9. Saleh, O.A., Bigot, S., Barre, F.X., and Allemand, J.-F. (2005). Analysis of DNA supercoil induction by FtsK indicates translocation without groove-tracking. Nat. Struct. Mol. Biol. *12*, 436–440.
10. Seidel, R., van Noort, J., van der Scheer, C., Bloom, J.G., Dekker, N.H., Dutta, C.F., Blundell, A., Robinson, T., Firman, K., and Dekker, C. (2004). Real-time observation of DNA translocation by the type I restriction modification enzyme EcoR124I. Nat. Struct. Mol. Biol. *11*, 838–843.

Biomolecular Nanomanipulation Laboratory, Institut Jacques Monod, Centre National de la Recherche Scientifique and Universités de Paris VI and Paris VII, 2 Place Jussieu, 75251 Paris Cedex 05, France.
E-mail: strick@ijm.jussieu.fr

DOI: 10.1016/j.cub.2006.03.040

Linguistic Relativity: Does Language Help or Hinder Perception?

A recent study has explored the interplay between language and perception through the brain's visual pathways. The results suggest an influence of linguistic categories on the speed of colour discrimination.

Mikhail Masharov and Martin H. Fischer

One of the fundamental debates in cognitive research is about the extent to which our language influences or constrains our perception. Students of human cognition usually encounter this long-standing debate first in the light of the radical proposal by Benjamin Whorf that "we dissect nature along lines laid down by our native languages ..." [1]. In its strong version, this 'Whorfian hypothesis' of linguistic determination of cognition has been refuted as we can perceive objects and events that have no corresponding words in our mental lexicon. For example, New Guinea aborigines discriminate the colours green and blue even though they have only one lexical entry to describe both colours [2].

In its weaker form, however, the proposal that language influences our thinking — linguistic relativity — has frequently been resurrected. Studies of colour perception [2,3], categorization [4,5], and numerical cognition [6], among many others, support this view, while others do not [7,8]. The Whorfian hypothesis has recently received attention following the report of limited numerical abilities in Amazonian Indians whose language includes only three number words [9]. Contrary to the Whorfian prediction, however, their numerical performance with large sets of objects was found to be comparable to that of French controls when more appropriate tests were used [10,11].

The issue of making use of appropriate testing methodologies has plagued research into linguistic relativity, with many results turning out to be task-dependant [7,8]. Recent approaches with implicit test measures have addressed this concern and also allowed for performance comparisons within subjects, as opposed to the traditional between-subjects designs. For example, memory for arbitrary object–name pairs, such as 'apple–Patricia', is better when the gender of the proper name is congruent with the grammatical gender of the object name than when the two genders are incongruent [4].

Gilbert *et al.* [12] have now followed up on the idea of using implicit test measures and added a neuro-anatomical dimension to the idea of linguistic relativity. The authors tested the Whorfian hypothesis by presenting different visual information to the two brain hemispheres of their participants. Because of structural characteristics of the visual pathways in the brain, stimuli that are presented on the right side of the current point of eye fixation — in the right visual field — are initially projected to the left cerebral hemisphere, while those presented in the left half of the visual field are projected to the right cerebral hemisphere [13]. This contralateral projection seems to apply to the whole retinal image, including foveated stimuli [14], but it does not generally lead to performance asymmetries, because of frequent eye-movements (two or three per second) and rich inter-hemispheric neural connections. There is, however, a well-documented right visual field advantage in recognition of briefly presented printed words, which is attributable to the dominance of the left hemisphere for language processing [15]. By presenting slightly different visual inputs to the two hemispheres, Gilbert *et al.* [12] were able to show that language makes different contributions to the perception of colour in the left and right visual fields.

