Phantom limb “touch” suggests that a “mind-limb” extends beyond the physical body

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Summary

A phantom limb is the vivid subjective experience of the presence of a limb that is absent congenitally or through amputation. The **phenomenon of phantom limb “touch”** has not been reported to our knowledge. We have completed exploratory experiments with subject M.G., a 56-year-old, college educated woman with congenital digital agenesis (missing five fingers of the left hand). In many respects, M.G. experiences her phantom fingers in the same way as other phantom limb subjects. However, she also reports physical sensations in her finger buds, palm and arm (tingling, warmth, pressure) when her phantom fingers are “touched” by an object or by her right hand. When “touched” on the head by M.G., other people report feeling warmth and pressure, and seeing inner visual images (e.g., a dark circle with a white ring of light) which are reminiscent of visual sensations evoked by electrical brain stimulation.

In earlier work (Mays and Mays, 2008), we postulated that **the *self-conscious mind* (SCM)** is an autonomous non-material entity, a “field of consciousness”. Ordinarily, the SCM is united with and operates through the mediation of the brain, but can separate temporarily from the body in the near-death experience (NDE). This view is supported by evidence from NDEs and from various neurological phenomena. NDE phenomena include apparent subtle interactions with physical processes (light, sound, surfaces), including interactions with “in-body” persons, suggesting that the *non-material* SCM is able to interact in some *physical* way with brain neurons.

Since the SCM, in this view, is a spatially extended field, coextensive with the physical body, then in the absence of a physical limb, a part of the SCM will still project beyond the stump as **a kind of “mind-limb”** which is experienced as a phantom limb. The spatial region of the phantom/mind-limb then should exhibit some of the properties of the SCM “body” in the NDE out-of-body experience, such as **(1) subtle interactions when a physical object enters the spatial region** of the phantom, possibly causing physical sensations in the body, and **(2) subtle interactions of the phantom limb with another person's physical body**, which could be felt by the other person, and **(3) a faint glowing of the phantom in the dark**, similar to reports by some NDErs of seeing their own out-of-body form.

In our experiments with subject M.G. in September 2007, **we found preliminary evidence supporting the first two properties**. The experimental sessions with M.G. were exploratory. From a preliminary interview and M.G.'s answers to a questionnaire, we had formulated some expectations but we found that the phenomena of her phantom finger “fields” differed somewhat from these expectations. In particular, we found that the finger “fields” were dynamic and somewhat diffuse. As a result, we found that interactions could not be repeatably measured at least in the ways we tried to measure them. Several methodological problems were noted in the experiments we performed, most notably our failure to control precisely where the interactions were directed, so the results were inconclusive. On the other hand, it is clear that interactions with M.G.'s fingers do occur and that they have the character of physical or physiological sensations rather than “psychic impressions”.

Our preliminary assessment is that **M.G.’s phantom fingers appear to have an objective reality in the space beyond her body**. They appear to be “fields of sensation and touch” extending beyond her physical hand. We would expect other limb-deficient subjects to experience similar effects. If our assessment holds true, then the phantom limb can be used to study the physical interaction of the mind with the brain.

The self-conscious mind (SCM)

In our earlier paper (Mays and Mays, 2008), we highlighted three aspects of the **phenomenon of the near-death experience** (NDE):

1. the apparent **continuity of consciousness** with the cessation of brain function during cardiac arrest, including veridical out-of-body experience (OBE) of the physical environs during the period of global cerebral isoelectricity,

2. the **veridicality of NDE OBE perceptions**, many of which are verified informally, with cases of *non-veridical* perceptions only rarely reported (Holden, 2006), and with at least two cases of formally corroborated *purely visual* veridical perceptions – the doctor "flapping" his arms (Cook, Greyson, and Stevenson, 1998) and the nurse peeking around the curtain (Sartori, Badham, and Fenwick, 2006), and
3. the **overall phenomenology of the NDE OBE**, where the individual appears to retain all of the perceptual, mental, volitional, emotional, and memory faculties as within the body, frequently retains a spatial form, but with enhanced faculties, apparently as a result of being freed from the physical body. The NDEr "body" appears to be non-material but there are apparent interactions with physical processes such as light and sound, and in some cases subtle interaction with solid objects.

These NDE phenomena strongly suggest (1) that consciousness can continue with no electrical brain function, (2) that consciousness can separate from and operate independently of the body, and (3) that same human being exists *out of the body* during the NDE, freed of the constraints and limitations of the body during this time, and exists *within the body* before and after the NDE. Thus we proposed the existence of a non-material **self-conscious mind** (SCM) as a "field of consciousness", a region of space where a person's consciousness exists, which nonetheless is able to interact with the physical processes of the brain.

