precisely because in this system syntactic composition is impaired.

In Broca’s production, semantics is less visible because in this case syntax guides the process by which semantic information is encoded within a sentence through word order and inflectional processes. So, as the neurological evidence shows, the system can make less use of available semantic information.

The possibility of an independent generative semantic system is also independently supported by reports that indicate that the posterior superior temporal region, associated with Wernicke’s aphasia, and not the left anterior frontal cortex, associated with Broca’s aphasia, is engaged during lexico-semantic processing both at the lexical [13,14] and sentence levels [15,16]. (In fMRI studies, this association sometimes also involves BA 47, an area not crucially associated with syntactic processing). This converges with the analysis presented here. It points to a cortical substrate for semantic combinatorial processes, one which predictably remains intact in the Broca’s system.

Concluding remarks
Altogether, three points have been argued here: (1) a large body of neurological evidence suggests that semantics behaves as an independent combinatorial system in the brain; (2) one current linguistic model shows how this system is actually part of the architecture of grammar; and (3) syntactic and semantic processes are not equally visible in comprehension and production. This highlights the inevitable connection between the language capacity and the manner in which it is accessed.

As we seek to build connections between brain-based linguistic observations and abstract models of representation, several long-term research questions suggest themselves: In what way can cognitive neuroscience in general inform research that seeks to isolate purely syntactic processes from semantic ones? How do world knowledge and semantics connect? What are their cortical ‘markers’? What other neurological and processing criteria could be used for determining this? To be sure, these questions have long been at the center of cognitive neuroscience of language research; the present arguments constitute a motivation to pursue them through less traditional, theoretical architectures and look at what neurology and cognitive neuroscience can contribute.

References

Language, thought and color: recent developments

Paul Kay¹ and Terry Regier²

¹International Computer Science Institute, University of California, Berkeley, USA
²University of Chicago, Illinois, USA.

The classic issue of color naming and color cognition has been re-examined in a recent series of articles. Here, we review these developments, and suggest that they move the field beyond a familiar rhetoric of ‘nature versus nurture’, or ‘universals versus relativity’, to new concepts and new questions.
The ‘Whorfian’ debate over color naming and color cognition has been framed by two questions:

(1) Is color naming across languages largely a matter of arbitrary linguistic convention?
(2) Do cross-language differences in color naming cause corresponding differences in color cognition?

In the standard rhetoric of the debate, a ‘relativist’ argues that both answers are Yes, and a ‘universalist’ that both are No. However, several recent studies, when viewed together, undermine these traditional stances. These studies suggest instead that there are universal tendencies in color naming (i.e. No to question 1) but that naming differences across languages do cause differences in color cognition (i.e. Yes to question 2). These findings promise to move the field beyond a conceptually tired oppositional rhetoric, towards a fresher perspective that suggests several new questions. Here, we review these recent studies, the clarification they bring to the debate, and the further questions they raise.

‘Universalist’ beginnings
Color naming varies across languages; however, it has long been held that this variation is constrained. Berlin and Kay [1] found that color categories in 20 languages were organized around universal ‘focal colors’ – those colors corresponding principally to the best examples of English ‘black’, ‘white’, ‘red’, ‘yellow’, ‘green’ and ‘blue’. Moreover, a classic set of studies by Eleanor Rosch found that these focal colors were also remembered more accurately than other colors, across speakers of languages with different color naming systems (e.g. [2]). Focal colors seemed to constitute a universal cognitive basis for both color language and color memory.

The ‘relativist’ challenge
Recently, however, Debi Roberson and colleagues [3,4] failed to replicate Rosch’s results. They compared speakers of three languages: English, Berinmo, a language of Papua New Guinea, and Himba, a Bantu language – and did not find privileged memory, similarity judgments or paired associates learning in Berinmo and Himba at the proposed universal foci. Instead, they found that these cognitive variables were well predicted by the boundaries of each language’s color categories. This is a form of “categorical perception” of color (categorical perception is said to occur when stimuli that straddle a category boundary are perceived as more distinct than equivalently spaced stimuli within a category). Because color term boundaries vary across languages (see Figure 1a,b), speakers of different languages apprehend color differently. Moreover, these linguistic differences actually seem to cause, rather than merely correlate with, cognitive differences [5], confirming and extending earlier findings by Kay and Kempton. These results call into question the cognitively privileged status of the universal focal colors. And they provide a positive answer to question 2 above: language differences do cause differences in color cognition.

