



an altered state of consciousness

phantom  
LIMBS

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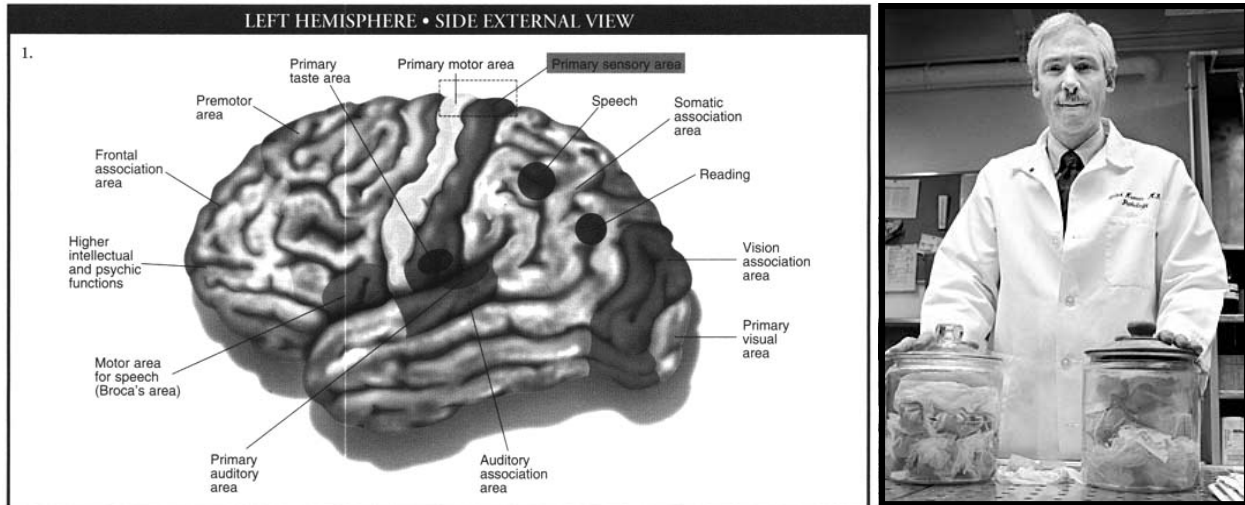
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Phantom limbs are a fundamental break in consciousness. A limb is amputated, but consciousness of the limb remains. This break in consciousness illustrates how it's truly all in your mind. Or more accurately, in your brain.

This paper will begin by exploring what consciousness is in its most general form, consciousness the word. It will then describe a specific sort of consciousness, consciousness of the body. By exploring how consciousness of the body is processed in the brain I hope to lay the foundation for understanding phantom limbs as a neurological phenomenon. Then I will describe phantom limbs in a (hopefully) straightforward Frequently Asked Questions format, drawing on current research and case studies. Finally I will comment on what phantom limbs tell us about consciousness itself.

What phantom limbs illustrate is that reality cannot be taken at face value. Our brain is a remarkably powerful organ which stores a vivid representation of the world, and sometimes that representation of the world can continue to exist even after that world disappears. When Lord Nelson lost an arm in battle he felt a phantom limb in its place. He declared this to be incontrovertible evidence of the immortal soul. I don't know about the soul, but it is certainly evidence of a brain. Specifically, of a little man that lives in your brain.



I'm going to use the thorny word consciousness, so I should define it first. I am conscious and Albert Einstein is not. My brain is in my head and his is in a jar. No brain, no consciousness, at least for humans in 2004. This is a biological prerequisite for human consciousness. However, someday Google may become conscious without a brain like ours, so a subjective definition is important as well. Here is a dictionary definition of consciousness from the **American Heritage Dictionary**:

### **conscious**

1. Having an awareness of one's environment and one's own existence, sensations, and thoughts.
2. Mentally perceptive or alert; awake: The patient remained fully conscious after the local anesthetic was administered.
3. Capable of thought, will, or perception: the development of conscious life on the planet.
4. Subjectively known or felt: conscious remorse.
5. Intentionally conceived or done; deliberate: a conscious insult; made a conscious effort to speak more clearly.
6. Inwardly attentive or sensible; mindful: was increasingly conscious of being watched.
7. Especially aware of or preoccupied with. Often used in combination: a cost-conscious approach to further development; a health-conscious diet.