In unusual circumstances, the SCM can separate from the brain and body, but ordinarily it appears as an autonomous entity, intimately united with them. In the united state, the SCM operates through the *mediation* of the brain. This view is supported by evidence from neurological phenomena, such as subjective antedating of sensory experiences and mental force, which suggest that a non-neural agency induces conscious experience and self-conscious awareness.

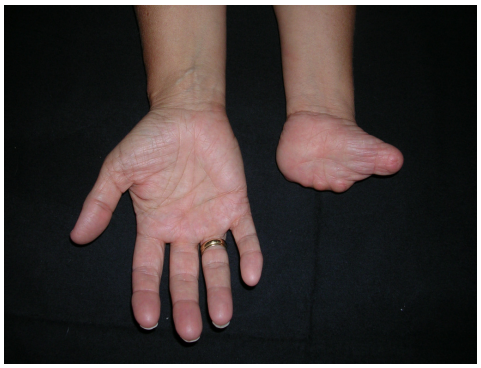
Mind-brain interaction: The NDEr's "body" (i.e., the SCM) appears to be non-material: the NDEr appears to pass easily through objects, can't be heard when speaking and is invisible to ordinary sight. However, subtle interactions in different modalities appear to occur with physical substances and energies and with in-body people. The NDEr "body" generally has a spatial form, apparently can be sensed by animals (Corcoran, 1996, p. 81) and, in some NDErs, appears to have an intricate, luminous structure (Moody and Perry, 1988, p. 10). The "body" appears to interact with physical energies: NDEr "sight" interacts with ambient light to provide veridical visual perceptions with normal colors and "hearing" interacts with sound vibrations from heart monitors, fluorescent lights and human speech to provide veridical auditory perceptions. The "body" appears to have subtle interaction with solid objects: some NDErs report a slight resistance in passing through objects, the ability to "bob" against the surface of the ceiling or feel the support of the hospital roof. In some cases the NDEr "body" appears to interact with another person's physical body: sensing the doctor's arm had a "very rarefied gelatin" consistency, with an electric current running through it (Moody and Perry, 1988, pp. 8-9), being able to tickle another person's nose until the latter sneezed (Corcoran, 1996, p. 83), or "merging" with another person's body to see and hear through their eyes and ears (Morse and Perry, 1990, p. 177; Greyson and Bush, 1996, p. 223). Such phenomena from the NDE OBE support the view that the self-conscious mind is able to interact in some physical way with the brain, through the neurons.

Neurological phenomena, such as Benjamin **Libet's** (1985) ***delayed awareness of willed action***, we believe, can be successfully reconsidered in light of this view. We propose that *all* mental events, including endogenous events such as the wish or intention to act, begin subconsciously and have a similar time-on requirement of about 500 msec. The subconscious wish then also requires a time-on of about 500 msec before coming to awareness, and therefore begins about 500 msec before the *awareness* of the wish to move (W). The actual wish to move thus occurs *subliminally* some 150 msec *prior to* the onset of the readiness potential (RP). So the wish to move in fact comes first.

Similarly, with ***phantom limb phenomena,*** we would expect the spatial region of the phantom limb to extend beyond the stump and exhibit some of the properties of the independent NDEr "body". Since the NDEr "body" apparently has subtle interactions with physical objects, we would expect a subtle interaction when a physical object enters the spatial region of the phantom, possibly causing physical sensations within the body. Since the NDEr "body" can sometimes interact with an "in-body" person, we would expect a subtle interaction of the phantom limb with another person's physical body, which could be felt by the other person. Since the NDEr can sometimes "see" her own out-of-body form, we would expect that there might be a faint glowing of the phantom in the dark. Interestingly, one phantom limb subject (A.Z.), a 44-year-old university-educated woman born without forearms and without legs (congenital tetramelia), stated, "In darkness, I have noted a faint glowing of my phantom body parts" (Brugger, Kollias, Müri, Crelier, Hepp-Reymond, and Regard, 2000).

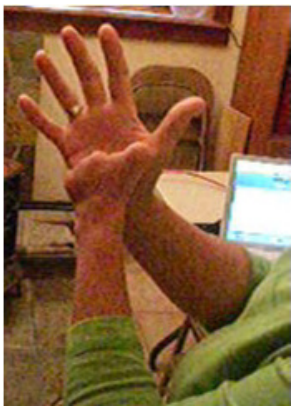
Subject M.G.'s physiological condition

It appears from visual examination of M.G.'s left hand that there was initial development of the five metacarpal bones which was arrested, probably during the first trimester. The cause of the agenesis is unknown. The thumb metacarpal appears to be nearly completely developed, whereas the finger metacarpals appear to have reached only about half of their development. The finger "buds" appear to be the ends of the shortened metacarpal bones or rudimentary proximal phalanges. M.G. has considerable flexibility in the use of her left palm, indicating muscle and ligament development and the flexible movement of the metacarpal bones. M.G. does not wear a prosthesis.



