Historical Perspective

The conscious access hypothesis: origins and recent evidence

Bernard J. Baars

Consciousness might help to mobilize and integrate brain functions that are otherwise separate and independent. Evidence for this 'conscious access hypothesis' was described almost two decades ago, in a framework called global workspace theory. The theory had little impact at first, for three reasons: because consciousness was controversial; the evidence, though extensive, was indirect; and integrative theory was unfashionable. Recent neuroimaging evidence appears broadly to support the hypothesis, which has implications for perception, learning, working memory, voluntary control, attention and self systems in the brain.

This article reviews the scientific rediscovery of consciousness through the lens of global workspace theory and its central hypothesis, the notion that consciousness facilitates widespread access between otherwise independent brain functions*. A number of observers have suggested some version of this idea, starting in the early 1980s, and similar ideas have increased in number in recent years (see Box 1).

The rediscovery of consciousness

The idea that consciousness has an integrative function has a long history. Global workspace theory suggests a fleeting memory capacity in which only one consistent content can be dominant at any given moment [1–6]. Dominant information is widely distributed in the brain. This makes sense in a nervous system viewed as a massive distributed set of specialized networks. In such a system, coordination, control, and problem solving could take place by way of a central information exchange, allowing some regions – such as sensory cortex – to distribute information to the whole. This strategy works in large-scale computer architectures, which show typical 'limited capacity' behavior when information flows by way of a global workspace [7,8]. A sizable body of evidence suggests that consciousness is the primary agent of such a global access function in humans and other mammals [1–6]. The idea is now favored by some scientists [7, 9–11] and philosophers including Dennett [12].

*Global workspace theory emerged from the cognitive architecture tradition pioneered by Alan Newell and Herbert A. Simon. Newell and his co-workers were the first to show the utility of a global workspace capacity in a complex system of specialized knowledge sources, which could cooperatively solve problems no single source could solve alone [55]. The empirical connection with consciousness was not made in this tradition, however.

Philosophical questions

Scientific efforts to understand consciousness evoked vigorous philosophical objections. These were essentially the classic mind–body problems: how does private experience relate to the physical world? How do subjective goals result in physical action? Philosophers typically focus on logical arguments and the apparent evidence of private experience. From this basis, conceptual puzzles abound.

> '...direct testing of the [conscious access] hypothesis is now possible...'

Difficult conceptual questions are routine when the sciences turn to new topics. The traditional scientific response is simply to gather relevant evidence and develop careful theory. Ultimately, philosophical controversies either fade, or they can compel changes in science if they have empirical consequences.

Scientific questions about evidence

What constituted relevant evidence for conscious functions was not obvious to many scientists. The apparent answer has emerged slowly over the past few decades. Today, conscious functions are studied experimentally by comparison with closely matched unconscious processes, an approach I have called 'contrastive analysis' [1–4]. Research traditions on subliminal priming, automaticity, and implicit cognition have made it clear unconscious comparison conditions for conscious processes are often available (see Table 1, Figs 1 and 2).

General criticisms of the theory

The conscious access hypothesis has only recently achieved a degree of consensus. Before brain imaging, it was necessarily dependent on indirect evidence. Integrative theories were often viewed as untestable. Certain assumptions – such as seeing the brain as a set of unconscious specialized networks – were controversial until the past decade. Global workspace theory was mistakenly thought to be a 'Cartesian theater,' though not by the author of that critique [12]. And of course, scientific explanations of consciousness were viewed with skepticism. In these respects contemporary science appears to be more receptive.

Seven predictions

Each of the following predictions was controversial twenty years ago, but evidence has accumulated for all of them, as noted below.

(1) *Conscious perception involves more than sensory analysis; it enables access to widespread brain sources, whereas unconscious input processing is limited to sensory regions*.

To many scientists the term 'conscious perception' seemed redundant, and 'unconscious perception' a self-contradiction. Yet in the last twenty years many sources of evidence have emerged for unconscious sensory analysis, raising the question 'what is the difference between conscious and unconscious aspects of perception?' Today we can treat perceptual consciousness as an experimental variable.

Dehaene *et al.* have recently shown that backward-masked visual words activate mainly visual cortex, whereas identical conscious words evoke widespread visual, parietal and frontal activation (Fig. 1) [8]. Tononi *et al.* and Srinivasan *et al.* have demonstrated in

 1364-6613/02/$ – see front matter PII: S1364-6613(00)01819-2

Box 1. Conscious access themes from the past 20 years.