The screenshot shows a 'VISUAL THESAURUS' interface. At the top, there are controls for 'HELP: ON OFF', 'DISPLAY OPTIONS', and 'RELATIONSHIPS'. The main area displays a network of words connected to the central word 'conscious'. The words include: 'intentional', 'witting', 'unconscious', 'self-conscious', 'sentient', 'sensitive', 'sensible', 'semiconscious', 'awake', 'alert', 'voluntary', and 'aware'. On the right, a 'MEANINGS' sidebar is active, showing 'NOUNS' and 'ADJECTIVES' categories. Under 'ADJECTIVES', several definitions are listed, such as 'intentionally conceived', 'knowing and perceiving', and 'able to feel or perceive'. At the bottom, there is a search bar with 'conscious' entered and a 'GO' button. The footer includes 'plumbdesign VISUAL THESAURUS' and 'CREATED USING THINKMAP | COPYRIGHT 2004 PLUMBEDSIGN, INC.'

So, what is consciousness? “In colloquial language, it denotes being awake and responsive to one's environment; what some call *reactivity*. This might contrast to being asleep or being in a coma” (wikipedia.org). There is more, however, to consciousness than being responsive.

In the most fundamental sense, **conscious is just a word**. Philosophers argue about it all the time, but nobody really listens to them. Words are defined by the people who speak them, and ‘conscious’ is no exception. In that sense, something is conscious if people decide to call it conscious. I haven’t scanned her brain or subjected her to a philosophical interview, but I call my friend Merit Buckley conscious. In a sense she has passed the **Turing Test** because I’ve had a conversation with her, but this is more a test of intelligence than consciousness. I call her conscious

simply because it makes sense. Why?

It makes sense because my experience of Merit activates the same network as the word **conscious**. I know she's **aware** because she walks around and doesn't run into stuff. I know she's **self-conscious** because she responds to her name. I know she's **sensitive** because I've seen her get mad at meter maids, etc.

The actual biological network that stores my concept of conscious is a salty neuron soup... but the word triggers something *like* the Visual Thesaurus on the previous page. This type of association is a basic psychological principal as old as Pavlov's Classical Conditioning experiments. He was able to associate a bell with food, such that dogs would salivate upon hearing the bell. In terms of language, words also get associated with each other (and with sounds, sights, emotions, etc).

A team at the University of South Florida documented some of these associations by having thousands of people free-associate words and recording the results. "More than **6,000 participants** produced nearly three-quarters of a million responses to 5,019 stimulus words. Participants were asked to write the first word that came to mind that was meaningfully related or strongly associated to the presented word on the blank shown next to each item. For example, if given [DINNER] \_\_\_\_\_, they might write [SUPPER] on the blank next to it. This procedure is called a discrete association task because each participant is asked to produce only a single associate to each word."

The table on the following page shows the correlation between words, with 1 ( - ) being the

highest. These are some examples of how the words conscious and unconscious were free-associated.

	DIN	SUP	EAT	LUN	FOO	MEA
DINNER	-	.54	.11	.10	.09	.09
SUPPER	.55		.02	.03	.17	.01
EAT					.41	.02
LUNCH	.27	.02	.08		.20	.06
FOOD			.41	.01		.02
MEAL	.21	.06	.06	.06	.49	

**Conscious:** alive, awake, aware, breath, dead, decision, diet, environment, knowing, pass out, poem

**Unconscious :** accident, asleep, awake, dead, dream, drunk, faint, feeling, repress, unknowing

This is a rough estimate of what the network surrounding the word ‘conscious’ would be. If something—technology or human—activates this network the word ‘conscious’ will be activated, even if only subconsciously. This reaction doesn’t require the approval of philosophers or scientists. It simply happens when enough of the network surrounding the word ‘conscious’ is activated. This activation spreads according to Hebbian learning theory, which describes the biological process by which information is stored in the brain.

