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

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possible world argument in which prescientific hypotheses can be explored. This is not a process amenable to falsification, even though it borrows data from the natural sciences, but it is a process that helps us to think hard about hypotheses we might like to construct. It was this kind of thinking that Darwin put to great effect when constructing his natural history.

Handedness: Neutral or adaptive?

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Abstract: Corballis seems to have not considered two points: (1) the importance of direct selection pressures for the evolution of handedness; and (2) the evolutionary significance of the polymorphism of handedness. We provide arguments for the need to explain handedness in terms of adaptation and natural selection.

According to Michael C. Corballis, the brain lateralization for vocalization might precede the lateralized control of the hands. This certainly has to be taken seriously. However, we would like to comment on two points that he has apparently not considered: (1) the importance of natural selection for the evolution of handedness; and (2) the significance of the polymorphism of handedness.

In the theory presented by Corballis, handedness is described as a neutral character. Right-handedness is regarded as a direct consequence of the left-hemisphere dominance for vocalization. It is, however, difficult to consider handedness as a neutral character. For most manual tasks, especially those tasks involved in competitive activities, increasing performance by the specialization of one hand is certainly adaptive. For example, lateralized cats are faster at catching a virtual prey on a screen with one paw, compared to cats that have not specialized one of their paws (Fabre-Thorpe et al. 1991). In humans, hand or arm lateralization, whatever the side, is probably an adaptation for many activities, such as tool making and tool use (MacNeilage et al. 1987) or stone throwing (Calvin 1982; 1983a; 1987; 1993).

In fights, being lateralized certainly is an advantage. For example, many weapons are held with only one hand. Increasing the power, speed, and maneuverability of a particular arm or hand, that is, specializing it, is certainly pivotal. Aggressive interactions are responsible for fundamental selection pressures acting during primate and human evolution (e.g., Archer 1994; Bridges 1996; Daly & Wilson 1989; Furlow et al. 1998; Guilaine & Zammit 2001; Haas 1990; Wrangham & Peterson 1996; Zollikofer et al. 2002). The higher prevalence of right-handedness might well be due to a previously existing cerebral bias. But the specialization of one forelimb leading to right- or left-handedness is better viewed as the result of natural selection. The constitutive cerebral bias might well have driven the adaptive lateralization towards right-handedness. Nevertheless, it is unclear how the left-brain lateralization for vocalization alone, without natural selection for hand or arm specialization, would lead to the actual right-handedness.

An important problem is not tackled by Corballis's theory. The existence of a polymorphism of handedness remains unexplained. Yet, it is observed in all known human populations (Raymond & Pontier, in press) and described since the Palaeolithic (e.g., Bermùdez de Castro et al. 1988; Groënen 1997a; 1997b; Lalueza & Frayer 1997). Left handedness is associated with several fitness costs (e.g., Aggleton et al. 1993; Annett 1987a; Coren & Halpern 1991; Daniel & Yeo 1994; Gangestad & Yeo 1997; Geschwind & Galaburda 1985a; 1985b;1985c; Grouios et al. 1999; McManus & Bryden 1991). The persistence of an apparently stable proportion of left-handers implies the balancing of these costs by some advantages.

One of the observed costs is the smaller size and weight of left-handers (Coren 1989; O'Callaghan et al. 1987; Olivier 1978). Size is a component of the reproductive value, at least in males (Mueller & Mazur 2001; Pawlowski et al. 2000). However, smaller size and weight is probably not a disadvantage in weapon fights. This is indicated by the fact that weapon fighting sports, such as fencing, do not have weight categories for competitions, as opposed to hand fighting sports, such as boxing. Generally, all sports using an object mediating an interaction between two opponents – racket, sword, ball – do not have weight categories, as opposed to all other interactive sports without such objects. This suggests that when weapons were prevalent in hominids, the weight (and probably height) disadvantage of left-handers in fights was considerably reduced. In addition, a frequency-dependent advantage favours left-handers in interactive sports (Goldstein & Young 1996; Grouios et al. 2000; Raymond et al. 1996). The persistence of the polymorphism of handedness might well be partly explained by an advantage of left-handers in weapon manipulation and fights. This polymorphism, as well as handedness itself, needs to be understood in the view of adaptation and natural selection.

Are human gestures in the present time a mere vestige of a former sign language? Probably not

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Abstract: Right-hand preference for conversational gestures does not imply close connections between the neural systems controlling manual and vocal communication. Use of speech and gestures may dissociate in some cases of focal brain damages. Furthermore, there are limits in the ability to combine spoken words and concurrent hand movements. These findings suggest that discourse production depends on multiple components which probably have different evolutionary origins.

Numerous theories have been advanced in an attempt to explain the manual asymmetry observed in many human activities. Corballis argues for a new evolutionary scenario on the basis of evidence from palaeontology, comparative psychology, and behavioural neuroscience. According to his account, right-handedness in genus Homo derives from an association of gestures and vocal signals in the communicative behaviour of our direct ancestors, whereby the dominant mode of communication progressively shifted from a manual to vocal modality. The hypothesis is intended to be falsifiable and indeed, several aspects of the theory deserve discussion. This commentary aims to examine the relevance of the specific argument concerning present-day human gestural activity. There is no doubt that people gesture as they talk and that in right-handers, these gestures are predominantly performed by the right hand. It does not follow, however, that the primitive language of humankind used the gestural modality and that present-day gestures are merely the remainder of that earlier stage. The alternative view favoured by other investigators is that spoken language derives from vocal communication or, more exactly, that gestures and speech coevolved in parallel from the beginning and that there are only limited connections between the two production systems.

Why do speakers gesture while talking? There is no simple answer to this question because different kinds of gestures probably depend on different mechanisms involved in discourse production. Some hand movements are called *iconic* or *representational* gestures because, like a drawing in the air, they depict the concept they express. Other gestures, sometimes called *beat* or *batonic* gestures, have simpler forms, no meaning, and relate to phrasal stress to emphasise some parts of speech. *Deictic* or *pointing* gestures constitute a third category in which reference is achieved