Roberson and colleagues have gone further, proposing that universal foci play no central role in color naming either (question 1). They argue that color categories are determined at their boundaries by language, and that best examples of categories are mere epiphenomena of this process [3]. The one universal constraint they do acknowledge is “grouping by similarity” – the very general principle that similar colors will tend to receive the same name. They also emphasize that they have studied languages of non-industrial societies, suggesting that the Berlin and Kay results – based mostly on languages of industrialized societies, which cluster near those of English (black dots).

Current status of the debate
However, when the above-mentioned ‘relativist’ results on color cognition are juxtaposed to some recent ‘universalist’ findings on color naming, the traditional stances break down. For despite the clear evidence that language affects color cognition, there is also new evidence...
for color naming universals. Kay and Regier [7] conducted
the first comprehensive objective tests of color naming
universals – in part in response to the ‘relativist’ claims
above – and found strong statistical evidence of universal
tendencies in color naming across languages of both
industrialized and non-industrialized societies, the latter
from the World Color Survey (WCS). Moreover, there is
evidence specifically for universal focal colors in naming.
Regier, Kay and Cook [8], extending earlier work by
MacLaury [9], found that best examples of color terms in
the WCS strongly tend to cluster near the proposed focal
colors (Figure 1c). This pattern would not be predicted if
the WCS strongly tend to cluster near the proposed focal
MacLaury [9], found that best examples of color terms in
space in a way that maximizes information. Steels and
color naming flow from a process that partitions color
occurring colors in the environment. Jameson and
in evolutionary tuning to the most frequently
above – and found at the same time, differences in color naming do induce differences in color
cognition (Yes to question 2).
This non-traditional pair of answers to our two main
questions suggests further questions that are
currently under investigation. Most broadly: which
aspects of color cognition shape language, and which are
shaped by it? How do these reciprocal influences work
together? Some initial answers are emerging, as we
now outline.

What causes universal tendencies in color naming?
Several explanations for universals in color naming have
been proposed. Kuehni [11] posits neurophysiological
support for the cardinal colors red, yellow, green and
blue. Lindsey and Brown [12] proposed that languages
spoken near the equator tend to lack separate terms for
green and blue because excessive exposure to ultraviolet
radiation from sunlight yellows the lenses of people living
in this region. However, this theory has been challenged
[13,14]. Shepard [15] suggested that the major phenom-
enal hue axes, especially blue–yellow, derive from
evolutionary tuning to the predominant sources of
natural illumination. Yendrikhovskij [16] also showed
that the sources of color naming universals could reside
in evolutionary tuning to the most frequently
occurring colors in the environment. Jameson and
D’Andrade [17] argued that the universal focal colors are
salience maxima in color space and that universals of
color naming flow from a process that partitions color
space in a way that maximizes information. Steels and
Belpaeme [18] emphasize the role of inter-speaker
communication, with evidence from simulations of inter-
acting agents. In short, there is no lack of explanations for
universals of color naming, some mutually consistent and
others not.

What causes categorical perception of color,
and is it really perceptual?
It has been widely assumed that language is the cause of
color categorical perception. This is suggested because – as
we have seen – named category boundaries vary across
languages, and categorical perception varies with them.
However, Franklin and Davies [19] have found startling
evidence of categorical perception at some of these same
boundaries in pre-linguistic infants and toddlers in
several language groups. Thus, some categorical color
distinctions apparently exist before language, and could
then be reinforced, modulated or eliminated by learning a
particular language.

