Mirroring and mu rhythm involvement in social cognition: Are there dissociable subcomponents of theory of mind?

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Impaired Theory of Mind

- Children with autism seem to have an impairment in the ability to conceive the mental states of others
- MNS appears to be impaired in autism
- Led to proposals that this system constitutes a neurobiological substrate for ToM

Subcomponents of ToM

- ToM involved in tasks attributing false beliefs to other, recognizing facial expression of emotion, and identifying social rhetoric
- Processes involved in these abilities are likely to overlap
- To test MN involvement in these processes, experiments must dissociate the neural process involved in each task

Tager-Flusber and Sullivan (2000)

- Used evidence from experiments with children with ASD and WS to propose distinct, partially independent processes: social-cognitive (SC) and social-perceptive (SP)

Social-Perceptive

- components involved in online attribution of intentions and emotions to other persons
- Proposed neurobiological substrate is the amygdala and medial temporal cortex
- Involved in biological motion and face perception

Social-Cognitive

- Appears late in development and function is assumed to include abilities typically identified with ToM
- Proposed substrate is the prefrontal cortex

Evidence for Dissociation

SP specific task:

- Subjects judge facial expressions of emotion based on photographs of only the eye region
- Children with ASD perform poorly, linked to abnormalities in the amygdala and superior temporal lobe
- Children with WS have intact amygdala and superior temporal lobes and perform as well as typically developing children

Evidence for Dissociation

SC specific task:

- Both ASD and WS children appear to perform poorly on the Sally-Anne false belief task and the “Smarties” unexpected contents task
- Both behavioral tests thought to require a representational understanding of other minds

Simulation Theory

- Proposes that understanding the actions of others, including their mental states, occurs through modeling those states within one's own mind
- SP subcomponent appear similar to mirror neuron based simulation

Theory-Theory

- Posits that individuals reason about other's minds using explicit mental representations
- Comparable to the late developing, representation based SC subcomponent

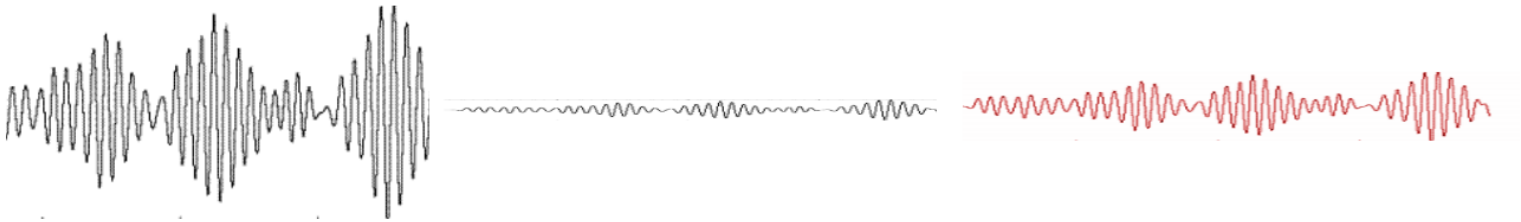
~~Mu Rhythm~~

- Alpha: 8-13Hz beta: 15-20Hz
- Measured over the sensorimotor cortex

Normal Oscillation

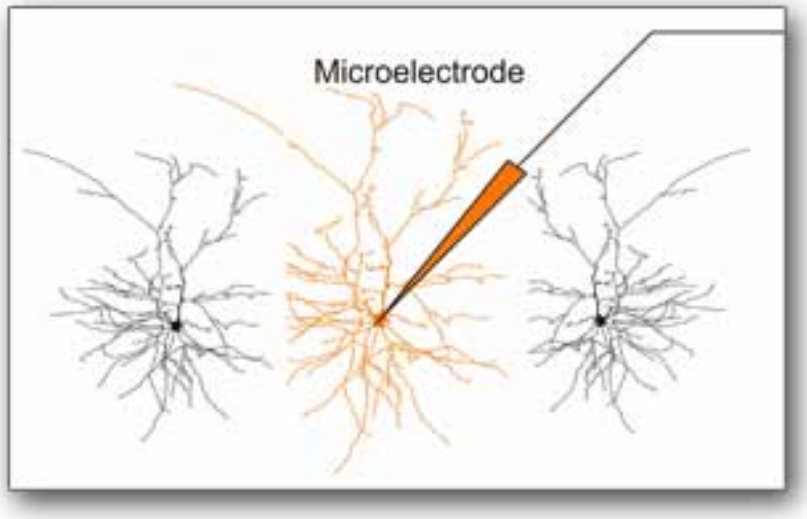
Self Action

Observed Action



fMRI

- Evidence of brain activity is not entirely indicative of mirror neuron activity
- Not very good temporal resolution



