

## **The Interpreter in Human Psychology.**

*Matthew E. Roser and Michael S. Gazzaniga  
Center for Cognitive Neuroscience, Dartmouth College*

### **I. The interpretive nature of consciousness**

Although writers may disagree on the degree to which the brain exhibits ‘modularity’ of function (Fodor, 2000; Pinker, 1997) there is growing evidence that the brain is not a generalized computing device exhibiting equipotentiality between regions (Lashley, 1950). Rather, the brain is a collection of functionally-specialized areas that carry out domain-specific processing, such as for object or face identity, spatial location, or emotional content. This evidence has motivated the view that consciousness, although experienced as a unitary and coherent whole, is instead a composite of fractionated and disparate processes that are drawn together in a dynamic network or ‘workspace’ (Baars, 1989; Dehane & Naccache, 2001). According to this hypothesis, consciousness, at any one time, comprises only those distributed processes that have been integrated into a large-scale system of cortical activity, and which receive attentional ‘amplification’. Consequently, much processing occurs outside of awareness (Zeki, 2003).

The most striking demonstration of the disunity of consciousness comes from studies of patients who deny that they have a severe cognitive deficit. For example, patients who exhibit hemispatial neglect, commonly as a result of right parietal damage, are often aware that they have been diagnosed with a deficit, but sometimes refuse to accept the diagnosis. To the patient, the notion that they neglect a side of space can seem nonsensical since their conscious experience has been reduced to encompass only a subset of perceptual and memory processes. As one patient put it *‘I knew the word*

*“neglect” was a sort of medical term for whatever was wrong but the word bothered me because you only neglect something that is actually there, don’t you? If it’s not there, how can you neglect it?’* (Halligan,1998).

Similarly in anosognosia for hemiplegia the paralysis of a limb is denied, even when the patient is confronted with their paralyzed hand (Ramachandran, 1996). This usually results from damage to the right hemisphere (Bisiach, Vallar, Perani, Papagno, & Berti, 1986; Gainotti, 1989). According to the workspace view of consciousness this happens because any remaining processing in the damaged domain is unavailable for integration into a widespread cortical system and cannot therefore contribute to awareness. Thus, a lesion in a specific location may wipe out not only processing of an attribute, such as input from a side of space or the body, but also the awareness that the attribute exists. For the patient, therefore, denying a deficit is congruent with their conscious experience.

These patients often exhibit a tendency to interpret experiences in a way that rationalizes conflicting information and involves considerable confabulation, or storytelling, that may diverge markedly from reality (Cooney & Gazzaniga, 2003; Gazzaniga, 2000). These confabulations are attempts to produce logical explanations for evidence of the patient’s impairments, which fit with their conscious experience. Bizarre confabulations that seem untenable to most people, because of conscious access to information that contradicts them, probably seem completely normal to patients to whom only a subset of the elements of consciousness are available for integration.

Confabulations reveal the piecemeal and interpretive nature of conscious experience. To construct a coherent narrative from the various elements of experience a

system for resolving ambiguities is needed. This system must take the information available from other brain processes, perceptual, motoric, mnemonic, and emotive, and integrate them into a stable description of reality that can be used for ongoing behavioral maintenance.

## **II. Interpretive processes in the two hemispheres**

A number of experimental findings suggest that the left hemisphere is particularly involved in incorporating available information into a stable representation of reality. Cutting the corpus callosum, the large band of axons that joins the two hemispheres, divides consciousness between the two hemispheres (Sperry, 1969). Lateralized presentation of visual stimuli can allow one hemisphere to be conscious of some event while the other hemisphere remains unaware of the exact nature of the stimulus. These 'split-brain' patients typically profess to feel completely normal.

