occurred when infants began to stand up and perform their first independent steps. Initially, when infants began to walk, and their upright balance was quite precarious, they increased their rate of two-handed responses for reaching and retrieving concealed objects. Yet, as soon as they developed relatively steady gait patterns and gained better upright balance, stable one-handed lateral responses reemerged (Corbetta in press; Corbetta & Bojczyk 2002).

Converging observations have been reported in studies aimed at assessing the role of posture on handedness in nonhuman primates (Spinozzi et al. 1998; Westergaard et al. 1998). Similar to human infants, and as reported by Corballis, nonhuman primates do not display clear hand preference at the population level. However, evidence shows that it depends – the strength of hand preference in nonhuman primates can be altered by task and postural constraints, just as in humans. In particular, Spinozzi et al.'s (1998) and Westergaard et al.'s (1998) research revealed that when subjects were asked to retrieve food from a quadrupedal posture, no clear pattern of hand preference emerged. In contrast, when the same subjects were constrained to adopt a bipedal posture to solve identical manual tasks, preferred biases in hand use increased significantly.

Together, these studies with human infants and nonhuman primates confirm the existence of a close interaction between posture and the lateral organization of the upper limbs. Moreover, these studies suggest that the adoption of the upright posture contributes significantly to enhance and stabilize the expression of manual preferences. Based on this evidence, it seems plausible that when bipedalism emerged in human evolution, about six to four million years ago, the progressive anatomical and neurophysiological changes that such adaptation incurred, entailed and facilitated the formation of right-hand use and brain lateralization. Moreover, based on the above-mentioned evidence, it is conceivable that the emergence of right-handedness might have come before the emergence of speech in human evolution, as handedness would have emerged closely aligned with the evolution of bipedalism. Our alternate proposal, however, would still be compatible with part of Corballis's scenario that gesture – and supposedly, in our account, lateralized forms of gesture – may have been associated with vocalizations and may have subsequently led to the evolution of congruent lateralized speech functions.

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Pumping for gestural origins: The well may be rather dry

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Abstract: Corballis's explanation for right-handedness in humans relies heavily on the gestural protolanguage hypothesis, which he argues for by a series of "intuition pumps." Scrutinizing the mirror system hypothesis and modern gesture as components of the argument, we find that they do not provide the desired evidence of a gestural precursor to speech.

Corballis traces gestural protolanguage in earlier hominids to vocal protolanguage in later hominids, giving rise to a legacy of overwhelming right-handedness in humans. His argumentation follows an extended path, one that is unfortunately more frequently based on appealing to intuitive plausibility than providing a critical evaluation of data. Here, we will be working the handles on two of Corballis's "intuition pumps," arguing that neither the mirror system nor human gesturing produce the flow of evidence he desires.

A recent version of the mirror system hypothesis argues that "Broca's area in the human contains a mirror system for grasping that is homologous to the F5 mirror system of [the] monkey, and this provides the evolutionary basis for language parity; i.e., an utterance means roughly the same for both speaker and hearer" (Arbib 2003a, p. 609). The central component of this hypothesis is simply a system that integrates perception and motor control. Corballis and Arbib go significantly further, however, drawing drastic evolutionary conclusions based on the link between skilled manual action in a nonhuman primate, sharing of intentional states, and a brain region that in humans is specifically involved in language production. The discovery itself is clearly important – neurons in primate F5 provide a substrate for integrating perceptual processing with motor activity, thereby potentially making manual tasks subject to joint attention among different individuals. Nevertheless, using the phenomenon as a pillar of language evolution is taking a long step beyond the data, where simpler interpretations are also available.

For example, there is ample and growing evidence that perceptual and motor systems routinely interact in the brain, working together in creating and shaping cognitive processes (e.g., Barsalou 1999; Hommel et al. 2001). The mirror system may be a powerful [instead of "prototypical"] example of such convergence, but is unlikely to be unique. Perceptuo-motor integration demonstrably plays a role in other aspects of human language and cognition, more likely traceable to activity in distributed networks than being restricted to Broca's area alone. Corballis appeals to the reader's evolutionary intuition by invoking the mirror system findings, the importance of which depends largely on assuming that perceptual and motor integration is playing a special, language-specific role. Our intuition is the opposite, that it would be surprising if such integration were not found to be a basic function of multiple brain areas underlying cognition. Finding that joint attention can play a role, is already implied by imitative, observational, or simply socially facilitated learning that both humans and nonhuman primates can show to varying degrees. Those phenomena are not specifically linked to F5 or Broca's area, which suggests that the integrative processing strategy involved is basic and widespread.