This new work was based on a visual search task. Each of the experiments was preceded by a colour-naming test to select right-handed participants who exhibited categorical perception of four colour patches with equidistant hues — A, B, C and D — by labelling them 'green', 'green', 'blue' and 'blue', respectively. The main experiment involved presenting, in each trial, a circle of 12 colour patches centered around the fixation point. One patch was a different colour than the rest, and participants indicated with two buttons whether this target was on the left or right side of their fixation point. Importantly, the target and distractor patches both belonged to either the same colour category — pairings AB or CD; within-category trials — or to different categories — AC, AD, BC or BD; between-category trials. The authors compared search speed for perceptual neighbours AB, BC, and CD, asking whether the pair BC would have an advantage over the other pairings because B and C are on different sides of a linguistic category boundary.

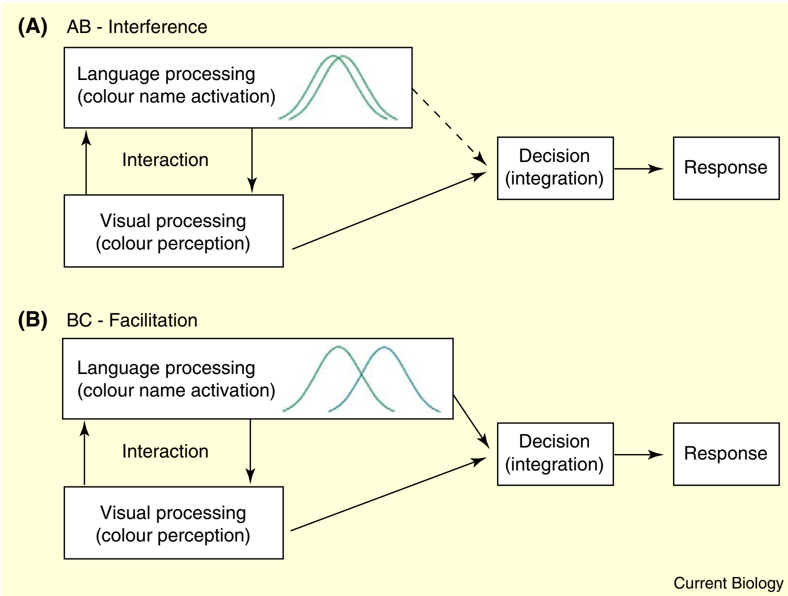

Figure 1. Schematic processing within the left hemisphere.

Discriminability is (A) reduced when the two colours belong to the same linguistic category (Green–Green), and (B) increased when they belong to different linguistic categories (Green–Blue).

Given the contralateral nature of visual projections to the cortex, Gilbert *et al.* [12] predicted that information from the right visual field would initially be more susceptible to modulation by lexical representations in the left hemisphere. Therefore, the effect of language on perceptual discrimination should be seen primarily for stimuli in the right visual field — colour discrimination should be faster for colour patches with different labels (BC), because their lexical distinction should enhance the perceptual difference. Additionally, discrimination between colours from the same lexical category should be slower in the right visual field than in the left visual field because the assignment of the same name to two colours should diminish their discriminability (Figure 1).

The main finding upheld these predictions — the results showed a faster search for between-category trials (BC) than for within-category trials (AB or CD), but only when the target patch appeared on the right side of the observer's fixation point. This was interpreted as a right visual field advantage for between-category search, attributable to the left-hemispheric language specialization and the resulting additional linguistic discriminability of the colours. This interpretation received support from control experiments in which a verbal load — for example, remembering a list of eight digits — abolished the right visual field advantage whereas a visual load — remembering a random pattern — did not. On the other hand, the right visual field advantage was reversed rather than just levelled under verbal load. This raises a question about whether the verbal task blocked the linguistic influence on the perceptual discrimination process, or instead made the search more difficult by interfering with the processing of lexical information. While Gilbert *et al.* [12] acknowledge that their results do not clearly discriminate between perceptual and post-perceptual interpretations of the categorical effect, it is clear that their methodology has promise for future research.