Palm up comparison of hands

Palm down comparison of hands



Side-by-side comparison of the left and right hands

Comparison with other phantom limb subjects

Similarities with other limb-deficient subjects: M.G. experiences her phantom fingers in many respects like other congenitally limb-deficient subjects (cf. Melzack, Israel, Lacroix, and Schultz, 1997, subjects C-01 to C-15). For example, M.G.'s phantom fingers are of normal shape and can move. They ap-

pear (they “light up”) when thought about or when her left arm rests on a surface; M.G. experiences proprioceptive sensations of them; they disappear when M.G. is not paying attention or is using her physical left hand. When the phantom fingers disappear, M.G. sometimes feels them telescoped in the upper arm near the shoulder.

Differences: There are several characteristics of M.G.’s phantoms which have not been reported in the literature to our knowledge:

1. M.G. sometimes feels her fingers as a “streaming out” beyond the normal finger lengths

2. M.G. can apparently “touch” the phantom “fingers” with the fingers of her right hand and feels sensations in both hands and up the left arm.

3. M.G. can apparently “feel” objects with the phantom fingers, again evoking sensations in the left hand (finger buds, palm, etc.) and up the left arm.

4. M.G. can apparently “touch” another person with her phantoms, who reports tactile sensations (e.g. warmth and pressure) and also unusual inner visual sensations when the “touch” appears to be directed toward the brain.

There are **three apparent states** of M.G.'s phantom fingers (see “Apparent field of sensation”, below):

- **Retracted or telescoped**: usually occurring during physical use of her left hand, where the phantom fingers either are not sensed at all or are only felt vaguely. The phantoms appear to retract or telescope in, perhaps as far as the upper left arm, near the shoulder.

- **Activated or “lit up”**: usually occurring when M.G. focuses attention on the phantom fingers but may happen spontaneously when the lower arm is in contact with an arm rest. M.G. can also cause her phantoms to “light up” when she begins to “touch” them with her right hand or when she tries to “touch” something with her phantoms. When the fingers are “lit up” there is a sense of streaming out from the finger buds but there is no definition of the finger “ends”.

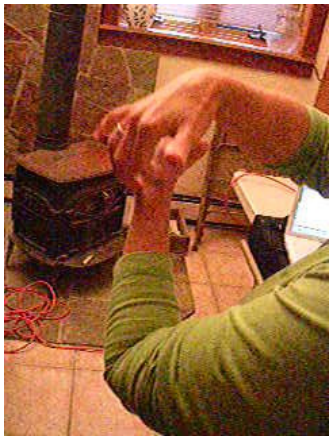
- **Focused**: usually occurring when M.G. “locates” or “finds” the fingers by touching and pulsing with the fingers of the right hand. M.G. appears to find the streaming column of a specific phantom finger and pulses it, following it down to where she feels the “end”. This process is done by following the sensations felt both in that finger's bud and in the right-hand finger pad. There can also be accompanying sensations going up the left arm, in particular “channels”, and also a strong feeling in a 2-3 sq. cm. area of the outer side of the upper left arm. Once the finger(s) are focused, they can more readily “touch” another person or an object, or be “touched”.

Locating and mapping phantom finger “ends”

M.G. “finding” her fingers: With eyes closed or looking away, M.G. goes through the process of feeling where the “ends” of her phantom fingers are, by pulsing them with the tips of the right-hand fingers. The “ends” appear to be somewhat farther out than where her fingers would normally be. M.G. can feel something more subtly even further out than the “ends” of her phantoms. Her right finger tips feel a warmth and resistance at the point of “contact” with the “end” of the phantom finger. **Physical sensations are felt when activating the finger “end”:** (1) a tingling in the corresponding finger bud, (2) a warmth and pressure in the left palm, and (3) a sensation on the outside surface of the arm going up the forearm to a specific spot in the outer upper arm. These latter rising sensations can sometimes go up into the left jaw and head. The left arm sensation is somewhat masked when the left arm muscles are holding the arm up, as

opposed to having the arm rest on something. After the exercise there is residual warmth and an increased circulation in the finger buds.