Presented here are some conscious access themes, from various authors. The frequency of such themes in the science and philosophy of consciousness has increased in recent years.

- **Baars, 1983** 'Conscious contents provide the nervous system with *coherent, global information*.' [a].
- **Edelman, 1989** 'Global mapping in a reentrant selectionist model of consciousness in the brain.' [b].
- **Damasio, 1989** 'Meaning is reached by time-locked multiregional retroactivation of widespread fragment records. Only the latter records can become contents of consciousness.'[c].
- **Freeman, 1991** 'The activity patterns that are formed by the (sensory) dynamics *are spread out over large areas of cortex*, not concentrated at points. Motor outflow is likewise *globally distributed*.... In other words, the pattern categorization does not correspond to the selection of a key on a computer keyboard but to an induction of a global activity pattern.' [Italics added] [d].
- **Llinas *et al.*, 1998** '... *the thalamus represents a hub from which any site in the cortex can communicate with any other such site or sites*. ... temporal coincidence of specific and non-specific thalamic activity generates the functional states that characterize human cognition. [e].
- **Edelman and Tononi, 2000** 'When we become aware of something ... it is as if, suddenly, many different parts of our brain were privy to information that was previously confined to some specialized subsystem. ... the wide distribution of information is guaranteed mechanistically by *thalamocortical and corticocortical reentry*, which facilitates the interactions among distant regions of the brain. ' [f] (pp. 148–149).
- **Dennett, 2001** 'Theorists are converging from quite different quarters on a version of the global neuronal workspace model of consciousness ... On the eve of the Decade of the Brain, Baars (1988) had already described a "gathering consensus" in much the same terms: "Consciousness", he said, is accomplished by a "distributed society of specialists that is equipped with a working memory, called a global workspace, whose contents can be broadcast to the system as a whole." ' [g] (p. 42).
- **Kanwisher, 2001** '...in agreement with Baars (1988), it seems reasonable to hypothesize that *awareness of a particular element of perceptual information must entail not just a strong enough neural representation of information, but also access to that information by most of the rest of the mind/brain.*' [h].
- **Dehaene and Naccache, 2001** 'We propose a theoretical framework ... the hypothesis of a global neuronal workspace. ...We postulate that this global availability of information through the workspace is what we subjectively experience as the conscious state.' [i].
- **Rees, 2001** 'One possibility is that activity in such a distributed network might reflect stimulus representations gaining access to a 'global workspace' that constitutes consciousness.' [j] (p. 679).
- **John, 2001** 'Evidence has been steadily accumulating that information about a stimulus complex is distributed to many neuronal populations dispersed throughout the brain.' [k].
- **Varela et al, 2001** '...the brain... transiently settling into a globally consistent state ... [is] the basis for the unity of mind familiar from everyday experience.' [l].

References

a Baars, B.J. (1983) Conscious contents provide the nervous system with coherent, global information. In *Consciousness and Self-Regulation* (Vol. 3) (Davidson, R.J. *et al.*, eds), Plenum Press

b Edelman, G.M. (1989) *The Remembered Present*, Basic Books

c Damasio, A.R. (1989) Time-locked multiregional retroactivation: a systems-level proposal for the neural substrates of recall and recognition. *Cognition* 33, 25–62

d Freeman, W.J. (1991) The physiology of perception. *Sci. Am*. 264,78–85

e Llinas, R. and Ribary, U. (2001) Consciousness and the brain: the thalamocortical dialogue in health and disease. *Ann. N. Y. Acad. Sci.* 929, 166–175

f Edelman, G.M. and Tononi, G. (1999) *A Universe of Consciousness*, Basic Books

g Dennett, D. (2001) Are we explaining consciousness yet? *Cognition* 79, 221–237

h Kanwisher, N. (2001) Neural events and perceptual awareness. *Cognition* 79, 89–113

i Dehaene, S. and Naccache, L. (2001) Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition* 79, 1–37

j Rees, G. (2001) Seeing is not perceiving. *Nat. Neurosci*. 4, 678–680

k John, E.R. *et al.* (2001) Invariant reversible qeeg effects of anesthetics. *Conscious. Cogn.* 10, 165–183

l Varela, F. *et al.* (2001) The brainweb: phase synchronization and large-scale integration. *Nat. Neurosci*. 2, 229–239

binocular rivalry that conscious visual input evokes more intense and coherent MEG responses from flicker-tagged input than a matched unconscious stream (Fig. 2) [12,13]. More evidence comes from other methods [14–18] (see Table 1).