Dividing the hemispheres can, however, reveal the interpretive nature of consciousness in the left hemisphere. In fact, the left hemisphere seems driven to generate hypotheses about information with which it is presented. Gazzaniga (2000) has termed this the 'left-hemisphere interpreter'. In one experiment (Gazzaniga, 2000) the patient is presented with two different scenes simultaneously, one to each hemisphere (Figure 1). The patient is then asked to use his or her left hand (controlled primarily by the right hemisphere) to choose an appropriate item from an array of pictures of objects that may or may not be typically found within the presented scenes. The left hemisphere, which has no knowledge of what was presented to the right hemisphere, can observe the actions of the right hemisphere. When the patient is asked to describe why they chose a

particular item, the left hemisphere, which houses the main centers essential for language production in most people, will often reply with an explanation for the action that is congruent with the scene presented to the left hemisphere. These rationalizations can be elaborate, including experiences from outside the experimental setting, and resemble the confabulatory explanations made by patients. Similarly, if a verb, such as 'laugh', is presented to the isolated right hemisphere the represented action may be carried out. When the patient is asked what they are doing the left hemisphere usually replies with a reasonable explanation for their action, while the patient remains unperturbed by the discord between their explanation and the true stimulus for the action (Figure 2).

Memory tasks also reveal the predilection of the left hemisphere for generating hypotheses about recent experiences, even when this is detrimental to performance. Studies in which each hemisphere of a split-brain patient is required to determine whether a picture was drawn from a previously-viewed set of scenes suggest that recognition-memory performance by the left hemisphere is more affected by expectations based on the meaning of the scenes than is performance by the right hemisphere (Phelps & Gazzaniga, 1992; Metcalf, Funnell & Gazzaniga, 1995). For instance, the left hemisphere often falsely 'recognizes' pictures as having been presented in an earlier session if they are congruent with one of the previously viewed scenes. It is thought that this is because the left hemisphere elaborates on the scenario presented and consequently confuses these internal elaborations with novel semantically-related distractor stimuli. The isolated right hemisphere does not exhibit this tendency, but instead, seems to maintain a more veridical representation in memory of recent events. Thus, a left-hemispheric interpretive system that elaborates on the information it receives may be primarily responsible for the

distortions of memory that have been well documented in normal subjects and for the apparent lack of memory deficit in some patients who have suffered insult to right-frontal cortex (Miller & Gazzaniga, 2000).

Another finding that hinted at the tendency for the left hemisphere to generate hypotheses about input it receives involved a task in which subjects had to predict the location (high or low on a screen) of a target stimulus. Neurologically-normal subjects usually distribute their responses according to the probability that each stimulus will appear, a strategy known as frequency matching, even though this is suboptimal. This tendency reflects a search for sequences in the stream of stimuli (Yellott, 1969, cited in Wolford, Miller, & Gazzaniga, 2004). Wolford et al. (2000) found that this response strategy was also displayed by the isolated left hemisphere of two split-brain patients, but that the right hemisphere maximized the number of correct responses by consistently choosing the location at which the target was most often displayed. The mode of responding adopted by the right hemisphere is also exhibited by animals. Essentially the same finding was obtained by testing patients who had sustained damage to either the left or the right frontal lobe. Thus the left hemisphere based its responses on a hypothesized pattern in the stimuli, but the right hemisphere did not. More-recent tests have revealed that the right hemisphere does, in fact, frequency match when presented with stimuli for which it is specialized for processing, such as faces, while the left hemisphere responds randomly (Miller & Valsangkar-Smyth, *in press*). These results were interpreted as suggesting that one hemisphere cedes control of the task to the other hemisphere, essentially 'giving up' on the task, if the processing required is outside of its domain of expertise (Wolford et al., 2004).

