# Getting it right by getting it wrong

Tom Sgouros

February 9, 2005

**Abstract**

A brief look at how information theory and the mathematical apparatus of error correction can inform how we think of our senses. An argument is presented that our senses depend on adequate error correction, and that correction of errors in one sense must come from another source of information. The possibility that our senses depend on adequate error correction further suggests that memory and consciousness may have played an evolutionary role simply by providing an alternate, and possibly lower cost, way to improve an animal's senses.

The article includes a suggestion for new vocabulary to promote understanding a brain made of many independent units of all different scales. The suggestion raises the possibility that this understanding may resolve the paradox of concepts depending on percepts and vice versa.

SONNET 141

In faith, I do not love thee with mine eyes,
For they in thee a thousand errors note;
But 'tis my heart that loves what they despise,
Who in despite of view is pleased to dote;
Nor are mine ears with thy tongue's tune delighted,
Nor tender feeling, to base touches prone,
Nor taste, nor smell, desire to be invited
To any sensual feast with thee alone:
But my five wits nor my five senses can
Dissuade one foolish heart from serving thee,
Who leaves unsway'd the likeness of a man,
Thy proud hearts slave and vassal wretch to be:
Only my plague thus far I count my gain,
That she that makes me sin awards me pain.

Shakespeare wrote about the five wits–common wit, imagination, fantasy, estimation, and memory was the classic enumeration—but this is an archaic usage. We know more about the brain now, and no one counts this way any more. But what about the senses? We count vision as one sense, since it all comes from light falling on the retina. But we already know that there are different kinds of cells that detect that light, so why these are considered only one sense is a bit unclear. People who study vision learn that they must differentiate it into many smaller parts: detecting light and shadow, contrast, color, motion, depth, and so on. In a similar fashion, ears detect pitch, volume, direction, and timbre, which is itself a complex quality. Fingers detect pain, heat, pressure, and so on.

In addition to the ways in which we can subdivide the canonical five, we can count more. It seems awkward to categorize proprioception and kinesthesia as "touch" and neither of them cover feeling hungry or hot or embarrassed (Damasio, 1999). Many animals have a vomeronasal organ for detecting pheromones, and we may, too (Meredith, 2001). We have an immune system, too, whose job it is to detect molecular changes in our environment and protect us from them.

Given this many senses (some of which are detected in the brain itself, like pheromones) it is challenging to make sense of the classical idea that sense information is something we receive. We are in the world, not receiving signals from the world. But never mind this, what is really interesting about our senses is that most of them are not very good.

For any sense, it's relatively easy to name an animal that does it better. Bird eyes, rabbit ears, dog noses, aye-aye fingers: each does its job better than our corresponding organ. It is by now even fairly straightforward to equip a robot with any one of these senses that, considered on its own, is more sensitive than one of ours.[1] The robot senses are a recent innovation, but the eyesight of eagles has been legendary for a long time. In other words, all this has long been obvious, and so is the reply that our minds are what make the difference. But what difference do they make?

Information theory can provide an answer. In his famous 1948 paper that introduced the theory to the world, Claude Shannon wrote about measuring the redundancy of a signal (Shannon, 1948). He presented a method of measurement, and showed its application to engineering problems of communication. But read a slightly a different way than he intended, his findings can shed light on how we understand the world around us.

Error correction is an important topic to engineers. In a communication engineer's terms, a message is wrong if it doesn't match the one sent. If there's no one sending the

[1]Most of us have daily contact with devices that have can improve on our sight or hearing. See (Burl et al., 2002) for a working example of a more exotic mechanical sense: smell.

message, it's not correct to speak of "errors" or of a message being "wrong." But, as Shannon points out, error correction is simply a technique for reducing uncertainty in a signal. When applied to a message between cooperating senders and receivers, you can call it error correction, but this is a special case. As it turns out, that was the special case in which he was most interested, and the rest of his paper (and the rest of the field) is concerned with only that.