(2) *Consciousness enables comprehension of novel information, such as new combinations of words.*

Unconscious input processing seems quite limited [19–21]. Repeated efforts to demonstrate multiple-word subliminal priming has not succeeded [22]. Likewise, multiple-word effects in unattended listening have not been shown to work [23]. Claims that sentences can be understood under general anesthesia are unsubstantiated, because of uncontrollable variation in depth of anesthesia [24–26]. Complex unconscious processes do exist in automatic functions and implicit cognition [27], but unconscious input processes seem to be quite limited in scope. These results support the prediction that consciousness is needed to integrate multiple sensory inputs, presumably by mobilizing specialized functions like syntax, semantics, high-level visual knowledge, problem-solving and decision making.

Although evidence on this point has been known for some decades, scientists have rarely used it to describe the functions of consciousness. That may be because the research focus has been on unconscious processes, such as subliminal priming and implicit cognition. It is as if unconscious processes have been the 'figure' for research and consciousness the 'ground,' which was often taken for granted. Combining the two can be very revealing.

Table 1. Evidence for wider cortical processing of conscious versus non-conscious events.

Source	Method	Results of non-conscious conditions (not reportable)	Results of conscious conditions (accurately reportable)
Sensory consciousness:			
Logothetis *et al.* multiple studies (e.g. [52])	Binocular rivalry between diagonal contrast edges, color, motion, and objects. Multi-unit recording in visual cortex of the macaque.	In early visual cortex 12–20% of cells responded. In object recognition areas (IT/STS) no cells responded.	In early visual cortex 12–20% of cells responded. In object recognition areas (IT/STS) 90% of cells responded.
Tononi *et al.* [12]	MEG of flickering input with binocular rivalry in humans, allowing tracing of input signal with high S/N ratio across large regions of cortex.	Widespread frequency-tagged activation in visual and non-visual cortex	50–80% higher intensity in many channels throughout cortex.
Srinivasan *et al.* [13]	As above.	Widespread frequency-tagged activation in visual and non-visual cortex.	Higher intensity and coherence in visual and non-visual cortex.
Dehaene *et al.* [8]	fMRI of visual backward masked vs. unmasked words in cortex.	Regional activation in early visual cortex only.	Higher intensity in visual cortex plus widespread activity in parietal and frontal cortex.
Rees *et al.* [53]	fMRI of unattended and attended words and pictures.	Less activation in word/picture areas of visual cortex	More activation in word/picture areas of visual cortex.
Kjaer *et al.* [16]	Subliminal vs. supraliminal visual verbal stimuli using PET.	Activation in visual word areas only.	Activation in visual word areas plus parietal and prefrontal cortex.
Beck *et al.* [14]	Change blindness vs. change detection	Activation of ventral visual regions including fusiform gyrus.	Enhanced activity in parietal and right dorsolateral prefrontal cortex as well as ventral visual regions
Vuilleumier *et al.* [18]	Seen and unseen faces in visuospatial neglect, using fMRI and ERPs.	Activation of ventral visual regions	Ventral visual activation plus parietal and prefrontal regions.
Driver and Vuilleumier [15]	Extinguished vs. conscious stimuli in unilateral neglect, fMRI and ERPs.	Activation in ventral visual regions including fusiform gyrus.	Activation also in parietal and frontal areas of the intact left hemisphere.
Learning and practice:			
Haier *et al.* [34]	PET before and after learning computer game Tetris.	Drastic drop in cortical metabolic activity.	Widespread, intense cortical metabolic activity.
Raichle *et al.* [35]	Word association vs. simple noun repetition before and after training.	Trained word association indistinguishable from simple word repetition.	More intense activity in anterior cingulate, left prefrontal and left posterior temporal lobe and right cerebellar hemisphere.
Mental effort:			
Duncan and Owen [50]	Meta-analysis of 10 tasks comparing low and high mental effort (including perception, response selection, executive control, working memory, episodic memory and problem solving)	Low prefrontal activation.	High prefrontal activation, in mid-dorsolateral, mid-ventrolateral and dorsal anterior cingulate cortex.
Waking vs. general anesthesia:			
John *et al.* [26]	QEEG for anesthesia vs. waking	Loss of gamma band activity, loss of coherence across major quadrants of cortex	Widespread gamma band coherence across and within hemispheres.