Another area of relative expertise in which the right hemisphere seems to ‘interpret’ available evidence is visuospatial perception. Split-brain testing suggests that both hemispheres are capable of a range of visual perceptual tasks, such as determining whether objects are of the same size or luminance. The right hemisphere, however, outperforms the left in tests of spatial ability, such as determining alignment and orientation (Corballis, Funnell, & Gazzaniga, 1999; 2002), and some, more sophisticated, visuospatial processes are only able to be performed by the right hemisphere in split-brain patients. Amodal completion, for example, in which occluded contours are perceived, and which requires the visual system to group stimuli and infer the contours, cannot be performed by the left hemisphere (Corballis, Fendrich, Shapley, & Gazzaniga, 1999). Similarly, only the right hemisphere is able to extract the causal structure from the spatial and temporal properties of the movements of colliding stimuli (Roser, Fugelsang, Dunbar, Corballis, & Gazzaniga, *in press*) and functional imaging of normal subjects has also suggested right-hemispheric involvement in this task (Fugelsang, Roser, Corballis, Gazzaniga, & Dunbar, *in press*). Thus the right hemisphere might also be said to engage in ‘interpretation’ of a kind which extracts structure from a fragmented sensory representation. Corballis (2003) has referred to this construction of higher-level representations of the visual environment as a ‘right-hemispheric visual interpreter’ and speculated that the poor performance of the left hemisphere on tasks requiring complex visual analysis may be due to its having lost visuospatial abilities it once possessed as lateralization of function evolved (Corballis, Funnell, & Gazzaniga, 2000).

The interpretive abilities of the isolated right hemisphere are, however, limited. The extraction of causal structure from collision events undertaken by the right

hemisphere was evident in the absence of the ability to perform another task that required logical reasoning about causal contingencies at a level that is achieved by two-year-old children (Roser et al., *in press*). For this task the left hemisphere was necessary. Earlier testing of two split-brain patients also found that only the left hemisphere could perform above chance on inferential tasks, such as choosing the picture representing the correct consequence of combining objects represented by two other pictures and carrying out simple mathematical operations, despite these two patients possessing some language comprehension in the right hemisphere (Gazzaniga & Smylie, 1984).

Recent functional imaging studies suggest that logical reasoning, such as deducing a conclusion from a set of premises seems to involve mostly left-hemispheric regions, including the left prefrontal cortex (PFC) (Goel & Dolan, 2003; Noveck, Goel, & Smith, 2004). Reasoning about abstract problems with no semantic content, so-called ‘content-independent reasoning’, has been found to elicit activity in a left-hemispheric frontal-parietal system. Content-dependent reasoning, in which tasks involve stimuli relevant to an individual’s beliefs, values, and goals, involves a left-hemispheric frontal-temporal system. These left-hemispheric regions overlap with, but extend beyond, areas involved in language.

Right-hemispheric activity is also apparent in some imaging studies of reasoning (Houde et al., 2000; Houde et al., 2001), although sometimes at levels of significance much lower than those seen in the left hemisphere (Goel & Dolan, 2003; Noveck, Goel, & Smith, 2004). Heterogeneity of experimental tasks may account for some differences in observed areas of activation, but results suggest that emotional factors, and conflicts between logical conclusions and beliefs, engage right ventral-medial prefrontal cortex.

This area was activated by the inclusion of an emotive component in a task in which subjects had to learn to inhibit a commonly-made logical error (Houde et al., 2000; Houde et al., 2001). This activation was in the same location as the damage sustained by Phineas Gage and by patients assessed by Damasio (1999) who exhibit logical reasoning problems thought to be due to the destruction of a crucial emotional component in reasoning (Houde & Tzourio-Mazoyer, 2003). This same region was also found to be active when a syllogism's logically-valid conclusion was not believable and is thought to be involved in inhibiting the response associated with a belief bias (Goel & Dolan, 2003). The involvement of additional regions outside the left hemisphere may underlie the behavioral observation that content-dependent (non abstract) reasoning is performed better than abstract reasoning even if the logical structure is the same. The developing picture, however, is that processing of logical rules is primarily undertaken by networks of regions within the left hemisphere.