These new results fit nicely into an emerging bigger picture of functional segregation of cognition in the human brain, both within and between hemispheres [16–18]. Pöppel and Wittmann [17] have suggested that, in addition to imposing a serialization of processing, the left hemisphere is specialized for fast and analytical processing while the right hemisphere specializes in slow and integrative processing. A similar view is that of hemispheric specialization for local versus global processing [18]. In contrast with the results reported by Gilbert *et al.* [12], however, a recent review [19] did not find significant differences in competition between lexical and colour information within each of the two hemispheres when performing the Stroop task. It is clear that new approaches to the study of the relationship between brain and language (see http://www.ynic.york.ac.uk/rtn-lab) are likely to keep the debate alive and help paint the picture of the linguistic influence over perception.

References

1. Whorf, B. (1956). Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf, J.B. Carroll, ed. (Cambridge, MA: MIT Press), p. 231.
2. Kay, P., and Regier, T. (2006). Language, thought and color: recent developments. Trends Cog. Sci. *10*, 51–54.
3. Davidoff, J., Davis, I., and Roberson, D. (1999). Colour categories of a stoneage tribe. Nature *398*, 203–204.
4. Boroditsky, L., and Schmidt, L. (2000). Sex, syntax, and semantics. Proc. Cog. Sci. Soc. *22*, 42–47.
5. Lucy, J. (1992). Grammatical Categories and Cognition: A Case study of the Linguistic Relativity Hypothesis (Cambridge: Cambridge University Press).
6. Brysbaert, M., Fias, W., and Noel, M.-P. (1998). The Whorfian hypothesis and numerical cognition: Is 'twenty-four' processed in the same way as 'four-and-twenty'? Cognition *66*, 51–77.
7. Li, P., and Gleitman, L. (2002). Turning the tables: language and spatial reasoning. Cognition *83*, 265–294.
8. Malt, B., Sloman, S., Gennary, S., Shi, M., and Wang, Y. (1999). Knowing versus naming: similarity and the linguistic categorization of artifacts. J. Mem. Lang. *40*, 230–262.
9. Gordon, P. (2004). Numerical cognition without words. Science *306*, 496–499.
10. Pica, P., Lemer, C., Izard, V., and Dehaene, S. (2004). Exact and approximate arithmetic in an Amazonian Indigene group. Science *306*, 499–503.
11. Gelman, R., and Butterworth, B. (2005). Number and language: how are they related? Trends Cog. Sci. *9*, 6–10.
12. Gilbert, A., Regier, T., Kay, P., and Ivry, R. (2006). Whorf hypothesis is supported in the right visual field, but not the left. Proc. Natl. Acad. Sci. *103*, 489–494.
13. Gazzaniga, M., Ivry, R., and Mangun, G. (1998). Cognitive Neuroscience: The Biology of Mind (New York: Norton Publishers), p. 125.
14. Lavidor, M., and Walsh, V. (2004). The nature of foveal representation. Nat. Rev. Neurosci. *5*, 729–735.
15. Chiarello, C., Liu, S., and Shears, C. (2001). Does global context modulate cerebral asymmetries? A review and new evidence on word imageability effects. Brain Lang. *79*, 360–378.
16. Goodale, M., and Milner, D. (2004). Sight Unseen: An Exploration of Conscious and

Unconscious Vision (Oxford, UK: Oxford University Press).
17. Pöppel, E., and Wittmann, M. (1999). Time in the mind. In The MIT Encyclopedia of the Cognitive Sciences, R. Wilson and F. Keil, eds. (Cambridge, MA: MIT Press).
18. Christman, S. (2001). Individual differences in Stroop and local-global processing: A possible role of interhemispheric interaction. Brain Cog. *45*, 97–118.
19. Belanger, H., and Cimino, C. (2002). The lateralized Stroop: A meta-analysis and its implications for models of semantic processing. Brain Lang. *83*, 384–402.