(3) *Working memory depends on conscious elements, including conscious perception, inner speech and visual imagery, each mobilizing widespread functions.*

Working memory (WM) is traditionally defined as rehearsable immediate memory, including inner speech and visual imagery [28]. Active WM elements like perceptual input, rehearsal, and recall are reportable and therefore meet the standard operational definition of conscious events. However, this point was not widely appreciated until the past decade [29].

Recently, John *et al.* found that quantitative EEG across six WM tasks showed three widespread cortical components, accounting for 90 percent of the variance [26]. A posterior–anterior component might reflect conscious perceptual interaction with frontal executive regions; a left-to-right component might reflect inner speech; and a centrifugal component from the region of the anterior cingulate might reflect effortful task elements. These conscious elements of WM all involve widespread brain interaction, consistent with the conscious access hypothesis.

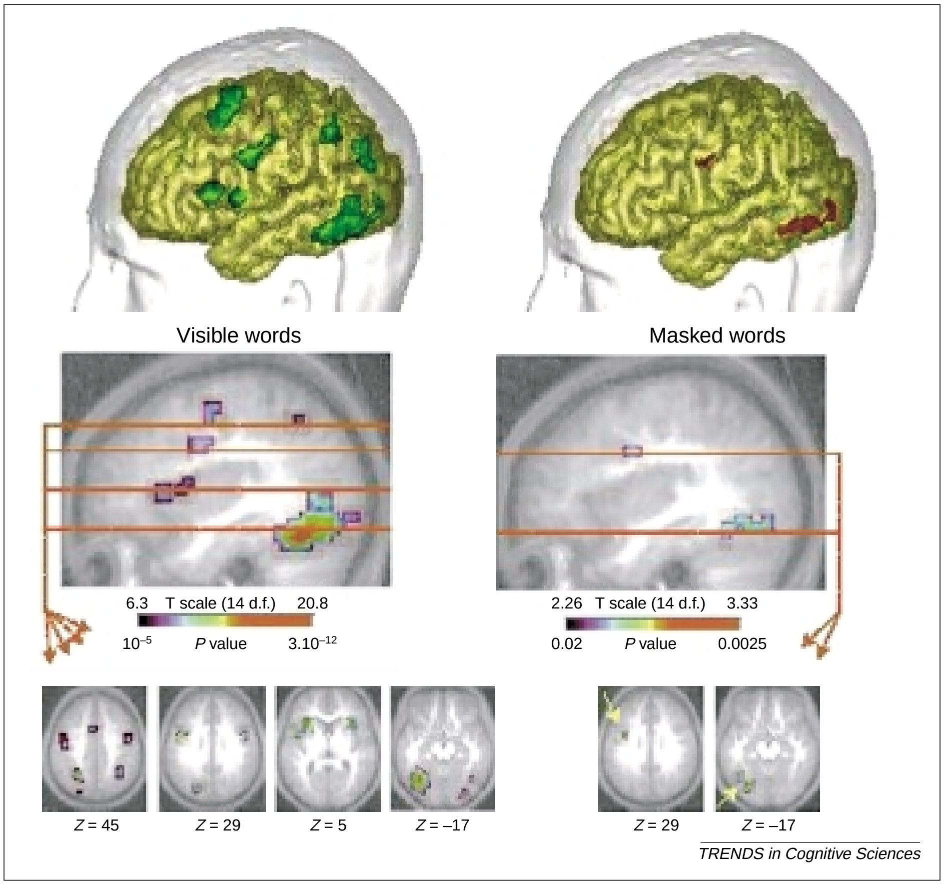


Fig. 1. Conscious versus masked visual words. The conscious access hypothesis predicts wider activation of conscious compared with matched unconscious events. Dehaene and co-authors compared fMRI activation to visible and backward-masked words [9]. (a) Group activations in the left hemisphere only, as seen through translucent three-dimensional reconstruction of the skull and brain of one of the participants. In these transparent views, the deep activations in fusiform, parietal and mesial frontal cortex appear through the overlying lateral cortices. (b) Sagittal and axial views of the group activations in Talairach space, superimposed on the mean anatomical image of the 15 participants. The results revealed an activation in the left fusiform gyrus that showed a 12-fold increase in activation on visible trials relative to masked trials. (Modified from Ref. [9].)