That the left hemisphere solves syllogisms by abstracted reasoning is also suggested by the observation that the suppression of the right hemisphere by electroconvulsive therapy (ECT) leaves patients inclined to accept conclusions that are absurd but based on strictly-true logic. After left-hemispheric ECT the same absurd conclusions are indignantly rejected (Deglin & Kinsbourne, 1996). Thus, if the right hemisphere is suppressed by ECT or damaged, as in hemispatial neglect, the left hemisphere seems to persist in applying logical rules to its reduced subset of consciously experienced inputs, with little heed paid to their 'common sense' likelihood. The resulting confabulatory explanations for life events may serve to resolve conflicts between potentially-contrary information, and may make perfect sense within the limited

sphere of the left hemisphere's consciousness, but they can often diverge sharply from reality. Disconnection of the right hemisphere from the left by callosotomy also results in interpretation from a reduced range of available input although, in split-brain patients, the intact right hemisphere may prevent confabulations from becoming too outlandish.

### **III. An evolutionary perspective**

Maintaining a stable representation of reality over time must involve the incorporation of input from multiple distributed brain processes, but for the resulting construct to bear a resemblance to reality this process must occur in an orderly, logical, fashion. Evidence suggests that interpretation of perceptual and cognitive processes, and the construction of a personal narrative, depends on the left hemisphere, as, to a large degree, do language and logical reasoning. The common functional requirement between these domains is the need to manipulate units of information in a syntactic manner, that is, according to formal rules sometimes involving several levels of recursion. For instance, in constructing an explanation for one's response to a stimulus, such as the actions of another, the interpretive system must take account of the rule that causes must always precede effects. Taking multiple perceptual, mnemonic, and cognitive processes and combining them in a rule-based manner in order to generate a novel description of current experience is likely subserved by brain systems in the left hemisphere, including, but not limited to, the areas classically associated with language. Although verbally expressing a confabulatory story to explain one's experiences obviously depends on language, it is probably not the case that nothing more than language mechanisms are involved in interpretation. The observation that a number of extra-linguistic areas are

recruited in logical inference, and the placid acceptance of circumscribed conscious experience as representative of reality by many brain injured patients, suggests that interpretation is not merely story telling, but is instead an essential component of consciousness involving many brain areas.

The close association between language, logic, and interpretation, suggests a similar evolutionary history. Pre-frontal cortex in humans does not seem particularly large when compared to other primates (Roth, 2001) suggesting that human interpretive abilities cannot be accounted for simply by appealing to absolute or relative PFC size. Instead, changes to structural and functional organization and the relative size of regions within the PFC may be more-promising avenues for investigation (Fuster, 1997).

Important differences between human and non-human brains do, however, exist in this area. For instance, Broca's area in the left frontal lobe, which is involved in syntactic processing in language, is asymmetric in humans. Modern apes do not exhibit the same hemispheric asymmetry in the homologue of this area (Sherwood, Broadfield, Holloway, Gannon, & Hof, 2003). The earliest date for the emergence of Broca's area is around two million years ago, with the genus *Homo*, as suggested by its appearance in skull endocasts (Falk, 1983; Tobias, 1987). If syntactic combinatorial abilities in tool production (Ambrose, 2001), and in either manual or vocal communication (Corballis, 2002), first emerged with this genus then interpretive abilities, drawing on the same mechanisms for rule-based operation, may have emerged alongside.

In fact, interpretation of one's own behavior, and the behavior of others, in mental terms may only have become necessary once behavioral complexity, and flexibility, evolved to a point at which it became impossible to represent the range of possible

behaviors as simple abstractions based on statistical co-occurrence. The uniqueness to humans of a mentalistic representation of the self and of others is suggested by research that delineates the limitations of chimpanzee cognition (Premack, 2004), and which points out that behavioral abstraction can account for many findings that have been taken as evidence for mentalistic representation in chimpanzees (Povinelli & Giambrone, 2000; Povinelli & Vonk, 2003).

Interpreting one's conscious experience in a coherent manner underlies a conception of oneself as a mental entity, with continuity through time, and with control over one's actions. This capacity stems from the systems that make humans unique, the left-hemisphere's ability for generative, recursive, thought.