Single Cell Recording

- Invasive -> Not enough subjects

Social Perceptive/Social Cognitive

Simulation Theory/Theory-Theory

Early Developing/Late Developing Components

Emotional/Cognitive Empathy

Goal:

To test MN involvement across these two previously proposed components of ToM (Social-Perceptive and Social-Cognitive)

Assumptions and Predictions:

- SP and SC components of ToM interact fluidly in healthy subjects
- SP tasks are more heavily reliant on MN than SC tasks
- If a certain task is more heavily reliant on MN activity:
  - Accuracy will be correlated with Mu suppression
- If a task is less reliant on support of MNS
  - Accuracy will not be correlated with Mu suppression
  - This may indicate that additional processing mechanisms are required

Hypothesis:

- If the subcomponents of ToM are independent, mirror neuron activity should be correlated with accuracy in the SP tasks rather than the SC tasks.

Method

Subjects

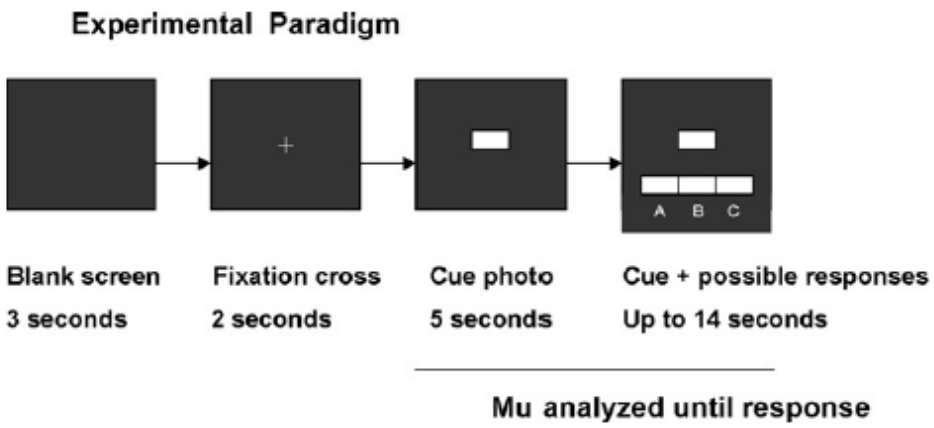
- 23 right handed college students
  - 12 male, 11 female
  - All healthy, no diagnosis of mental disorder or stimulant use within the last 2 hours
  - Mean age of 21.3

Baseline Task

- this test was previously found not to produce mu suppression
  - Oberman et al. (2005)
- measured mu rhythm responsiveness while mirror neurons were believed to be inactive
- subjects viewed a 2minute video of two circles moving up and down a screen
- occasionally the circles would stop moving
  - if this occurred the subjects were told to press a button on the keyboard

Experimental Paradigm

- Each subject performed one of two tasks and a control task
  - SP or SC
- Stimuli were presented in blocks on computer screen
  - 2 minute breaks between blocks



Social-Perceptual Task

- Same process as described
- But used the eye-region of the face
  - Eye Task
- First block of 28 trials were to match emotion
- Second and third blocks of 14 trials each were either gender-matching or race-matching
- Believed to be a good measure of SP because of its perceptual ambiguity
  - Performance is spared in Williams Syndrome
  - Performance impaired in ASD