“Let us assume that the persistence or repetition of a reverberatory activity (or "trace") tends to induce lasting cellular changes that add to its stability.... When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased.”

- Donald Hebb (1949)

So, in this sense, I call Merit conscious because when the set of neurons associated with

Merit fire, the set of neurons surrounding the word 'conscious' also fire. This set of neurons is not just similar words. I also have a strong disposition to call anything with humanoid features conscious, so much so that I thought Buggs Bunny was conscious when I was a kid. This is an example of visual activation spreading to the language centers of the brain. Auditory, sensory and olfactory regions are also linked to the language centers and they all work together to produce the subjective concept of consciousness.

Consciousness is whatever people decide to call conscious (according to this intentionally vague definition). It could only be humans, or humans and mammals, or humans and technology and mammals, etc. Consciousness is just a word, and the *idea* of consciousness is whatever people use that word to refer to. This can be measured using free association, or brain activation (assuming higher resolution scanning than today). The word 'conscious' activates a web of words, expectations, and meanings. If something activates that network it is probably conscious.

That is a definition of what consciousness *is* (a word). But what does consciousness *mean*? According to the 6,000 subjects performing free-association it is part of a network that includes [alive, awake, aware, breath, dead, decision, diet, environment, knowing, pass out, poem]. It's opposite 'unconscious' is part of a network that includes [accident, asleep, awake, dead, dream, drunk, faint, feeling, repress, unknowing]. The dictionary definition is "Having an awareness of one's environment and one's own existence, sensations, and thoughts." Humans can also be unconscious when they are asleep or passed out, implying that it is a particular waking state. Currently this state is only supported by human brains.





What this means is that your conscious awareness of your body is quite different from how you look on the outside. If you look at Michelangelo's David he's mostly trunk and thighs, but bodily awareness is all hands and face. Perhaps you've heard that everyone is beautiful inside, but that's not true. Inside, everyone is incredibly ugly. The figure at right is a homunculus, what we would look like if neural representation was equivalent to physical appearance. He's the little man that lives in your brain. Given this brief description of how the brain processes consciousness of the body, I will proceed to the issue at hand. Phantom limbs.

"Look ye, carpenter, I dare say thou callest thyself a right good workmanlike workman, eh? Well, then, will it speak thoroughly well for thy work, if, when I come to mount this leg thou makest, I shall nevertheless feel another leg in the same identical place with it; that is, carpenter, my old lost leg; the flesh and blood one, I mean. Canst thou not drive that old Adam away?" "Truly, sir, I begin to understand somewhat now. Yes, I have heard something curious on that score, sir; how that a dismasted man never entirely loses the feeling of his old spar, but it will still be pricking him at times. May I humbly ask if it really be so, sir?"

-Captain Ahab in Herman Melville's **Moby Dick** (1851)

"There's this *thing*, this ghost-foot, which sometimes hurts like hell—and the toes curl up, or go into spasm. This is worst at night, or with the prosthesis off, or when I'm not doing anything. It goes away, when I strap the prosthesis on and walk. I still feel the leg then, vividly, but it's a *good* phantom, different—it animates the prosthesis and allows me to walk."

-a patient in Oliver Sacks' **The Man Who Mistook His Wife For A Hat** (1985)

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If you have a limb amputated it doesn't disappear. The doctor may put it in the trash can or sell it on the black market or whatever they do with it, but you will still feel a *phantom* limb. Remember, you didn't have brain surgery, so that ugly little homunculus inside you is still intact, and he still has an arm. 90 to 98% of patients experience a phantom limb. That means you. This is one of the most common cases of mind over matter, or more accurately, brain over matter.