Pulsing finger causes sensation up the arm

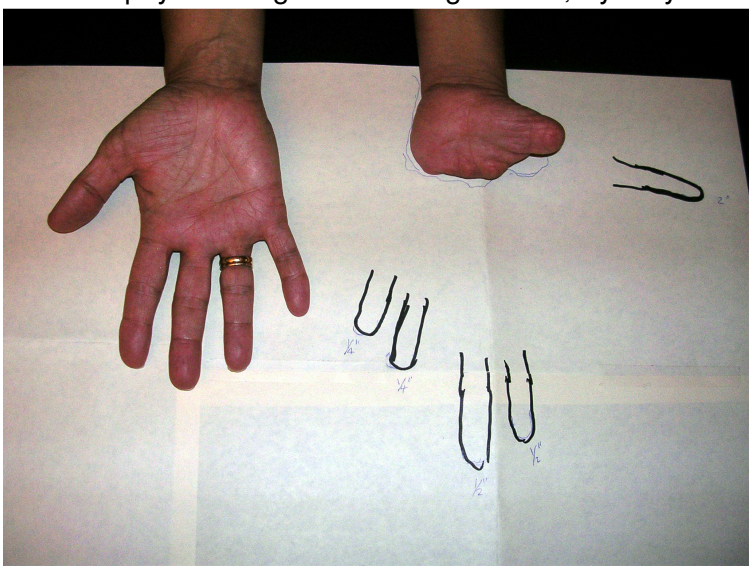

Path that sensation goes up the arm


Path of sensation going up the arm


Residual feeling in particular spot in upper arm

Sense of "streaming" and different "thicknesses": M.G. usually feels a streaming sensation of her phantom fingers where there are two points, a weaker point, about a foot away from the "end", where there is the first sensation of the finger, then a stronger point much closer where the finger "end" is felt, where there is a firmer sensation both in the right finger and in the finger bud. "The right fingers kind of make "ends" on the phantoms. Usually I feel [the phantoms as] a streaming out [and] the right hand touches where the tips of the fingers would be. The feeling actually starts further out – that's what I mean by [my left hand has always felt] "big" – but closer in it's heavier, thicker. There's a dense place, about where the finger "ends" would be…" Pulsing and pushing further into her phantoms beyond the "ends" produces a more intensive sensation of "dih, dih, dih", like a touching or tapping or a kind of magnetic resistance (two same-pole magnets pulsing together), felt in the finger buds. To M.G., it feels almost as if the phantom fingers are being pushed from their normal place further up her arm.

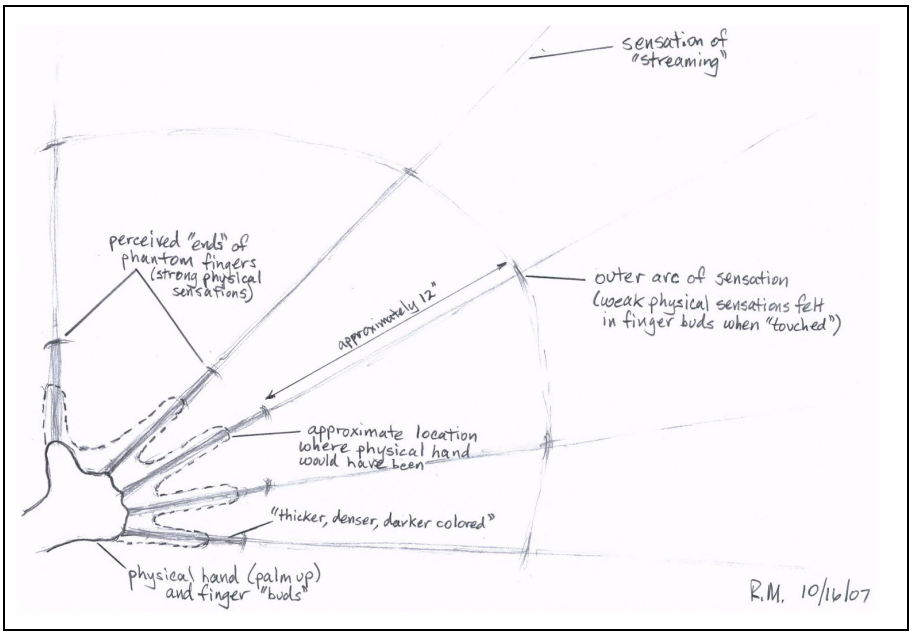
Map of phantom finger layout after "finding" them. The phantom "ends" generally appear to be longer than the physical fingers of the right hand, by only a small amount (ring finger) to perhaps 2" (thumb).

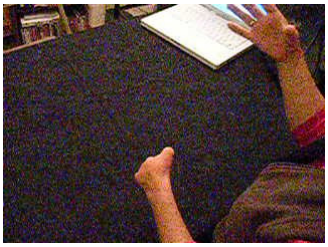


The numbers by each finger indicate the approximate apparent height of the "finger" tips above the table at the time of measurement, ranging from 1/4" to 2".

The fingers appear to be able to bend and curl up toward the palm but M.G. has never felt the fingers bending "backwards". In one mapping session, there was apparent curling up of the fingers above the table, indicating that this procedure can be problematic.