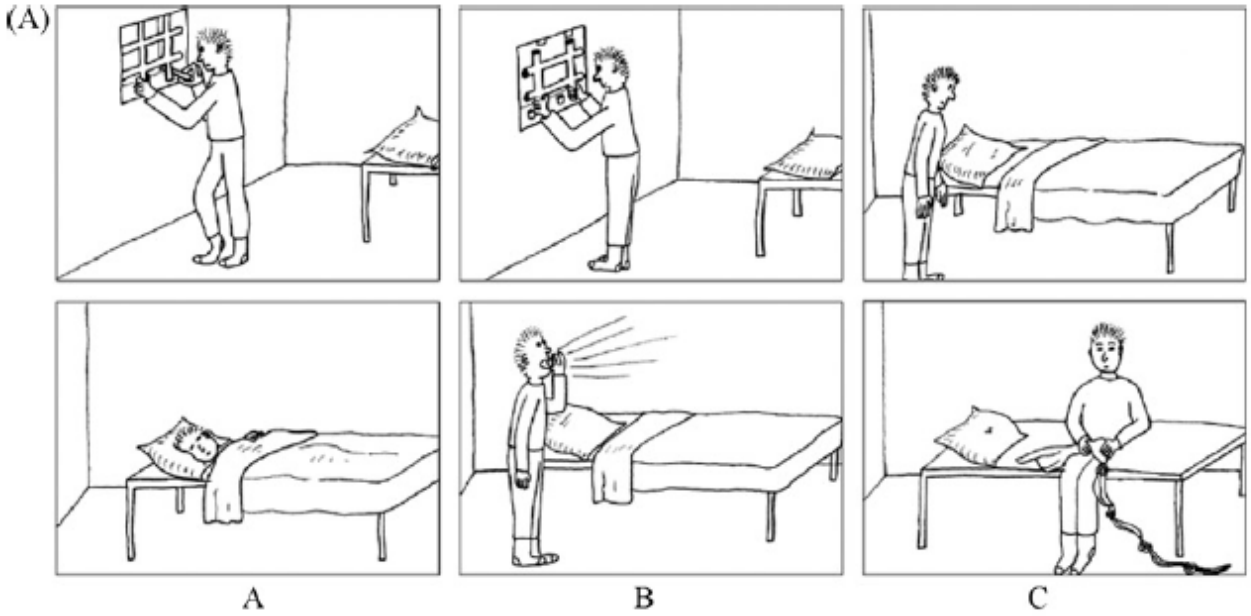
Eye Task

(A) (B) (C)