But what about signals that come without a sender? One cannot call a received signal "wrong" in this case, but one can look for ways to reduce the uncertainty of that signal that might be introduced by an unreliable or inadequate receiving apparatus.[2] Shannon pointed out that many signals are somewhat redundant, and if they are not, you can add information via what he called the "correction channel." In his presentation, he pointed out that the sender of a message can add the correction information into the same communication channel as the original message, thereby creating a message with a redundancy greater than the inverse of the reliability of the communication channel. Such a message can be perfectly transmitted, despite a noisy and unreliable channel.

For a message without a sender, it is not possible to add information to the channel. Nonetheless, the mathematics Shannon used to prove his points is still applicable, if only the information that comes in the correction channel can be acquired in some other channel. Another way to say this is that you cannot correct a signal with information gleaned from that signal. You can only correct it with information found from some other source. You can't reduce the uncertainty in one sense's signal with information from that same signal. You have to use something else.

For an example, imagine a bad radio, and the assignment to transcribe speech you hear on that radio. Imagine how much easier this will be if the speech is in the language you speak than if it is in some foreign language. With the extra information you already have (knowledge of the language), the task is feasible. Without it, transcription is all but impossible, save on the clearest of radios.

Though it is not typically done, it is possible to conceive of communication between two computers this way. My computer has a wire sticking into it from the wall. It can understand oscillating voltages on that line only because they conform to a widely published communication standard that says what bytes to make out of certain patterns of voltages. Those standards have been embodied in my computer by its designer, just as similar standards were embodied in whatever computer is on the other end of that wire. At a higher level, there is another published standard that says what email message to make out of those bytes. Essentially, the computer has applied error corrections, based on pre-existing knowledge, at two different levels.[3]

[2]"Inadequate" may seem normative here, like "error," but the point is only that one may be trying to extract more information than is available due to the fuzziness of the signal.

[3]Correct reception of email will involve many more levels than this, really, but two will do for illustration.

As with machines, so with people, too: corrections can happen at many levels. For vision, a rod cell can be corrected by being paired with a companion cell next door, and a companion patch of cells can be so paired, too. At a higher level, an interpretation of color can be corrected by the overall level of shadow. Higher still, an estimate of depth can be corrected by parallax. Higher still, you might use your understanding of perspective effects. Higher still, you might recall that you had put down the bucket on the way to the tree, so the bucket is probably closer than the tree, even if the relative sizes don't give much clue.

"Correction" has a normative flavor that is not intended here, and "reducing uncertainty" is awkward. For the sake of having names assigned to these concepts, I propose to call the additional information needed to correct some sensory signal the "context" of that signal. Further, the process of correcting the signal with the context shall be called "understanding" the signal, and the transformed (corrected) signal will be the "meaning" of the signal.

When we try these words on for size, it seems that they fit fairly well. Statements made using them make sense, even if the features they name are not the ordinary ones. For example, as you ascend the levels, from the the small scale to the larger, the "context" required for "understanding" tends toward the richer. At the lowest level, the context might just be a companion pulse from some rod cell. Moving up, the context becomes a patch of such cells, or information assimilated from hearing or memory. This mirrors usage in other domains where, for example, a grammar standard is a richer form of context than a spell-checker,

We can go further with these words. You might also say that a signal cannot be properly understood without its context, which is an unremarkable observation about life, but more interesting with the new definitions of these words. You might add that when the receiver is high-fidelity, additional levels of context do not add much. But when the receiver is not reliable it may be that multiple levels of context are necessary to extract the meaning. Still further, you can always add more context to understand new meaning from a sensation, and a change in context can force a change in meaning of some sensation. The new usage of these words, applied to the correction of senses at both low and high levels, corresponds to the standard way we understand these words.

If you assume that an understanding unit is some smaller part of the whole, then these words can be used in an internally consistent way that is also more or less consistent with how we use them to talk about a whole person. Though we still don't know much about the magical connection between neural processes and consciousness, it is unremarkable to talk about a brain as made up of zillions of independently acting sub-systems. Should this be the case, we should also expect that the language we use to describe the system and its parts might need adjustment.