Apparent "field of sensation" around M.G.'s physical left hand: M.G.'s phantom fingers appear to be a structured but diffuse "field of sensation" in the region beyond her finger buds, where her fingers normally would have been. The phantom limb field is experienced as a "streaming out" from the finger buds and has two regions of sensing: an **outer arc** about 14-18" beyond the finger buds where weak physical sensations begin to be felt, and a more definite **finger region** a little beyond where her fingers would ordinarily be, where M.G. feels the "ends" of her fingers are. In "finding" her phantoms, M.G. first feels the general outer arc (a weaker sensation) but in that area there is a place where she can feel sensations in the hand. This is the stream of the phantom finger, which M.G. can trace, following the sensation down to the "end" of the finger. The fingers are usually more diffuse and big, streaming out when they are first "lit up", and then by interacting with her right fingers, they form up and become more defined. M.G. can use objects like a table to "activate" her fingers but the table interaction feels more vague if the fingers are not activated first by her right hand. In any case, the phantoms appear to become defined by interacting with something "meeting" them. Otherwise they are "streaming", or they are not sensed at all because they have retracted or retreated (perhaps up the arm to the upper arm) and need to be "lit up" or "called out".




"Outer arc" of phantom thumb


Apparent "end" of phantom thumb


"Outer arc" of middle finger

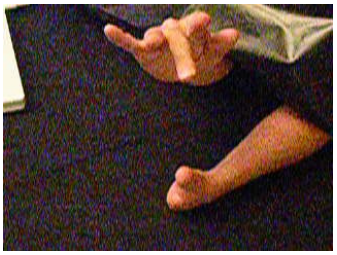

Apparent "end" of middle finger

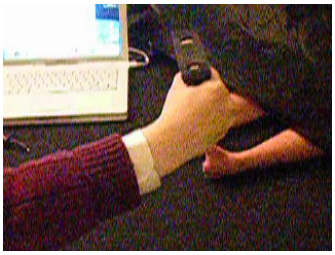
Sensation of "touching" an object

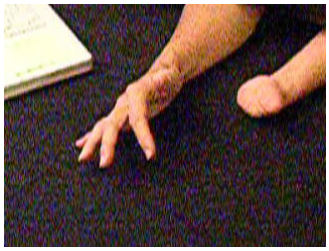
M.G. can sense the presence of her left phantom fingers through interaction with the fingers of her right hand, with another person's body or with an object's surface. She **senses the presence of the object through physical sensations** such as warmth, pressure or tingling in her left finger buds, palm, wrist, arm or other areas of her body. After M.G. has been using her phantom fingers for a time, her hand usually shows increased skin color and her finger buds at times show observable twitching.

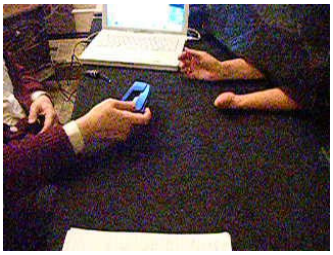
We performed an exploratory **single-blind test of the sensation of an object** "felt" by M.G.'s phantom fingers, with feedback. M.G. was blindfolded, seated behind a black plastic screen. M.G. demonstrated that sensations appeared to occur from interactions with the object, but repeatable sensations were not

conclusively demonstrated. Serious methodological problems were evident afterward that make the test inconclusive. These included that experimenter was moving within the “outer field” of the phantom fingers and the stimulation was, in almost every case, off slightly from the finger “end” position.


Pulsing to locate phantom thumb


Testing “touch” of phantom thumb


Pulsing to locate forefinger


Testing “touch” of forefinger

In another session, M.G. sensed a difference **between “touching” an object and the researcher's hand**. With the hand, the difference was clearly evident of a more solid, “harder”, “thicker” feeling in the palm of M.G.’s left hand, more like pressure, and a strong pulling on the thumb finger bud. The object (a metal stapler) had a different effect, making her finger bud twitch and felt less “direct” and more “remote”. **M.G. did not report any other images, “impressions” or less diffuse sensations which might be characterized as “psychic impressions”.**

“Touching” another subject's face and head

M.G. can **“touch” another person and that person can generally sense the interaction**, particularly if he/she is attending to the area being “touched”. The sensations experienced by the other subject can be warmth, a white light, a shadow or darkness, or a particular light pattern such as a dark circular disk surrounded by a white ring.

M.G. interactions with S.M. in different areas of the face: We started with “touching” the eyes, ears, nose, cheeks and lips, as presumably tactilely sensitive areas of the face, primarily to determine the latency or delay in sensation. We concluded after some time that there were two types of sensations evoked: tactile sensations (warmth, pressure) and inner visual sensations, sometimes quite striking (darkness or brightness, a dark ring surrounded by a bright white light, etc.) The latency of sensation was typically 3-4 seconds but sometimes was almost instantaneous and sometimes 10-15 seconds.


M.G. focusing thumb for “touch”. S.M. has eyes taped shut.


“Touching” left cheek.


Pointing to sensation of warmth felt, location was confirmed by M.G.