Much of the evidence for categorical ‘perception’ of color
comes from tasks that involve memory; hence it could be
that the category effects stem from memory rather than
perception. Recently, however, Franklin et al. [20] found
that both adults and infants respond categorically in a
visual search task that minimizes the involvement of
memory. They concluded that the effect was probably truly
perceptual. This is a tentative conclusion that deserves
further investigation. The perceptual status of ‘categorical
perception’ of color is currently an object of study, as is its
status with respect to innateness, learning and unlearning.

Summary
The debate over color naming and cognition can be
clarified by discarding the traditional ‘universals versus
relativity’ framing, which collapses important distinc-
tions. There are universal constraints on color naming,
but at the same time, differences in color naming across
languages cause differences in color cognition and/or
perception. The source of the universal constraints is not
firmly established. However, it appears that it can be said
that nature proposes and nurture disposes. Finally,
‘categorical perception’ of color might well be perception
sensu stricto, but the jury is still out.

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The cognitive science of holes and cast shadows

Roberto Casati

CNRS-Institut Nicod, EHESS-ENS Paris, France; and Università IUAV, Venice, Italy

Owing to their peculiar nature of ‘quasi-objects’ or ‘negative objects’ (absences with a shape), shadows and holes are a promising source of insight about the representation of physical objects in cognition. In philosophy, informal conceptual analysis has uncovered interesting common features. (i) Both holes and cast shadows (henceforth simply ‘shadows’) are dependent features; they cannot exist without objects hosting or casting them. Both shadows and holes are somewhere between being regions of space and fully-fledged material objects: they are (ii) similar enough to bounded regions of space in that they have a location, a shape, a size, and are as immaterial as space is, but are (iii) more object-like as they can persist over time and move [1].

To what extent are shadows and holes represented as object-like, and why?

We know more about shadows than we do about holes, although shadows are just that: holes in light. Light makes all the difference, turning the shapes drawn by shadows into valuable sources of perceptual information. Perceptual representations of shadows should be fit for the particular requirements of controlled and automatic visual information processing. Controlled cognitive processes use shadow shapes and locations as premises in inferences to describe the spatial distribution of objects (shadow casters, screens etc.), as in astronomy [2], x-ray analysis, electronic microscopy, and aerial geological photography. Renaissance painters laid down the foundations of the mathematical study of shadows, later subsumed under projective geometry.

Early investigations of the automatic processing of shadows [3] capitalized on these results to yield shape- and space-from-shading algorithms for machine vision. It is now clear that shadows are used at a very early stage in visual processing [4] to extract distance and position, and this raises an intriguing problem: they should be labelled by the visual system as shadows very early on (i.e. as transitory features, dependent upon casters, as opposed to permanent and independent features). However, marks bearing little resemblance to shadows suffice for vision, and tolerance of impossible and generally geometrically incongruous shadows [5,6] indicates that the processing of shadows is not tuned to the exact norms of geometry. Much as they are informative, shadows also constitute noise as they are salient features of the visual scene (because of high luminance contrast at their boundary) and it takes very little to make them look like independent surface features (e.g. by drawing a line at their boundary; this is why line drawings of shadows do not work). Visual cognition eliminates this noise and provides only limited conscious access to shadows.

Taken together, the informativeness vs noise aspects of shadows makes it reasonable for the visual system to extract from them useful information at a relatively early stage, and then erase later access to shadows to prevent them from being mistaken for objects. This might explain why we are generally unable to detect shadow inconsistencies unless these are pointed out explicitly; an inconsistent or impossible shadow does not look like an impossible figure as no conflict ever arose in constructing its representation. Finally, tolerance of incongruent shadows aligns well with the idea that shadows’ representations are mainly position indicators (see Figure 1). This suggests that there exists an overarching perceptual representation genus – ‘position indicating mark’ – of which ‘shadow’ is a species (another species is ‘reflection’; very much like shadows, reflections indicate position but the conformity of their shapes goes unchecked). Illusions of impossible holes would be harder to construct than those of impossible shadows, as constraints dictated by light (uniformity of direction from a single source) do not have a counterpart in the domain of holes.

Corresponding author: Casati, R. (casati@ehevs.fr).

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