**Does phantom limb creep up on you, clenching its virtual fingers around your throat?** Not usually. Ramachandran quotes two researchers on this subject, Moser (1948) and Carlen (1978). Moser found that 75% of phantoms appear immediately after surgery, in which case it's like you never lost a limb at all. In fact, you might wake up and wonder if the doctor has done anything. Carlen found less immediate phantoms when he studied Israeli soldiers after the Yom Kippur War. 33% reported phantoms after surgery, and 32% reported phantoms within 24 hours. In both cases pretty much everybody reported a phantom limb (100% in Moser and 99% in Carlen). If you have an amputation, you will experience a phantom, and sooner rather than later. In-

Interestingly, lepers in India have been reported to lose limbs without developing phantoms. This may occur because they have time to gradually incorporate a stump into their homunculus.

As Captain Ahab asks, **“Canst thou not drive the old Adam away?”** Not really, at least not without destroying the homunculus’ hand with brain damage. Oliver Sacks detailed a case of a sailor with a phantom finger, which was always poking him in the eye. He finally lost the phantom finger when diabetic neuropathy destroyed part of his brain. In fact, he lost the consciousness of having any fingers at all, which is not exactly an ideal solution. Usually the phantom simply disappears on its own. Only about 30% of phantoms last for decades (Sunderland 1978, qtd in Ramachandran) and many disappear within a year. But Ahab be damned, the phantom isn’t a bad ghost to be driven away. Remember the words

of Dr. Sacks’ patient: “it’s a *good* phantom, different—it animates the prosthesis and allows me to walk.” Many patients voluntarily ‘wake up’ their phantoms after they’ve disappeared. “One such patient, under my care, describes how he must ‘wake up’ his phantom in the mornings: first he flexes the thigh-stump towards him, and then he slaps it sharply - ‘like a baby’s bottom’ - several times. On the fifth or sixth slap the phantom suddenly shoots forth, rekindled, *fulgurated*, by the peripheral stimulus. Only then can he put on his prosthesis and walk” (Sacks). It kind of helps to have a ghost to possess the lifeless prosthetic and make it real.

**Prediction of Phantom Pain (Statistically) on the Basis of Risk Factors, Calculated from the Results**

Age	Upper Limb		Lower Limb			
	Distal	Proximal	Distal		Proximal	
	Single		Single	Bilateral	Single	Bilateral
10	0.33	0.48	0.53	0.83	0.68	0.91
20	0.39	0.56	0.60	0.87	0.74	0.93
30	0.46	0.63	0.66	0.90	0.79	0.95
40	0.54	0.69	0.73	0.92	0.84	0.96
50	0.61	0.75	0.78	0.94	0.87	0.97
60	0.67	0.80	0.83	0.96	0.90	0.98
70	0.73	0.84	0.86	0.97	0.92	0.98
80	0.79	0.88	0.89	0.97	0.94	0.99

**Does it hurt?** Unfortunately, yes it can hurt. “In a study of several thousand amputees,

Sherman *et al* (1984) found that >70% of them continued to experience phantom limb pain as much as 25 years after the amputation. Shooting pains which seem to travel up and down the limb, burning sensations and intense cramping sensations (“It feels like my foot is in a vice”) are frequently described.” (Ramachandran). If the limb is in pain before amputation, the phantom will ‘remember’ the pain. If the limb was paralyzed before amputation, the phantom is paralyzed too.

According to a study of 536 subjects by Dijkstra *et al*, the most important risk factors for developing phantom limb pain were bilateral amputation (both limbs amputated) and lower limb amputation. Thus, you are at the most risk of developing phantom limb pain if both of your legs are amputated. If the stump is painful there is also a higher chance of experiencing pain in the phantom (81.5% as compared to 53%). Age is also a factor. If you’d like to calculate your probability of developing phantom limb pain, you can imagine the amputation (far or near from your center and one or both limbs) and use the table on the previous page.