We attempted an exploratory **single-blind test with “touching” the nose** and found that we did not control for the direction of pointing: visual sensations appeared to be evoked when the “touch” of the

nose was in line with the brain and little was felt otherwise. The results, showing no better than random correct versus incorrect answers, were thus inconclusive.


No sensation felt: direction of thumb apparently down


Dark circular disk: direction of thumb apparently level


Dark circular disk: direction of thumb apparently level


No sensation felt: direction of thumb apparently down

M.G. interactions with S.M. at different points on the back of the head: the motivation for this session was to test the idea that the sensations S.M. was reporting were due to interactions with tactile nerves in the skin (warmth, pressure) and with the brain (inner visual images). Therefore, "touching" the head more directly in the brain regions might elicit more inner visual images. This proved correct, particularly with point 9, described in more detail below.


"Touching" with phantom thumb "end"

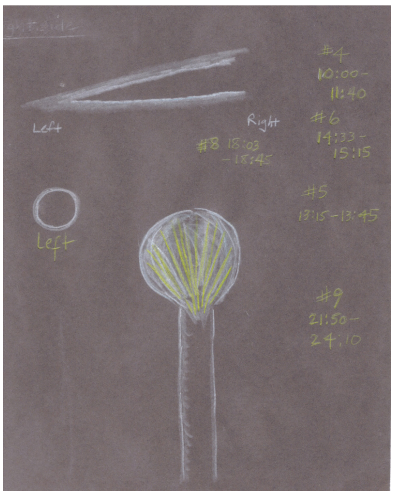

Points "touched": the 3 top points produced the "sword" image


Points "touched": the blue spot is point 9


Points "touched": red point evoked a strong sense or warmth

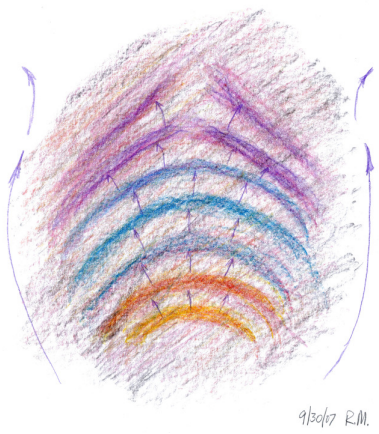
We tried both "touching" using the "outer" region of the phantom thumb as well as the inner "end". We found that no sensations were elicited from the "outer" thumb, but sensations were elicited when the inner end of the thumb was used. In all, 9 points were tested as shown in the following photographs:

The sensations reported by S.M. included: activation of the sinuses, energy coming out of the top center of head, "charged" feeling in the head, warmth, stream of light from right to left like a dark sword shape with a shimmering white outlining it (an inner visual image "added to" the normal visual field), a black disk with a white ring or corona around it, and an opening of a channel of darkness in solar plexus with shimmering white light surrounding it.



S.M.'s inner visual sensations, when various points were "touched" by M.G., include (1) a **dark blade or sword shape** with white edges, forming from right to left (3 points), (2) a **dark round disk with white ring** around it in left field (1 point, also seen in earlier sessions when nose was "touched"), and (3) a **channel of darkness with shimmering white light surrounding it**, like a column (in abdomen rising up to head); the top of the channel (in the head) is exploding light (point 9). **S.M. described point 9** as the opening of a channel of darkness in the solar plexus (abdomen) with shimmering white light surrounding it, like a column; the top of the channel (in the head) is exploding light. It is like going up a tunnel with light at the top. "It's dynamic, it has a movement, like I am moving (upward) through it, with a light streaming out. My whole head, my whole skull is just white, just filled with light, with my whole skull feels like it's being energized, with a pulsing of the skull." Later, "I felt like I was being lifted out into a fuller dimension of percep-

tion... I could still see all around me in the room, yet a part of me was moving inwardly. It was me, at the same time... The light was pure, pristine. It wasn't a blinding light... I felt at peace and at home. I felt a warm, gentle [feeling of] coming to myself, who I really am... It's what I've always wished to feel like, to be all the time...” The visual and sensory experiences were clearly related to what M.G. was doing and S.M. has never had experiences like them before, in meditation or at other times.



Interactions with a different second subject: It was important to see what differences there would be with a different subject receiving “touch” from M.G. in the head regions similar to those with S.M. A similar protocol was used, “touching” four points on researcher R.M.'s head, similar to points on subject S.M. and also a point from the front, between the eyebrows. The results with R.M. were similar in general to S.M. but different in degree. There were similar sensations of warmth on the skin, activation of the sinuses and pressure in the skull. There were only two visual sensations: a subtle white clouding of the visual field with the eyes open, and when the point between the eyebrows was “touched”, with the eyes closed, R.M. perceived inwardly a moving colored image, an arc of color that started from the bottom of the visual field and moved slowly up, changing color as it moved up, until it disappeared at the top of the visual field, and then repeated the process.