Taken at face value, the discovery of mirror neurons can lead one in many possible directions, and it does not specifically support a gestural-origins hypothesis of language. Unfortunately, speculation seems particularly prone to run roughshod over available data when language evolution becomes the topic of discussion. Rizzolatti and Arbib's (1998) argument that mirror system function can instantiate an elementary case grammar is a case in point. Both these authors and Corballis attach very specific evolutionary hypotheses to a neural phenomenon whose implications are as yet just beginning to be explored. It seems wiser to exercise more restraint, until there is at least some sense of the many different roles that mirror neurons, or something like them, may be playing in various brain regions across species.

Gesturing in modern humans is another of the intuition pumps Corballis invokes. Here, the data do convincingly show that gesture is an important partner to normal speech, and that it develops into a full-fledged linguistic system when the vocal-auditory channel is unavailable. Once again, however, implications for the evolutionary emergence of human language are much less clear. Gestures observed in conjunction with modern speech are largely not linguistic in nature, being iconic instead and lacking the requisite complex structure (Goldin-Meadow & McNeill 1999). Contrary to intuition, in fact, gesturing does not necessarily further the talker's linguistic goals (Krauss et al. 1995). In addition, the fact that manual signing can develop into an explicitly linguistic system demonstrates only that critical aspects of the human capacity for language are likely modality-independent. Rather than specifically implicating gesture as the origin of spoken language, this outcome readily suggests other interpretations – for example, that increasingly complex general sequential-learning capacities played a critical role (Christiansen et al. 2001; Conway & Christiansen 2001).

As before, the strongest implication may be that convergence among perceptual and motor systems is a critical underlying component of language. As Kendon (1991) points out, multimodal information is continually brought forth as an essential part of human cognition. That gesture can effectively stand in for signaling in the auditory-vocal modality highlights that integration is important, but not that the manual component per se has played a special role. On the contrary, speech is the normal means of linguistic communication across the entire human species, with gesturing always being ancillary. Gesture takes on language properties only by dire necessity, which is surely not the sort of evidence that compels a view that language evolved sequentially from gesture to speech. It instead suggests primacy for the latter, but with both modalities being more fundamentally rooted in the integration of sensory and motor channels in underlying neural organization.

While ultimately about right-handedness, Corballis's argument relies most heavily on the gestural-origins hypothesis and the various bits of evidence that can be marshaled in its support. In our view, he has not produced a straightforward progression of inexorable inferences and necessary implications. Instead, he presents a series of intuition pumps and primes the reader to think along the lines desired. Making the case requires rather more than intuitively pumping for it, and a critical and balanced evaluation of the data would be a better way to proceed.

Possible phylogenies: The role of hypotheses, weak inferences, and falsification

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Abstract: This commentary takes issue with Corballis's claim to have presented a falsifiable hypothesis. It argues that Corballis has instead presented a framework of weak inferences that, although unfalsifiable, might help to constrain future theory-building.

Corballis ends his article with the claim "my hypothesis is not simply a just-so story" (sect. 6, last para.) and that it could be falsified. In making this statement Corballis is displaying a sensitivity to past criticisms of the evolutionary endeavour, and he is laudably trying to expose his speculations to due scrutiny. Prior to this, Corballis lays out the structure of his argument and indicates possible points of weakness, but despite this openness, I am not convinced that the overall hypothesis in this paper is falsifiable, and I shall present my concerns in this commentary.