**Association Between Phantom Pain and Risk Factors: Univariate Analysis**

	Phantom Pain % (n)	P	OR
Sex		0.733	—
Female (138)	73.2 (101)		
Male (335)	71.6 (240)		
Amputation reason: vascular or diabetes mellitus		<0.001	4.0
yes (194)	87.1 (169)		
no (285)	62.8 (179)		
Extremity ☆		<0.001	5.6
lower (392)	79.6 (312)		
upper (90)	41.1 (37)		
Bilateral amputation ☆		0.001	8.2
yes (41)	95 (39)		
no (441)	70 (310)		
Amputation level		0.038	1.6
proximal (186)	78.0 (145)		
distal (293)	69.6 (203)		
Phantom sensations		<0.001	19.5
yes (383)	83.6 (320)		
no (87)	20.7 (18)		
Stump pain ☆		<0.001	3.9
yes (270)	81.5 (220)		
no (166)	53.0 (88)		
Prosthesis use		0.128	—
<8 hours per day (80)	78.8 (63)		
≥8 hours per day (391)	70.3 (275)		

**What parts of the body can produce phantoms?** Most reports are of legs or arms, but there are reports of phantom facial features, internal organs (colon, uterus, rectum), and penises. The phantom penis can experience phantom erections and ejaculations, the phantom rectum can experience phantom gas, and the phantom uterus can experience phantom menstrual cramps. Limbs have more neural representation in the homunculus and have correspondingly richer phantom sensations. Other body parts like breasts have far less neural representation than say, a hand, but vivid experiences (like pain) can encode an image of them pretty deeply in the brain. Ramachandran has suggested that a body part that receives a lot of attention (as in a traumatic loss) is likely to produce a phantom.

**What if I don't have any limbs?** Strangely enough, children born without limbs very often have phantom limbs, possibly because they are born with cortical motor and sensory areas intact. It may be that the brain monitors motor signals going out of the homunculus and that this creates a feedback loop reinforcing the illusion of a phantom limb. Ramachandran reported a case of a woman born without arms who could nevertheless feel her phantom arms gesticulating during conversation.

**What if I'm not an amputee?** A few interesting experiments can allow individuals to alter their 'normal' experience and experience phantom sensations. One is called the *phantom nose experiment* (Ramachandran & Hirstein, 1997). "The subject sits in a chair blindfolded, with an accomplice sitting in front of him, facing the same direction. The experimenter then stands near the subject and with his left hand takes hold of the subject's left index finger and uses it to repeatedly and randomly to tap and stroke the nose of the accomplice, while at the same time, using his right hand, he taps and strokes the subject's nose in precisely the same manner, and in perfect synchrony. After a

few seconds of this procedure, the subject develops the uncanny illusion that his nose has either been dislocated, or has been stretched out several feet forwards, demonstrating the striking plasticity or malleability of our body image. The more random and unpredictable the tapping sequence the more striking the illusion. We suggest that the subject's brain regards it as highly improbable that the tapping sequence on his finger and the one on his nose are identical simply by chance and therefore 'assumes' that the nose has been displaced—applying a universal Bayesian logic that is common to all sensory systems. The illusion is a very striking one and we were able to replicate it on 12 out of 18 naïve subjects” (Ramachandran 2002). Another experiment is:

1. Purchase a fake arm
2. Seat the subject at a table with one arm on the table, one beneath
3. Place the fake arm on the table so it looks like both arms are on the table
4. Tap the real hand and the fake hand in synchrony as subject watches the fake hand

The sensations should feel like they're coming from the fake hand.

It is also fun to pull out a hidden hammer and hit the fake hand to induce phantom limb pain.

## The Neural Mechanism

In phantom limb the homunculus' limb survives while the physical limb does not. Basically. The full picture is, of course, more complicated. Some interesting neurological evidence does demonstrate the central role that the homunculus plays.

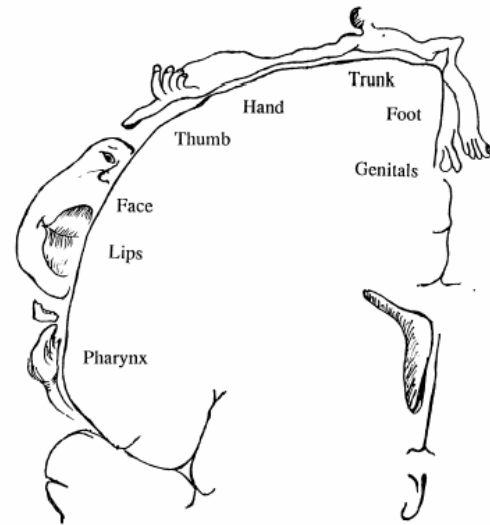


Fig. 1 The Penfield 'homunculus'. Notice that the hand area is bordered below by the face, and above by the upper arm and shoulder: the two regions where reference fields are usually found in arm amputees.