Discussion

In our view of the autonomous self-conscious mind (SCM), **the phantom limb is a kind “mind-limb” projecting beyond the stump**, which should exhibit some of the properties of the “body” in the NDE, such as **subtle interactions when a physical object enters the spatial region of the phantom** and **subtle interactions of the phantom limb with another person's physical body**, felt by the other person. In our experiments with M.G., we found preliminary evidence supporting both of these properties. M.G. reports physical sensations when her phantom fingers are “touched” and presents observed physiological reactions. Other people report subtle but definite physiological sensations when “touched”, as well as distinct inner visual images. The phenomena of M.G.'s phantom fingers suggest that there is **a “field of sensation” that can both experience “touch” and can itself “touch”.**

Apparent objective reality: M.G.’s subjectively experienced phantom limb has an apparent objective reality: (1) “touching” physical objects evokes physical sensations in the finger buds, in the left palm and along the left arm, and presents objective physiological reactions (increased skin color, twitching of the finger buds); (2) “touching” another person evokes subtle but definite physiological sensations (warmth, pressure in the head and sinuses) and distinct, unusual inner visual images.

Additional evidence: Additional phenomenal evidence supports the view that the phantom limb has objective spatial reality extending beyond the physical body.

1. **Similarity of “touch” with electrical brain stimulation:** The inner visual images evoked by “touch” are reminiscent of visual sensations evoked by electrical brain stimulation as reported by Wilder Penfield and others in the 1950s and 1960s: for example, a brilliant ball, a streak, a shadow, a light, etc. reported by Penfield and Rasmussen (1950); colored spots, oblique lines and annuli or rings reported by Marg and Dierssen (1965). We observed that the visual imagery appeared to occur only when the “touch” was directed (even inadvertently) toward the second subject’s brain. This suggests that the imagery results from an interaction between the phantom finger and the second subject’s brain.

2. **Reported visual perception of phantoms:** Phantom limb subject (A.Z.), a 44-year-old university-educated woman born without forearms and without legs (congenital tetramelia), stated, “In darkness, I have noted a faint glowing of my phantom body parts” (Brugger, Kollias, Müri, Crelier, Hepp-Reymond, and Regard, 2000). M.G. also reported “almost seeing” her phantom fingers physically once, when she was 6 or 7. While doing pull ups for the first time, during a gym class, “the phantom fingers felt like they were going over the bar (fingers pointing toward me). The sun was shining so I kind of saw [my phantom fingers] inwardly. I did feel that there was something holding on the bar and I got this shape that seemed to come out of my hand curling over the bar… The awareness was inward and the sun was shining, and I could almost see it, not like separate fingers but more like a whole. I could almost see it physically.” Such direct “perceptions” suggest an objective reality but could also be explained as “suggestibility” or “wishful thinking”.

3. **Tactile sensations follow subjectively felt movement of phantom hand:** One reported subject (F.A.) had his right arm amputated 8 cm below the elbow after a boating accident. F.A. showed a striking ability to move his phantom at will. He experienced a referral of sensation on the face and at two different arm locations, on the stump and the biceps, which formed two complete “maps” of his phantom hand. When F.A. subjectively rotated (pronated) his phantom hand to the left, the touch sensation of the biceps map shifted 1.5 cm to the left (toward the body) and shifted back on return to the original hand position. As a demonstration of this, if a drop of water was placed, say, on the pinkie finger region on the arm, when F.A. rotated the phantom hand, he felt the water moving from the pinkie to the ring finger (Ramachandran, 1993a, p. 10419; 1993b, p. 65). The movement of the phantom hand maps with pronation and the movement of the sensation of the water drop from one phantom finger to the adjacent one suggest that the “field” of phantom sensation has a direct, objective mapping to the arm, consistent with an objective spatial reality.

4. **Use of functional prosthetic devices reduces phantom limb pain:** The active use of functional prostheses, such as myoelectric or Sauerbruch prostheses, has been found to be positively correlated with reduced “reorganization” and reduced phantom limb pain (Lotze, Grodd, Birbaumer, Erb, Huse, and Flor, 1999; Karl, Mühlnickel, Kurth, and Flor, 2004; Weiss, Miltner, Adler, Bruckner, and Taub, 1999). The use of a cosmetic prosthesis did not result in reduced phantom limb pain. Reduced cortical “reorganization” and pain with the use of a functional prosthesis suggest that the active use of the prosthesis “focuses” the objective phantom limb back to its correct location, relative to the physical body. If this interpretation is correct, then phantom limb pain would at least in part be due to an “unfocused” or “deformed” post-amputation phantom.