(4) *Conscious information enables many types of learning, using a variety of different brain mechanisms*.

The possibility of unconscious learning has been debated for decades, but there appears to be no robust evidence so far for long-term learning of unconscious input. Phenomena like unconscious priming operate over a range of seconds, and cannot account for learning and development.

In contrast, the evidence for learning of conscious episodes is very strong. A major brain structure, the hippocampus, seems specialized for learning conscious events. Although hippocampus is activated in the subliminal mere exposure effect, this is unlikely to be its primary function [30].

Kosslyn described conscious visual memory capacity as ‘truly staggering; it is so large that it has yet to be estimated.’ [31]. Standing found that recognition accuracy for 10 000 pictures shown for 5 s each over several days was better than 96 percent [32]. No intention to learn was needed. This suggests that whatever becomes focally conscious enters episodic memory. All these points suggest a major brain specialization for learning conscious events.

Even implicit learning requires conscious information [33]. All implicit learning paradigms ask subjects to pay conscious attention to a set of stimuli. What is unconscious is not the target stimuli, but the regularities that appear to be inferred from them. The conscious access hypothesis suggests that awareness of target stimuli allows access to implicit learning mechanisms.

Consciousness is also involved with skill acquisition. As predicted by the hypothesis, novel skills, which are typically more conscious, activate large regions of cortex, but after automaticity due to practice, the identical task tends to activate only restricted regions [34,35] (Table 1).

Thus a variety of learning types, involving different brain regions and mechanisms, seem to depend on consciousness, consistent with the hypothesis.

(5) *Voluntary control is enabled by conscious goals and perception of results*.

Like consciousness, voluntary control has been controversial. Yet studies of automaticity, inadvertent errors, and some types of brain damage suggest that similar complex behaviors can be either under voluntary or involuntary control [1,36,37]. Volition can also be studied as an experimental variable.

Conscious feedback training provides spectacular examples of the scope of access to almost any neuronal population and even single neurons [38]. Single spinal motor units can come under voluntary control with auditory feedback. After brief training subjects have learned to play drumrolls on a single motor unit, with simultaneous silencing of surrounding units [39]. There is no evidence that unconscious feedback can do this. Apparently conscious feedback enables control of a very wide range of activities in the nervous system, consistent with the idea that consciousness enables widespread access in the brain.

(6) *Selective attention enables access to conscious contents, and vice versa*.

The modern attention literature makes little mention of consciousness, but selective attention can be defined as selection among potential conscious contents [1]. In support of this distinction, brain regions underlying conscious vision seem to be separate from those involved in the selection of visual objects and events [40,41]. According to the theory, many attentional mechanisms exist, whose function is to bring different events to consciousness, leading to global distribution of information. There is an urgent need to integrate research on attention and consciousness.

(7) *Consciousness enables access to ‘self’: executive interpretation in the brain*.

The notion of ‘self’ has also been controversial. Yet current cognitive neuroscience recognizes executive functions that are very much like intuitive self functions.

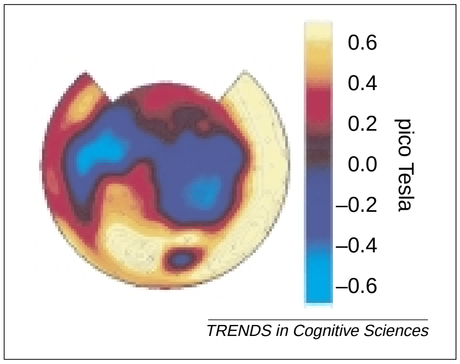


Fig. 2. Conscious versus unconscious streams in binocular rivalry. Conscious visual stimulation evoked wider and more intense activity compared with closely matched unconscious input, in a study by Tononi *et al.* [8]. MEG was used to monitor flicker-tagged competing binocular stimuli, yielding matched neuronal firing for both the conscious and unconscious streams with high signal-to-noise ratios. The scan shows MEG differences between frequency tags for the conscious and unconscious streams. Activity in many MEG channels shows 50–80% greater power for conscious input. (Modified from Ref. [8].)

There is evidence for a mutual dependence between consciousness and executive input. Carefully diagnosed cases of executive dysfunction in Dissociative Identity Disorder, fugue and hypnosis are marked by spontaneous reports of 'time loss' – a loss of one executive interpreter's reported access to conscious events while another is dominant [42,43]. This highly reliable feature suggests a binding between conscious contents and self functions. A similar dissociation can be found in split-brain patients, with each hemisphere exercising executive control over one side of the body, based on conscious input limited to half of the visual field [44,45]. Consciousness might therefore enable access to self functions as well.