See (Stevens, 1999).

According to this formulation, the sensations we get do not *mean* anything without context. That is, with context, we can tell that a footprint is a sign of danger or a source of succor. Rustling leaves could be a predator in the bushes, or rain; I can tell the difference by whether my head is wet. The idea also has a philosophical pedigree. Kant was right: percepts without concepts are blind. Unfortunately his ideas of concepts and percepts were too simple. To him a concept was an idea that might be grasped by an entire mind, and a percept was data received from the world. In the view presented here, his “concepts” appear as our “context,” evident at all levels, ranging from a companion rod cell to an understanding of perspective, and from a memory of what a bear smells like to an appreciation of infatuation as a motivating factor in crimes.

Sensation is not monolithic, and is processed, or understood, at many different levels. The meaning understood by one unit might become the signal to be decoded by a unit at a higher level (another arrangment not anticipated by Kant). You can understand what you see with the context of what you hear, and understand what you hear based on what you feel. The classic critique of Kant’s epistemology is that sensation cannot be mediated because it’s not possible to acquire the concepts except through sensation. But here is a rejoinder to that critique that does not depend on chicken-and-egg debates: context is acquired at many different levels, and many different sources, and can begin at levels as low as companion cochlear cells. Experience is built from the ground up.

Critics of Kant (to bring the same debate into more modern times, or more technical subjects, we might refer to critics of Helmholtz’s theory of unconscious inference, like Gibson’s theory of sensation (Gibson, 1966)) are also eliding the facts of materialism. Once you believe that minds are instantiated in bodies, what problem is there? Experience is not just the mind gathering abstract sensations—sitting in some virtual headquarters receiving bulletins from the outposts of the senses—but the body interacting with the world and with itself, at all levels simultaneously. I am not sitting in here receiving sensations from the world. I am out here in the world feeling and doing. An example from introspection: I think differently when I feel hungry. That is, some things look appetizing to me when I am hungry that do not look nearly as good when I am not. This cannot be simply a reaction to hunger, as one might recoil from pain. I actually think differently based on the state of my real-world body. The paradox of reconciling concepts and percepts only comes from imagining an immaterial self.

As has been alluded to a number of times above, there is one way to use a sense to check itself: memory. Remembering what you saw a moment ago is a good way to check your vision right now. Remembering that lions often make a growling noise might provide the important context to interpret a sound heard on the veldt. Keeping track of one’s own history and learning from experience is an excellent way to qualify one’s sense impressions. That is, a memory—and an understanding of whose memory it is—are essential aids in turning our weak senses into useful tools for survival and reproduction.

It is tempting a this point to suggest that increasing fitness for animals with better senses provides a story for the evolution of memory and consciousness. But nothing said here would imply that evolving a massively complex error-correcting machine is inevitable for any species. On the other hand, it is clear that this is just a strategy comparable to improving the acuity of the sense detectors themselves. That is, the evolutionary pressure that demands sharper senses could apply to retinas and make them clearer and sharper, or it could apply to memory and consciousness. Which path a species takes could simply be one of those random contingencies of history, but once on the path, the pressures to refine the error correction with ever increasing layers of context would provide a clear path to burgeoning brain size.

## References

Burl, M. C., Sisk, B. C., Vaid, T. P., and Lewis, N. S. (2002). Classification performance of carbon black-polymer composite vapor detector arrays as a function of array size and detector and composition. *Sensors and Actuators, B*, 87(1):130–149.

Damasio, A. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. Harcourt Brace, New York.

Gibson, J. J. (1966). *Senses Considered as Perceptual Systems*. Houghton Mifflin, Boston.

Meredith, M. (2001). Human vomeronasal organ function: A critical review of best and worst cases. *Chemical Senses*, 26:433–445.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27:379–423, 623–656. The classic paper, founding the field of information theory. The theory also had important contributions in its formative years from Wiener, but this paper is still the clearest statement I know of.

Stevens, W. R. (1999). *UNIX Network Programming*. Prentice-Hall, Inc., 2d edition. The authoritative source.