## References

- Ambrose, S.H. (2001). Paleolithic Technology and Human Evolution. *Science* 291, 1748-1753.
- Baars, B. J. (1989). *A cognitive theory of consciousness*. Cambridge University Press, Cambridge
- Bisiach E., Vallar G., Perani, D., Papagno, C., & Berti, A. (1986). Unawareness of disease following lesions of the right hemisphere: Anosognosia for hemiplegia and anosognosia for hemianopia. *Neuropsychologia* 24, 471-482.
- Cooney, J.W., & Gazzaniga, M. (2003). Neurological disorders and the structure of human consciousness. *Trends in Cognitive Sciences* 7, 161–165.
- Corballis, M.C. (2002). *From hand to mouth: The origins of language*. Princeton University Press, Princeton, NJ.
- Corballis, P. M., Fendrich, R., Shapley, R. M., & Gazzaniga, M. S. (1999). Illusory contour perception and amodal boundary completion: Evidence of a dissociation following callosotomy. *Journal of Cognitive Neuroscience* 11, 459–466.
- Corballis, P. M., Funnell, M. G., & Gazzaniga, M. S. (1999). A dissociation between spatial and identity matching in callosotomy patients. *Neuroreport* 10, 2183–2187.
- Corballis, P.M., Funnell, M., & Gazzaniga, M.S. (2000). An Evolutionary Perspective on Hemispheric Asymmetries. *Brain and Cognition* 43, 17–134.
- Corballis, P. M., Funnell, M. G., & Gazzaniga, M. S. (2002). Hemispheric asymmetries for simple visual judgments in the split brain. *Neuropsychologia* 40, 401–410.
- Corballis, P.M. (2003). Visuospatial processing and the right-hemisphere interpreter. *Brain and Cognition* 53, 171–176.
- Damasio, A.R. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. Harcourt Brace, New York, NY.
- Deglin, V.L. and Kinsbourne, M. (1996). Divergent thinking styles of the hemispheres: how syllogisms are solved during transitory hemisphere suppression *Brain and Cognition* 31, 285–307.
- Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: Basic evidence and a workspace framework. *Cognition* 79, 1–37.
- Fodor, J. (2000). *The Mind Doesn't Work That Way: The Scope and Limits of Computational Psychology*. MIT Press, Cambridge, MA.

Falk, D. (1983). Cerebral cortices of the East African early hominids. *Science* 221, 1072–74.

Fugelsang, J.A., Roser, M.E., Corballis, P.M., Gazzaniga, M.S., & Dunbar, K.N. Brain mechanisms underlying perceptual causality. *Cognitive Brain Research* (in press).

Fuster, J.M. (1997). *The Prefrontal Cortex*. Lippincott-Raven Price. Philadelphia, PN.

Gainotti, G. (1989). Disorders of emotion and affect in patients with unilateral brain damage. In *Handbook of Neuropsychology*, Vol. 3, (F.Boller & J. Grafman, eds.) pp 345-381. Elsevier, Amsterdam.

Gazzaniga, M.S. (2000). Cerebral specialization and interhemispheric communication: Does the corpus callosum enable the human condition? *Brain* 123, 1293–1326.

Gazzaniga, M.S., Smylie, C.S., Baynes, K., Hirst, W., & McCleary, C. (1984). Profiles of right hemisphere language and speech following brain bisection. *Brain and Language* 22, 206-220.

Goel, V., & Dolan, R.J. (2003). Explaining modulation of reasoning by belief. *Cognition* 87, 11-22.

Halligan, P.W. and Marshall, J.C. (1998). Neglect of awareness. *Consciousness and Cognition* 7, 356–380.

Houdé O., & Tzourio-Mazoyer N. (2003). Neural foundations of logical and mathematical cognition. *Nature Reviews Neuroscience* 4, 507-514.

Houdé O., Zago L., Crivello F., Moutier S., Pineau A., Mazoyer B. & Tzourio-Mazoyer N. (2001). Access to deductive logic depends on a right ventromedial prefrontal area devoted to emotion and feeling: Evidence from a training paradigm. *Neuroimage* 14, 1486-1492.