This point might turn out to be so fundamental that the order of the seven predictions could be reversed. Conscious perceptual input to frontal regions might lead to executive interpretation and control, which enables working memory, voluntary action, voluntary selective attention, and accurate report. Even the role of consciousness in learning could be a consequence of voluntary attention. Thus conscious access to self-systems of the prefrontal cortex might enable the other functions [1–6].

Possible mechanisms of global access

The brain mechanisms of widespread conscious access are unclear at present. Dehaene and Changeux have focused on frontal cortex [9], Edelman and Tononi on complexity in re-entrant thalamocortical dynamics [46,47], Singer and colleagues on gamma synchrony [48], Flohr on NMDA synapses [49], Llinas on a thalamic hub [50], Newman and Baars on thalamocortical distribution from sensory cortex [1,51], and so on. Several of these mechanisms could work together.

Conclusions

Consciousness might be a gateway to brain integration, enabling access between otherwise separate neuronal functions. Although this case can be made with cognitive evidence, direct testing of the hypothesis is now possible by brain monitoring. More studies are needed to explore the hypothesis.

Acknowledgement

The author gratefully acknowledges the support of The Neurosciences Institute, San Diego, and its Director Gerald M. Edelman, in preparing this paper.

References

1 Baars, B.J. (1988) *A Cognitive Theory of Consciousness*, Cambridge University Press
2 Baars, B.J. (1997) *In the Theater of Consciousness: The Workspace of the Mind*, Oxford University Press
3 Baars, B.J. (1998) Metaphors of consciousness and attention in the brain. *Trends Neurosci.* 21, 58–62
4 Baars, B.J. *The Conscious Access Hypothesis: Global Workspace Theory and Brain Dynamics*, MIT Press (in press)
5 Baars, B.J. (1983) Conscious contents provide the nervous system with coherent, global information. In *Consciousness and Self-Regulation* (Vol. 3) (Davidson, R.J. *et al.*, eds), Plenum Press
6 Baars, B.J. (1993) How does a serial, integrated and very limited stream of consciousness emerge from a nervous system that is mostly unconscious, distributed, parallel and of enormous capacity? Experimental and theoretical studies of consciousness. *Ciba Found. Symp.* 174, 282–303
7 Franklin, S. and Graesser, A. (1999) A software agent model of consciousness. *Conscious. Cogn.* 8, 285–301
8 Tononi, G. *et al.* (1998) Investigating neural correlates of conscious perception by frequency-tagged neuromagnetic responses. *Proc. Natl. Acad. Sci. U. S. A.* 95, 3198–3203
9 Dehaene, S. *et al.* (2001) Cerebral mechanisms of word masking and unconscious repetition priming. *Nat. Neurosci.* 4, 752–758
10 Dehaene, S. and Naccache, L. (2001) Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition* 79, 1–37
11 Kanwisher, N. (2001) Neural events and perceptual awareness. *Cognition* 79, 89–113
12 Dennett, D. (2001) Are we explaining consciousness yet? *Cognition* 79, 221–237
13 Srinivasan, R. *et al.* (1999) Increased synchronization of neuromagnetic responses during conscious perception. *J. Neurosci.* 19, 5435–5448
14 Beck, D.M. *et al.* (2001) Neural correlates of change detection and change blindness. *Nat. Neurosci.* 4, 645–650
15 Driver, J. and Vuilleumier, P. (2001) Perceptual awareness and its loss in unilateral neglect and extinction. *Cognition* 79, 39–88
16 Kjaer, T.W. *et al.* (2001) Precuneus–prefrontal activity during awareness of visual verbal stimuli. *Conscious. Cogn.* 10, 356–365
17 Rees, G. (2001) Neuroimaging of visual awareness in patients and normal subjects. *Curr. Opin. Neurobiol.* 11, 150–156
18 Vuilleumier, P. *et al.* (2001) Neural fate of seen and unseen faces in visuospatial neglect: a combined event-related functional MRI and event-related potential study. *Proc. Natl. Acad. Sci. U. S. A.* 98, 3495–3500
19 Goodale, M.A. *et al.* (1991) A neurological dissociation between perceiving objects and grasping them. *Nature* 349, 154–156
20 Monahan, J.L. *et al.* (2000) Subliminal mere exposure: specific, general, and diffuse effects. *Psychol. Sci.* 11, 462–466
21 Bornstein, R.F. and D'Agostino, P.R. (1992) Stimulus recognition and the mere exposure effect. *J. Pers. Soc. Psychol.* 63, 545–552
22 Greenwald, A.G. and Liu, T.J. (1985) *Limited Unconscious Processing of Meaning*, Psychonomics Society
23 MacKay, D.G. (1973) Aspects of a theory of comprehension, memory and attention. *Q. J. Exp. Psychol.* 25, 22–40
24 Merikle, P.M. and Daneman, M. (1996) Memory for unconsciously perceived events: evidence from anesthetized patients. *Conscious. Cogn.* 5, 525–541
25 Baars, B.J. (2001) The brain basis of a 'consciousness monitor': scientific and medical significance. *Conscious. Cogn.* 10, 159–164
26 John, E.R. *et al.* (2001) Invariant reversible qeeg effects of anesthetics. *Conscious. Cogn.* 10, 165–183
27 Bargh, J.A. and Ferguson, M.J. (2000) Beyond behaviorism: on the automaticity of higher mental processes. *Psychol. Bull.* 126, 925–945
28 Baddeley, A. (1998) Working memory. *C. R. Acad. Sci. Ser. III* 321, 167–173
29 Baddeley, A. (2000) The episodic buffer: a new component of working memory? *Trends Cogn. Sci.* 4, 417–423
30 Elliott, R. and Dolan, R.J. (1998) Neural response during preference and memory judgments for subliminally presented stimuli: a functional neuroimaging study. *J. Neurosci.* 18, 4697–4704
31 Kosslyn, S.M. and Ochsner, K.N. (1994) In search of occipital activation during visual mental imagery. *Trends Neurosci.* 17, 290–292
32 Standing, L. (1973) Learning 10,000 pictures. *Q. J. Exp. Psychol.* 25, 207–222
33 Reber, A.S. (1989) More thoughts on the unconscious. Reply to Brody and to Lewicki and Hill. *J. Exp. Psychol. Gen.* 118, 242–244
34 Haier, R.J. *et al.* (1992) Regional glucose metabolic changes after learning a complex visuospatial/motor task: a positron emission tomographic study. *Brain Res.* 570, 134–143
35 Raichle, M.E. *et al.* (1994) Practice-related changes in human brain functional anatomy during nonmotor learning. *Cereb. Cortex* 4, 8–26