The diagram at right shows a picture of the homunculus. As you can see, the hand area is very near the face. When Merzenich *et al* (1984) cut off



Fig. 3 Regions on the left side of patient V.Q. which elicited precisely localized referred sensations in the phantom digits 4 weeks after amputation. The region labelled 't' always evoked sensations in the phantom thumb, 'P' from the pinkie, 'I' from the index finger, and 'B' from the ball of the thumb.

the middle fingers of adult monkeys, they found that the corresponding cortex was partially taken over by the pointer and ring fingers. Furthermore, in monkeys who are forced to use one finger very often the corresponding cortex becomes enlarged, at the expense of its neighbors. The motor and sensory cortex are actually remarkably adaptable. So, if the problem with phantom limb is in the homunculus, one can predict that the facial cortex will begin to overlap with the arm cortex. This leads to the prediction that stimulation on the face would stimulate the phantom limb as well. This is true.

As the case of V.Q. (previous page) and others shows, phantom limb is closely linked to the homunculus. The neural mechanism is likely twofold, involving inhibition and excitation. Neurons can both excite and inhibit. When the limb is amputated it is possible that some of its inhibitory neurons become less active, allowing competing neurons from the facial areas to take over. It is also possible that new excitatory neurons from the facial area branch into the hand and arm region. An interesting fact is that the lower limbs are cortically mapped near the genitals. This means that very often, contact on the genitals can cause sensations in the phantom foot. One subject even reported feeling erotic sensations in their foot and an improved orgasm. This could also explain the appeal of foot massages.

These peculiar phenomena point to the homunculus as the main cause of phantom limb sensations. The complete cause is actually more broad than this. It involves a whole Neuromatrix, as R. Melzack would put it. He theorized a neural network collecting feedback from the Central Nervous System (brain and spinal cord) and Peripheral Nervous System (rest of body). The Neuromatrix theory defines bodily consciousness as being the sum of all the information on the net-

work. This theory is in opposition to the traditional conception of bodily consciousness as being based wholly on sensory information. The traditional theory fails because it cannot explain phantom limbs—the perception of a limb when all sensory information is missing. Ramachandran *et al* theorized that input from the face, genitals, and other adjoining cortex areas also feed into the Neuromatrix, helping keep the phantom limb active with sensory input as well. The basic point I hope to illustrate is that cutting off a limb in the world is not the same as cutting off the limb as represented in your brain. For a full amputation, the homunculus would need to be operated on as well.

## Phantom Limb as an Altered State

What do phantom limbs tell us about consciousness? Let me repeat the definition listed earlier: According to 6,000 subjects performing free-association it is part of a network that includes [alive, awake, aware, breath, dead, decision, diet, environment, knowing, pass out, poem]. Its opposite 'unconscious' is part of a network that includes [accident, asleep, awake, dead, dream, drunk, faint, feeling, repress, unknowing]. The dictionary definition is "Having an awareness of one's environment and one's own existence, sensations, and thoughts."

Phantom limb patients are aware of the existence and sensations of their phantom limb. There's certainly no denying the all too frequent pain. However, *the limb is not really there*. One of the words on the consciousness network is 'environment' - but a phantom limb flies in the face of all environmental evidence. It simply isn't there. Except in one person's consciousness, it is. In this sense phantom limb is an altered state of consciousness.

Phantom limb also makes the line between reality and virtual reality blurry. If illusions are so natural to the human brain, then who is to say that Virtual Reality is 'unnatural'? The Buddha once said that all experience was illusion. This idea is hard to grasp because *this* of course is real. I am standing here and I can feel my arms and legs right here. This body is real, after all. Or is it?

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