Houdé O., Zago L., Mellet E., Moutier S., Pineau A., Mazoyer B., & Tzourio-Mazoyer N. (2000). Shifting from the perceptual brain to the logical brain: The neural impact of cognitive inhibition training. *Journal of Cognitive Neuroscience* 12, 721-728.

Lashley, K. (1950). In search of the engram. *Symposia of the Society for Experimental Biology* 4, 454-482.

Metcalf, J. Funnell, M., & Gazzaniga, M.S. (1995). Right hemisphere memory superiority: studies of a split-brain patient. *Psychological Science* 6, 157-164.

Miller, M.B., & Gazzaniga, M.S. (2000). Recovered memory function following lateralized cortical damage. In *Neocortical Epilepsies*. *Advances in Neurology* (P.D.

Williamson, A.M. Siegel, D.W. Roberts, V.M. Thadani, & M.S. Gazzaniga. eds.) pp. 15-21. Lippincott Williams & Wilkins, Philadelphia, PN.

Miller, M.B. & Valsangkar-Smyth, M. Probability matching in the right hemisphere. *Brain and Cognition* (in press).

Noveck, I.A., Goel, V., & Smith, K.W. (2004). The neural basis of conditional reasoning with arbitrary content. *Cortex* 40, 613-622.

Phelps, E.A., & Gazzaniga, M. S. (1992). Hemispheric differences in mnemonic processing: The effects of left hemisphere interpretation. *Neuropsychologia* 30, 293-297.

Pinker, S. (1997). *How the Mind Works*. W.W. Norton & Company. New York, NY.

Povinelli, D.J. & Giambrone, S. (2000) Escaping the argument by analogy. In *Folk Physics for Apes* (Povinelli, D., ed.), pp. 9–72, Oxford University Press.

Povinelli, D.J. & Vonk, J. (2003). Chimpanzee minds: suspiciously human? *Trends in Cognitive Sciences* 7, 157-160.

Premack, D. (2004). Is Language the Key to Human Intelligence?. *Science* 303, 318-320.

Ramachandran, V.S. and Rogers-Ramachandran, D. (1996). Denial of disabilities in anosognosia. *Nature* 382, 501–502.

Roser, M.E., Fugelsang, J.A., Dunbar, K.N., Corballis, P.M., & Gazzaniga, M.S. Dissociating causal perception and causal inference in the brain. *Neuropsychology* (in press).

Roth, G. (2001). The Evolution of Consciousness. In *Brain Evolution and Cognition* (Gerhard Roth and Mario F. Wullimann eds.) John Wiley & Sons, New York, NY.

Sherwood, C.C., Broadfield, D.C., Holloway, R.L., Gannon, P.J. & Hof, P.R. (2003). Variability of Broca's Area Homologue in African Great Apes: Implications for Language Evolution. *The Anatomical Record Part A*, 276–285

Sperry, R.W. (1969). A modified concept of consciousness. *Psychological Review* 76, 532-536.

Tobias, P. V. (1987). The brain of *Homo habilis*: A new level of organization in cerebral evolution. *Journal of Human Evolution*. 16 741–61.

Wolford, G., Miller, M.B., & Gazzaniga, M.S. (2004). Split decisions. In *The Cognitive Neurosciences III*. (M.S. Gazzaniga editor-in-chief). MIT Press. Cambridge, MA.

Yellot, J.I., Jr. (1969). Probability learning with noncontingent success. *Journal of Mathematical Psychology* 6, 541-575.

Zeki, S. (2003). The disunity of consciousness. *Trends in Cognitive Sciences* 7, 214–218.

## **Figure Captions**

Figure 1.

The method for testing each hemisphere of a split-brain patient. Each hemisphere receives only the visual input presented contralateral to fixation. Each hemisphere then chooses an item congruent with the scene presented.

Figure 2.

Lateralized presentation of a command to the right hemisphere can lead to left-hemispheric interpretation of the actions initiated by the isolated right hemisphere.