36 Baars, B.J. (1993) Why volition is a foundation issue for psychology. *Conscious. Cogn.* 2, 281–309

37 Baars, B.J., ed. (1992) *The Experimental Psychology of Human Error: Implications for the Architecture of Voluntary Control* (Series on Cognition and Language), Plenum Press

38 Evans, J.R. and Abarbanel, A., eds (1999) *Introduction to Quantitative EEG and Neurofeedback*, Academic Press

39 Simard, T.G. and Basmajian, J.V. (1967) Methods in training the conscious control of motor units. *Arch. Phys. Med. Rehabil.* 48, 12–19

40 Baars, B.J. (1999) Attention versus consciousness in the visual brain: differences in conception, phenomenology, behavior, neuroanatomy, and physiology. *J. Gen. Psychol.* 126, 224–233

41 Baars, B.J. (1997) Some essential differences between consciousness and attention, perception, and working memory. *Conscious. Cogn.* 6, 363–371

42 Hilgard, E.R. (1988) Commentary. Professional skepticism about multiple personality. *J. Nerv. Ment. Dis.* 176, 532

43 Putnam, F.W. (1995) Investigating multiple personality disorder. *Br. J. Psychiatry* 166, 122–123

44 Gazzaniga, M.S. and Sperry, R.W. (1967) Language after section of the cerebral commissures. *Brain* 90, 131–148

45 Sperry, R.W. (1968) Hemisphere deconnection and unity in conscious awareness. *Am. Psychol.* 23, 723–733

46 Tononi, G. and Edelman, G.M. (1998) Consciousness and complexity. *Science* 282, 1846–1851

47 Edelman, G.M. (1989) *The Remembered Present*, Basic Books

48 Engel, A.K. and Singer, W. (2001) Temporal binding and the neural correlates of sensory awareness. *Trends Cogn. Sci.* 5, 16–25