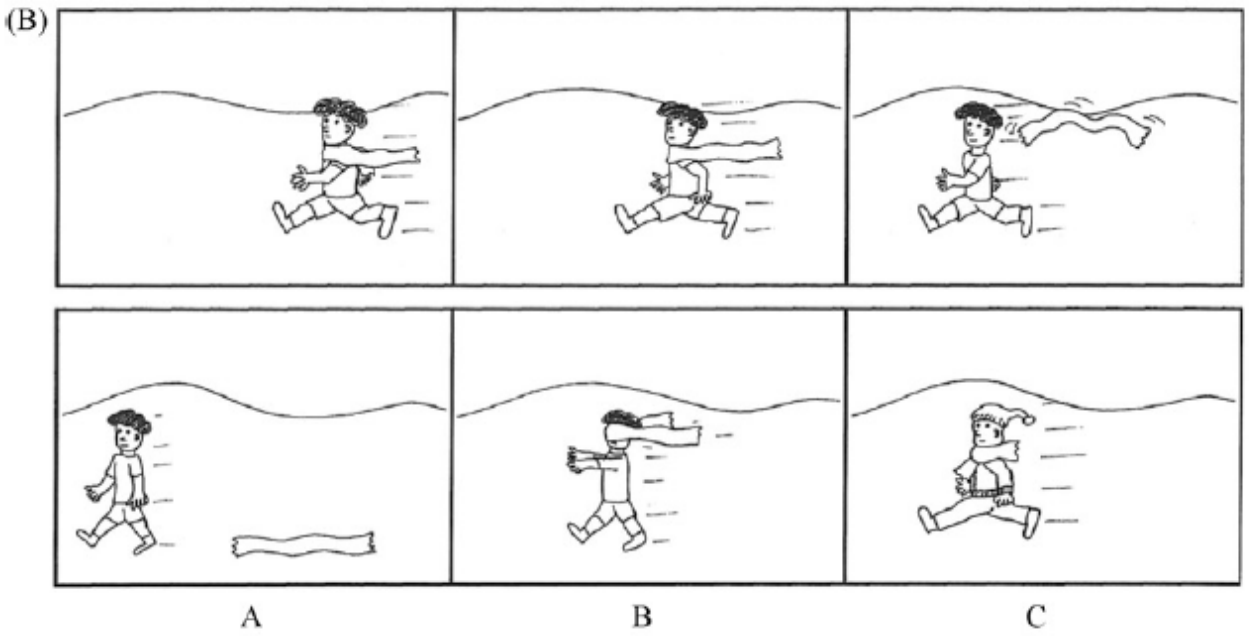
Social-Cognitive Task

- Almost identical process to the one described earlier
  - but presented a cartoon sequence of 3 frames instead of the one cue photo
- Asked to identify one of three cartoon frames that followed up on the initial 3
- 3 types of cartoon tasks
  - Mental attribution (28 trials)
  - Physical causation with characters (14 trials)
  - Physical causation without characters (14 trials)

