Embodiment illusions via multisensory integration

COGS160: sensory systems and neural coding

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The illusory hand

This hand is my hand. Activation of the premotor cortex during the rubber hand illusion. In the illusion, normal individuals experience an artificial limb (rubber hand) as if it were part of their own body. (Left) The subject observes a facsimile of a human hand (the rubber hand) while one of his own hands is hidden from view (gray square). Both the artificial hand and the subject’s hand are stroked, repeatedly and synchronously, with a probe. The green and yellow areas indicate the tactile and visual receptive fields, respectively, for neurons in the premotor cortex (red circles). (Right) The subject experiences an illusion in which the felt touch (green) is brought into alignment with the seen touch (illusory position of arm; blue). This brings the visual receptive field (yellow) into alignment with the rubber hand, resulting in activation of premotor cortex neurons.

Botvinnik, Science 2004
This hand is my hand

• An *illusion of ownership* induced by synchronous touches to visible fake hand and hidden own hand.

• Visual and tactile information integrated to recalibrate location of hand

• *Testable* via self-report, proprioceptive drift, response to threats, and brain activity
Necessary conditions for illusion

- Minimize visual, tactile and proprioceptive discrepancy:
  - fake hand of same laterality, and oriented similarly to real hand
  - synchronous touches to both hands, at approximately the same position
  - fake and real hands placed close to each other (<35cm)

*Petkova, Ehrsson, PLoS ONE 2009*
Testing effect of illusion

- Self-report degree of ownership via questionnaires
  - compare against asynchronous touches (control condition)
- Blind pointing to location of hand
  - measurable error in perceived location, despite proprioceptive feedback
- Skin conductance response to threat to fake hand, e.g., with a knife
  - shows fear/avoidance response similar to when real hand is threatened
Neural basis of fake hand illusion

- Brain responses (fMRI) recorded when fake hand threatened with a sharp needle.
  - Illusion induced via synchronous touches
  - Self-report perceived ownership, anxiety level at threat
  - Examine activity in *pain-related* areas: anterior cingulate, left insula
  - Examine activity in *premotor, multisensory* areas: SMA/pre-SMA, intraparietal sulcus

*Ehrsson et al., PNAS 2007*
Threat perceived as real

- Threat to fake hand induces anxiety similar to threatening real hand
- Vividness (self-report) of illusion correlates with anxiety due to threat

Ehrsson et al., PNAS 2007
Premotor areas activated under threat

- pre-SMA shows activation when fake hand threatened
  - but only subsequent to synchronous touching, i.e., when illusion is active
  - may be related to avoidance movement, or suppression thereof
- Activity level similar to when real hand threatened

Ehrsson et al., PNAS 2007
Emotional response to threat

- Left anterior insula and ACC activated when illusory hand threatened
  - areas associated with anticipated pain, emotional processing
- Activity correlates with self-report of illusion vividness
Multisensory activity predicts ACC activity

- Premotor and left intraparietal sulcus activity covary with insula
- Parietal regions known to participate in multisensory integration
Can illusions *induce sensory perception*?

- Previous experiments induce a *change in localization* of the hand
  - caused by reconciling visual and tactile input
  - an essentially *multisensory* illusion
- Can illusions *create sensory percepts*?
  - e.g., flash-induced double-beep, “cutaneous rabbit”
Touch sensation transfers across hands

- Left hand, and *fake* right hand touched simultaneously
- real right hand hidden, not stimulated

*Petkova, Ehrsson, PLoSONE 2009*
Subjects report ownership of right hand

“felt it was my hand”

“felt touch on fake hand”

“felt touches on both hands”

- Self-reported, only following synchronous touches
- *also report sensation of touch on right hand*
Subjects report ownership of fake hand

- Skin-conductance responses seen when fake hand threatened with knife
- Illusion only if fake hand right and oriented correctly.
- Mechanism?
  - neurons with bilateral receptive fields in the parietal cortex (studies in monkey)
  - callosal projections across hemispheres (lesion studies)
  - may explain length of time needed to induce illusion (several minutes)
Does identity illusion transfer across whole body?

- Subjects see mannequin’s perspective through head-mounted display
- Simultaneous touches applied to abdomen of subject and mannequin
- Upto 1 minute of stimulation, synchronous or asynchronous

Petkova, Ehrsson, PLoS ONE 2008
Subjects report identifying with mannequin

- Illusion *only produced by synchronous touches, similar form*
- subjects don’t identify with non-humanoid objects (e.g., a box)
Subjects respond to threats to the mannequin

- Significant skin conductance response when fake body threatened
  - threat-specific response (e.g., to knife but not to spoon)
  - only when illusion is induced
  - generalized to entire body, i.e., when part of mannequin threatened different from that used to induce ownership illusion
“Body swap” with experimenter

- Subjects see experimenter’s perspective through head-mounted display
- squeeze each other’s hand synchronously or asynchronously
- report illusion of “body swap”, shaking hands with themselves
- respond to knife threat to experimenter’s hand more than their own
Discussion

- Ownership, localization are *top-down sensations*
  - as opposed to entirely afferent signals from body
  - constantly updated via multisensory integration
- Visual & somatosensory information *integrated* across the whole body
  - ownership illusion transfers from one body part to whole body
- Bimodal/multimodal cells in premotor and posterior parietal cortex may participate in localization
- Ownership illusion *different from* recognition, e.g., in a mirror, and from tool use