
33 Kinoshita, S. (2003) The nature of masked onset priming effects in naming: a review. In *Masked Priming. The State of the Art* (Kinoshita, S. and Lupker, S.J., eds), pp. 223–238, Psychology Press
34 Kinoshita, S. and Woollams, A. (2002) The masked onset priming effect in naming: computation of phonology or speech-planning. *Mem. Cognit.* 30, 237–245
35 Forster, K.I. and Davis, C. (1984) Repetition priming and frequency attenuation in lexical access. *J. Exp. Psychol. Learn. Mem. Cogn.* 10, 680–698
36 Forster, K.I. (1989) Basic issues in lexical processing. In *Lexical Representation and Process* (Marslen-Wilson, W., ed.), pp. 75–107, MIT Press
37 Coltheart, M. *et al.* (2001) DRC: a dual route cascaded model of visual word recognition. *Psychol. Rev.* 108, 204–256
38 Coltheart, M. (1985) Cognitive neuropsychology and the study of reading. In *Attention and Performance XI* (Posner, M.I. and Marin, O.S.M., eds), pp. 3–37, Erlbaum

39 Coltheart, M. (ed.) (1996) *Phonological Dyslexia*, Erlbaum
40 Patterson, K.E. *et al.* (1985) *Surface Dyslexia: Cognitive and Neuropsychological Studies of Phonological Reading,* Erlbaum
41 McCarthy, R. and Warrington, E.K. (1986) Phonological reading: phenomena and paradoxes. *Cortex* 22, 359–380
42 Sternberg, S. (1969) The discovery of processing stages: extensions of Donders' method. *Acta Psychol. (Amst.)* 30, 276–315
43 Dehaene, S. *et al.* (2004) Letter binding and the invariant recognition of masked words. *Psychol. Sci.* 15, 307–313
44 McCandliss, B.D. *et al.* (2003) The visual word form area: expertise for reading in the fusiform gyrus. *Trends Cogn. Sci.* 7, 293–299
45 Kanwisher, N. *et al.* (1997) The fusiform face area: a module in human extrastriate cortex specialized for face perception. *J. Neurosci.* 17, 4302–4311
46 Forster, K.I. *et al.* (1987) Masked priming with graphemically related forms: repetition or partial activation? *Q. J. Exp. Psychol.* 39, 211–251
47 Rastle, K. and Bryasbert, M. (2006) Masked phonological priming effects in English: are they real? Do they matter? *Cognit. Psychol.* 53, 97–145
48 Finkbeiner, M. and Caramazza, A. Modulating the masked congruence priming effect with the hands and the mouth. *J. Exp. Psychol. Hum. Percept. Perform.* (in press)
49 Marr, D. (1982) *Vision,* W. H. Freeman and Co
50 Fabre, L. *et al.* (2007) Attentional modulation of masked repetition and categorical priming in young and older adults. *Cognition* 105, 513–532
51 Abrams, R.L. and Greenwald, A.G. (2000) Parts outweigh the whole (word) in unconscious analysis of meaning. *Psychol. Sci.* 11, 118–124