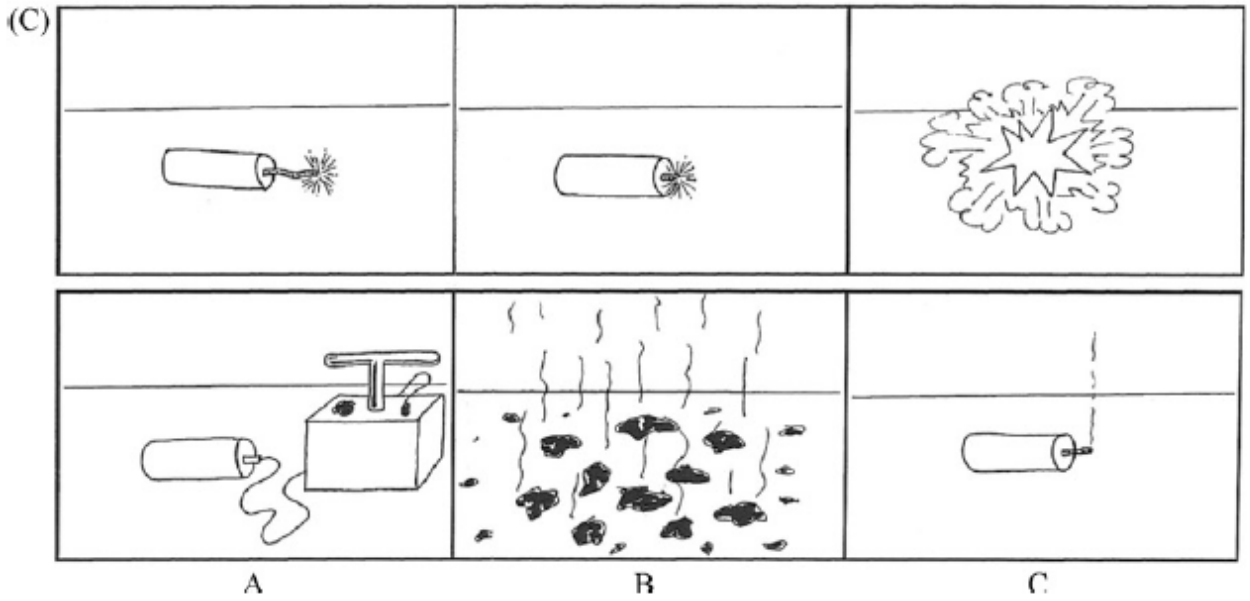
Mental Attribution



Physical Causation with Characters

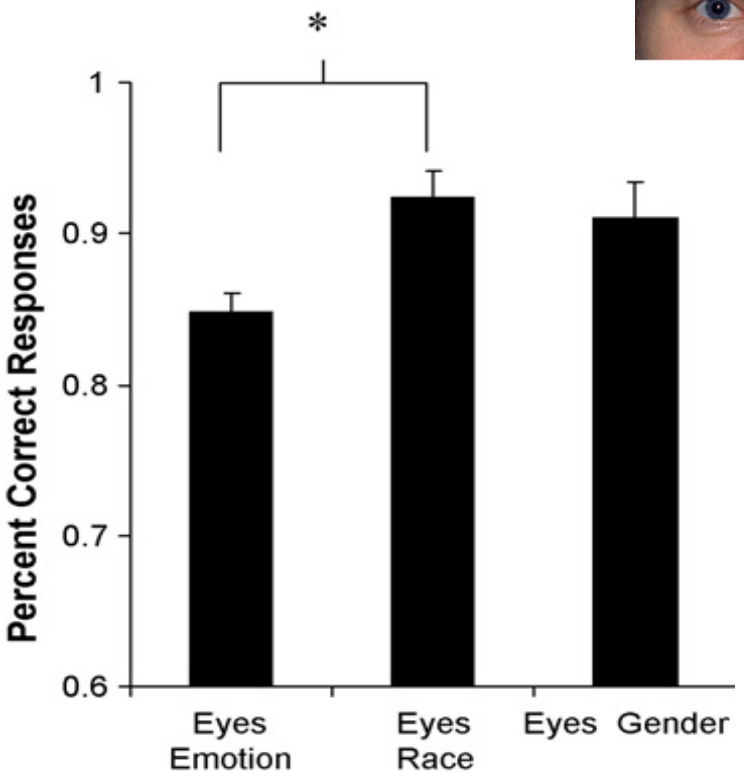


Physical Causation without Characters



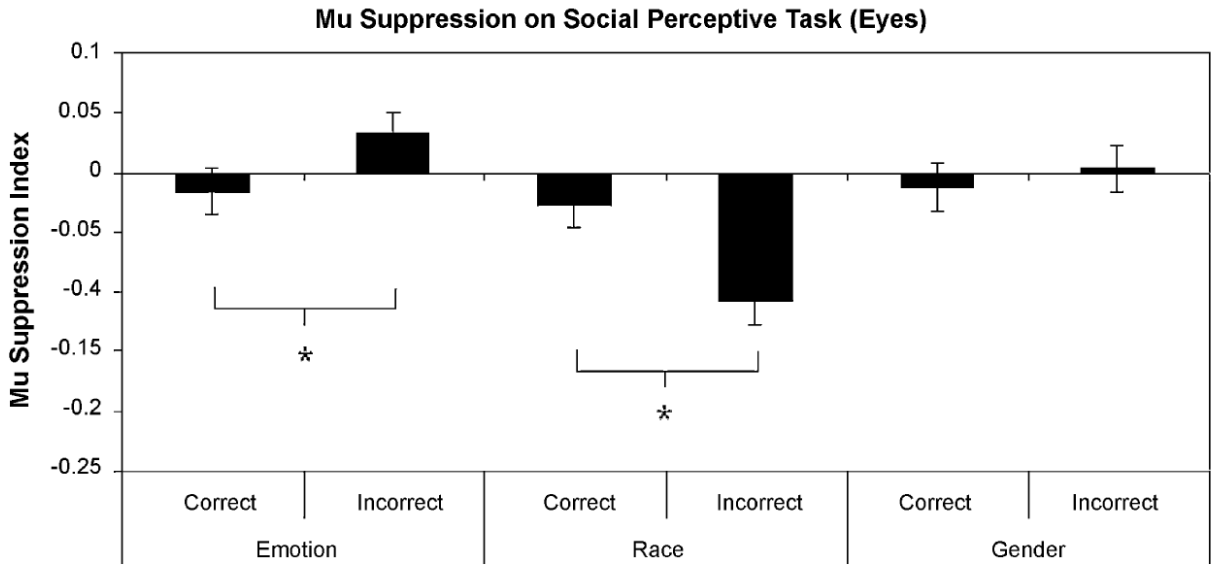
Analysis

Results : SP Tasks



A difference in the Emotion matching task compared to the Race or Gender matching tasks suggests emotion matching is a more difficult task

Results : SP Tasks



Statistically significant differences in the Mu suppression during the Emotion and Race matching tasks. No statistically significant differences in gender matching task.