Psychology Department, University of Dundee, Dundee DD1 4HN, Scotland, UK.
E-mail: m.masharov@dundee.ac.uk

DOI: 10.1016/j.cub.2006.03.039

Animal Behaviour: Old World Monkeys Build New World Order

New experimental evidence shows that policing behaviour by dominant monkeys stabilizes and integrates macaque societies.

Kevin N. Laland

As the architects of phenomenal feats of engineering, from the Great Wall of China to the Taj Mahal to New York city, we humans often fail to realise that other species are also impressive engineers in their own way. Countless animals manufacture nests, burrows, holes, webs and pupal cases; plants change levels of atmospheric gases and modify nutrient cycles; fungi and bacteria decompose organic matter; even bacteria fix nutrients. These activities collectively are known as niche construction, the capacity of living creatures to shape their worlds [1]. New research on the policing behaviour of high-status monkeys brings the study of niche construction into a whole new domain [2].

We flatter ourselves that human beings uniquely control the planet, and there is no doubting that human engineering and technology has taken niche construction to its zenith. Yet dated at 3.6 billion years ago, the first fossil evidence of life, preserved in rock as laminated structures known as stromatolites, is a manifestation of the niche-constructing activities of microbial mats, which played a vital part in constructing the Earth's oxygenated atmosphere.

While the fact that organisms engage in niche construction is widely recognized, the evolutionary and ecological significance of this activity has only recently received attention [1]. Currently, niche-construction is the focus of vigorous debates within the fields of evolutionary biology and ecology, precipitated by a small but rapidly growing group of biologists who seek recognition of niche construction as a fundamental biological process. Advocates of this viewpoint argue that there is both accuracy and utility in treating niche construction as a major evolutionary process in its own right, rather than as merely a product of evolution. Evolution is regarded as based on networks of causation and feedback in which organisms drive environmental change and organism-modified environments subsequently select organisms.

If you take a close look at an earthworm, for instance, you would see that these manifestly terrestrial creatures are structurally very poorly adapted to cope with physiological problems such as water and salt balance on land, and they would seem to belong in a freshwater habitat [3]. That is because earthworms have retained their ancestral freshwater kidneys, evolving few of the structural adaptations one would expect to see in an animal living on land. They survive in a terrestrial environment by building their own private swimming pools: that is, by tunnelling, exuding mucus and eliminating calcite, which produces well-aggregated soils with weakened matric potentials, allowing them to draw water into their bodies. Through their burrowing activities, earthworms dramatically change the structure and chemistry of the soils in which they live, often on a huge scale [4]. This example highlights a problem with the concept of adaptation. In this case it is the soil that does the changing, rather than the worm, to meet the demands of the worm's freshwater physiology [3]. So what is adapting to what? Advocates of the niche construction perspective feel that standard evolutionary theory short-changes the active role of organisms in constructing their environments.

Hitherto, niche construction theory has been largely restricted to the ecological and evolutionary domains: organisms modify resource distributions and natural selection pressures, with knock-on consequences for ecological dynamics and evolutionary trajectories. But a highly innovative recent paper by Jessica Flack and colleagues [2] has pioneered the application of niche-construction to the social sphere. Flack is a primatologist who studies a captive population of pigtail macaques, monkeys indigenous to South East Asia. These macaques live in large, mixed-sex groups, with each monkey regularly interacting with a subset of the individuals with whom they play, groom, forage, and so forth. These other individuals can be regarded as providing a set of commodities, or services, that are in many respects social equivalents to the set of ecological resources and conditions — prey availability, temperature, humidity and so forth — that characterize an organism's ecological niche.

Flack *et al.* [2] argue that, in the same way that the ecological niche can usefully be treated as frequency distributions of the resources used by a population, so the social niche can be viewed as composed of networks of social services provided by individuals. An attractive feature of this conception is that it allows the complex set of social interactions that underlie primate societies to be quantified, and sets the scene