Falsificationism was proposed by Popper (1959) both as a response to the problem of induction and also as a principle of demarcation, a method of distinguishing the natural sciences from all other epistemological effort. Falsificationism is not a loose position, but it is one that places strict constraints on the structure of scientific hypotheses. Hypotheses must contain a lot of information enabling detailed and precise predictions to be drawn, and it is this detail that increases the probability of the falsity of the hypothesis, as well as making it clear how to falsify it. Nonetheless, when falsification does not occur, the utility of the statement is enhanced by this precision. There are many problems with falsification as a philosophy of science – not least, issues surrounding the theory-dependence of methods – but as a guiding principle of scientific clarity, it is much sought after.

Corballis's article consists of a number of hypotheses, rather than a single one, and as such the overall collection might best be viewed as a story, which does not make the work less scientific, simply synthetic. The story is a long conditional argument of approximately the following form:

1. *If* spoken language gradually evolved from a system of manual gestures (hypothesis 1) *and:*
2. *If* mirror neurons (in area F5) are important for establishing and maintaining a system of manual gestures (hypothesis 2) *then:*
3. The point in time at which area F5 became left-lateralized might mark the point at which vocal language took over from gestural communication (hypothesis 3), *and:*
4. This lateralization might explain the drive to predominant right-handedness in humans (hypothesis 4).

Each of these hypotheses is fleshed out with a variety of comparative, empirical, and archaeological arguments from the literature, and, as such, they are grounded in substantial amounts of theory. However, Corballis sees the whole story as critically dependent on the veracity of hypothesis 1. If this can be falsified, the rest of the story dies with it, although he cautions that this would not mean that left-lateralized vocal control did not precede handedness. But how might one attempt to falsify the hypothesis that vocal language evolved from manual gestures? A hypothesis of this sort, about a possible phylogenetic event, is very low in detail and precision. For example, there is no comment about how this might have happened and what characteristics it would lend spoken language. Instead, as with all gestural theories of language, it is predicated upon a set of tantalising "facts" – the existence of full, "natural" sign-languages, home-signing, infant use of deictic cues and the common act of gesturing whilst speaking (see Dickins 2002 for a discussion of gestural theories) – and Corballis has reproduced some of these "facts." None of these behaviours carry signatures of an ancient, prelinguistic, or even prevocal heritage and role. All could equally be interpreted as evidence of gesture supporting speech at any given moment in the long history of language. This hypothesis does not meet Popper's standard and is perhaps best regarded as a weak inference.

Over recent years, there has been much discussion about the role of mirror neurons in the evolution of language. Such neurons are in area F5 in monkeys, a homologue of Broca's area, and this fact has raised much excitement. Researchers have wondered whether the imitative possibilities permitted by mirror neurons are a precursor to a communication system with intentional properties (Rizzolatti & Arbib 1998). Corballis has incorporated this as hypothesis 2, suggesting that such neurons might be used in establishing a gestural system of communication, and the novelty of this system, combined with the comparative evidence, might be taken to indicate an ancient, prelinguistic provenance for gesture.

Hurford (2003) has recently argued that although mirror neurons indeed afford imitation, and this imitation might be a function of the later emerging (and lateralized) Broca's area to some extent, the critical aspect of language – that of attaching an arbitrary sound to a representation of a concept in a symmetrical relation – cannot be a part of this system. If the system imitates, it has to have something to imitate – see a gesture, perform the same gesture – and this alone will not afford symbolic representation. Mirror neurons may simply have been of use when the critical innovations for language emerged. This hypothesis fails to make claims precise enough to open it to falsification, because it significantly fails to account for the core aspects of the phenomenon to which it is addressed. However, we can salvage something of Corballis's story. The existence of mirror neurons does not necessarily support a gestural theory, but it is the case that Broca's area is left-lateralized in most humans. It might be that this aspect of the evolution of vocal control did drive handedness, whether or not there is a relationship between gesture and speech. So, in effect, we can divorce hypothesis 4 from the preceding three. Nonetheless, hypothesis 4 is not sufficiently fleshed out to make the order of predictions that Popper would demand of it, and Corballis presents only correlation data to support it, which he admits might be illusory, and this is again a form of weak inference.

Corballis's story is not falsifiable, but this does not mean we need dismiss it as a "just-so" story. Instead, such speculative arguments should be seen as an important precursor to constructing tight hypotheses. Corballis's weak inferences provide a form of