5. **Mirror therapy for phantom limbs reduces phantom limb pain:** Ramachandran and Diane Rogers-Ramachandran (1996) described a novel treatment for phantom pain using a “virtual reality” mirror box, in which a mirror image of the intact limb is superposed on the phantom limb. The patient makes mirror symmetric movements with both hands and generally experiences vivid sensations of movement in the muscles and joints of the phantom. When the eyes are closed or the mirror is removed, the patient’s phantom arm remains frozen as before. The visual feedback of movement in response to volitional motor commands restores phantom limb movement and sensations. If the phantom hand has been clenched or frozen, it can be unclenched and the related pain is relieved. In general, the phantom pain is reduced or eliminated following a number of short mirror-box sessions and in some cases the phantom recedes completely (Ramachandran and Rogers-Ramachandran, 1996; Chan, Witt, Charrow, Magee, Howard, Pasquina, Heilman, and Tsao, 2007). With training in these movements, a dramatic increase in motor cortex (M1) activation was detected in some subjects, with a corresponding decrease in pain. Subjects not showing the increase in motor cortical activation had little or no pain relief. The effect of the phantom limb “movement” in conjunction with a mirror or computer-generated image in reducing pain is consistent with a “refocusing” of the objective phantom limb to its correct location.

6. **Delays in sensation/latency imply unusual involvement of neurons:** The referred sensations in phantoms are not exactly like normal touch or temperature sensations, because there is a 2-3 second latency before the sensation is felt in the phantom hand, and when the stimulus is removed, an "echo" of the sensation persists for 8-10 seconds afterward in the phantom. The sensory latency and echo, of course, do not occur in the *direct* touch sensations from the direct stimulus to the face or arm (Ramachandran, 1993a). These phenomena suggest that adjacent pathways, which are neurally close together to the hand at points along the path, for example in the thalamus (cf. Ramachandran, 1993a, p. 10418; Grüsser, Winter, Mühlnickel, Denke, Karl, Villringer, and Flor, 2001, p. 270), are involved in an unusual "crossover" or "induction" of neural impulses. Since the referred sensations appear within hours or days of the amputation, they are unlikely to be due to new neural synaptic growth. One possible mechanism that could drive such crossover of impulses would be a "mind body" which works through the neurons, which then must reorganize when the normal neural pathways no longer function, and "take over" other pathways. The alternate pathways end in other parts of the physical body. If the actual cross-over involves physiologically adjacent neurons, then the phantom/mind-limb will "refer to" regions that are cortically adjacent, such as the stump and the face, in the case of an arm amputation.

Alternate explanations

There are alternate explanations for these phenomena. The physiological sensations M.G. feels could be due to (1) **suggestibility/imagination** (the power of suggestion generates thought associations that prompt imagined states that are experienced); (2) proprioceptive or other neural **interaction between the right-hand fingers and the left-hand finger buds**; (3) sensations **evoked by focus of attention** (e.g. sensations of streaming, "touching"); (4) **body image projections from the brain** generate the "fields" that are sensed; (5) **cortical reorganization:** sensory pathways from the missing limb are taken over by cortically adjacent neurons; (6) **"psychic impressions" or images** received through other means. These explanations do not fully explain how an object entering a region well beyond the physical body, out of the subject's sight, can elicit subjective sensations and objective physiological changes, when the subject's reactions have none of the character of "psychic impressions" or images. However, to achieve consistent results, future "touch" experiments will require more rigorous controls and double-blinding.

The sensations that other subjects who are "touched" appear to feel could be due to: (1) **researcher bias** since the subjects were the researchers themselves who may have had unconscious expectations or biases; (2) **focus of attention on a specific area** evokes the sensations; (3) **single-blind experimenter bias** where the experimenter subconsciously influenced the outcome; (4) **suggestibility/imagination** (thought associations prompt imagined states appearing as "experiences"); (5) subjects are in a **meditative state** where such visual experiences can occur; (6) **"healing energy"** sent from M.G. causes the images;. The first three explanations can be addressed by more rigorous control of the experiment, with additional subjects and double blind controls. Subjects will still need to be told in general terms what sorts of sensations or experiences might occur. Otherwise, sensations that are actually experienced may be overlooked or dismissed as irrelevant. The last three alternate explanations do not fully explain the fact that (1) all of the inner visual images that were experienced in these experiments were completely unexpected and novel; (2) the images could not be self-evoked later (e.g. in meditation); (3) some of the sensations were very strongly felt, such that there was no doubt that the sensation occurred; (4) M.G. felt no sense of "sending", only of "touching".

Further investigations

- Testing "touch" of objects by using a palm down orientation to "anchor" the phantom fingers plus randomized double-blind testing of "touching" an object

- Testing “touch”/brain interactions with multiple additional subjects, double-blinded if possible
- Try movement of phantom finger while “touching” another person: does the sensation also move or change?
- Encourage other researchers to test other phantom limb subjects experiencing this phenomenon
- Enhance our model phantom limb phenomena as the result of the interaction of the self-conscious mind with the brain and body

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