49 Flohr, H. *et al.* (1998) The role of the NMDA synapse in general anesthesia. *Toxicol. Lett.* 100–101, 23–29

50 Llinas, R. *et al.* (1998) The neuronal basis for consciousness. *Philos. Trans. R. Soc. London Ser. B* 353, 1841–1849

51 Newman, J. and Baars, B.J. (1993) A neural attentional model for access to consciousness: a global workspace perspective. *Concepts Neurosci.* 4, 255–290

52 Sheinberg, D.L. and Logothetis, N.K. (1997) The role of temporal cortical areas in perceptual organization. *Proc. Natl. Acad. Sci. U. S. A.* 94, 3408–3413

53 Rees, G. *et al.* (1999) Inattentional blindness versus inattentional amnesia for fixated but ignored words. *Science* 286, 2504–2507

54 Duncan, J. and Owen, A.M. (2000) Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends Neurosci.* 23, 475–483

55 Newell, A. (1994) *Unified Theories of Cognition: The William James Lectures*, Harvard University Press

Bernard J. Baars

The Neurosciences Institute, 10640 John Jay Hopkins Drive, San Diego, California 92121, USA.

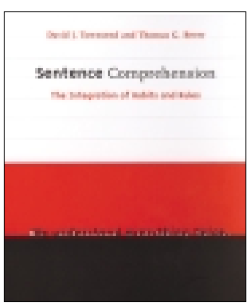
e-mail: baars@nsi.edu

Book Review

Breaking out of old reading habits

Sentence Comprehension: The Integration of Habits and Rules

by David J. Townsend and Thomas G. Bever, MIT Press, 2001. $24.95/£16.95 (x + 445 pages) ISBN 0 262 20132 1



'Most of the time what we do is what we do most of the time. Sometimes we do something new.' So say Townsend and Bever in their new book about people's ability to understand language. Such statements are obviously meant to amuse and perhaps also provoke the reader, but they also are intended to capture neatly the central theme of this excellent work: in general people tend to fall back on old habits but occasionally they do something novel. When this philosophy is applied to language processing, what emerges is the authors' central theoretical argument: sentences are understood through a combination of associationist principles and computational mechanisms.

Of course, the assertion that we usually see variations on the same theme with only the occasional new idea could be a cynic's assessment of the state of theorizing in psycholinguistics. Most approaches to sentence comprehension assume that a combination of stored information and productive rules forms the basis of our linguistic competence and performance. So have Townsend and Bever managed to say anything new in this book? In many significant ways, they have. Their highly original suggestion is that all sentences are essentially processed twice – first, associations get activated and yield a tentative, global parse from which a 'quick-and-dirty' meaning representation is derived; then, detailed syntactic computations are performed on the same word string. This second process fills in syntactic details and, more importantly, verifies that the meaning derived earlier conforms to syntactic principles. Moreover, do not fear that the first-stage global parse is just some *ad hoc* structure invented by psychologists to capture a limited aspect of the data; Townsend and Bever are as aware as any psycholinguists of the usefulness of modern linguistic theory, and their proposal is that the first-stage parse creates units similar to those proposed in Chomsky's Minimalist Program [1]. Another original assumption of the Townsend and Bever model is that the syntactic hypothesis derived from the first quick parse is constructed using all sources of relevant information; that is, it is constructed non-modularly. It is the second stage of syntactic analysis that is thought to be informationally encapsulated. All these ideas are quite different from what other theorists have proposed, including psycholinguists from both the connectionist and computational camps.

The book presents theoretical and empirical arguments for this habits-and-rules approach, which they term LAST: 'Late Assignment of Syntax Theory'. The findings that LAST attempts to capture are familiar to psycholinguists – that people are particularly attentive to function words such as *the* and *was* when they read sentences, and function words cue syntactic categories. Comprehenders access important aspects of meaning faster than they compute certain syntactic relations. At the same time, they are happier when sentence elements agree with each other on features such as gender and number than when they clash. And perhaps most critically, it appears that English language processors, at least, want sentences to conform to a fundamental agent–verb–patient (Noun–Verb–Noun, or NVN) template. This idea is hardly new; in fact, Bever made this suggestion over 30 years ago [2]. Yet, as they point out, it is astonishing how much of the extant data in psycholinguistics can be accounted for

  PII: S1364-6613(00)01837-4