Discussion of SP Task Results

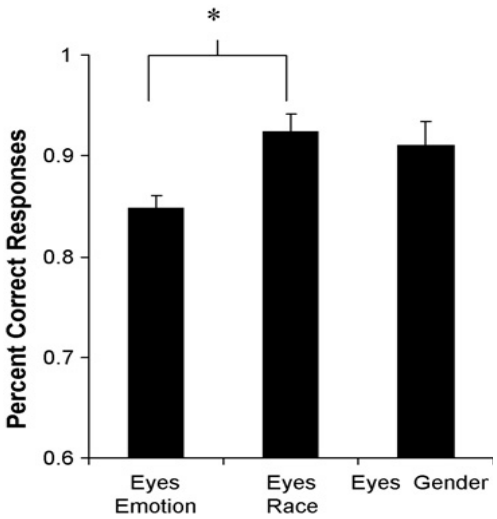
- Questions arising from results:
  - Rebound effect for incorrect responses?
  - Why positive vs negative correlations in different trials?

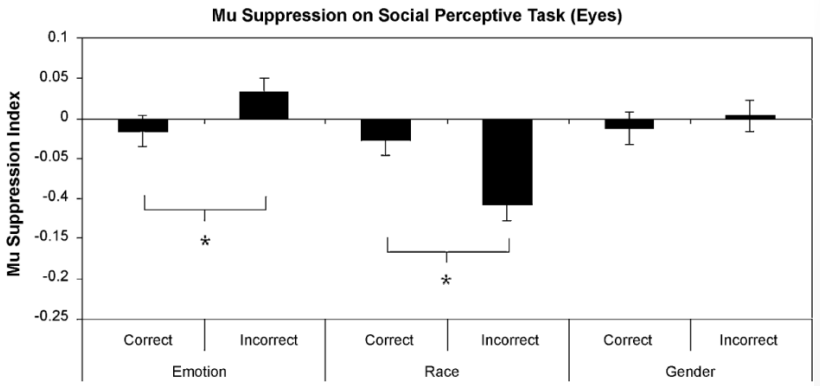
Discussion of SP Results Cont.

- Why statistic significance in Emotion and Race but not Gender?
- Mu Suppression differences in incorrect responses in all trials?

Discussion of Results

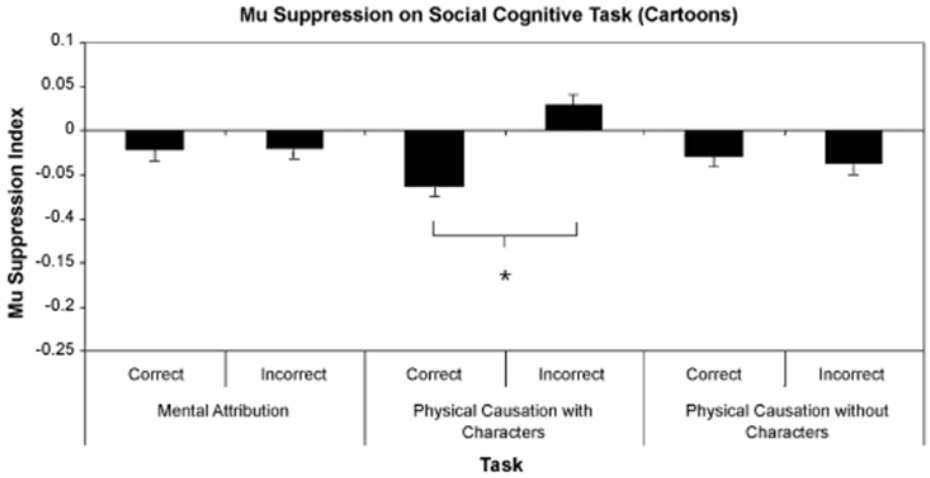
- According to the hypothesis, there should be a correlation between the difficulty of the test and the amount of Mu suppression.
- Did this occur?





SC Paradigm Correlations

- Mental Attribution task: no correlation between mu suppression and correctness
- PC-NC (control): no correlation between mu suppression and correctness
- PC-C (control): correlation between mu suppression and correctness (negatively correlated with mu suppression)



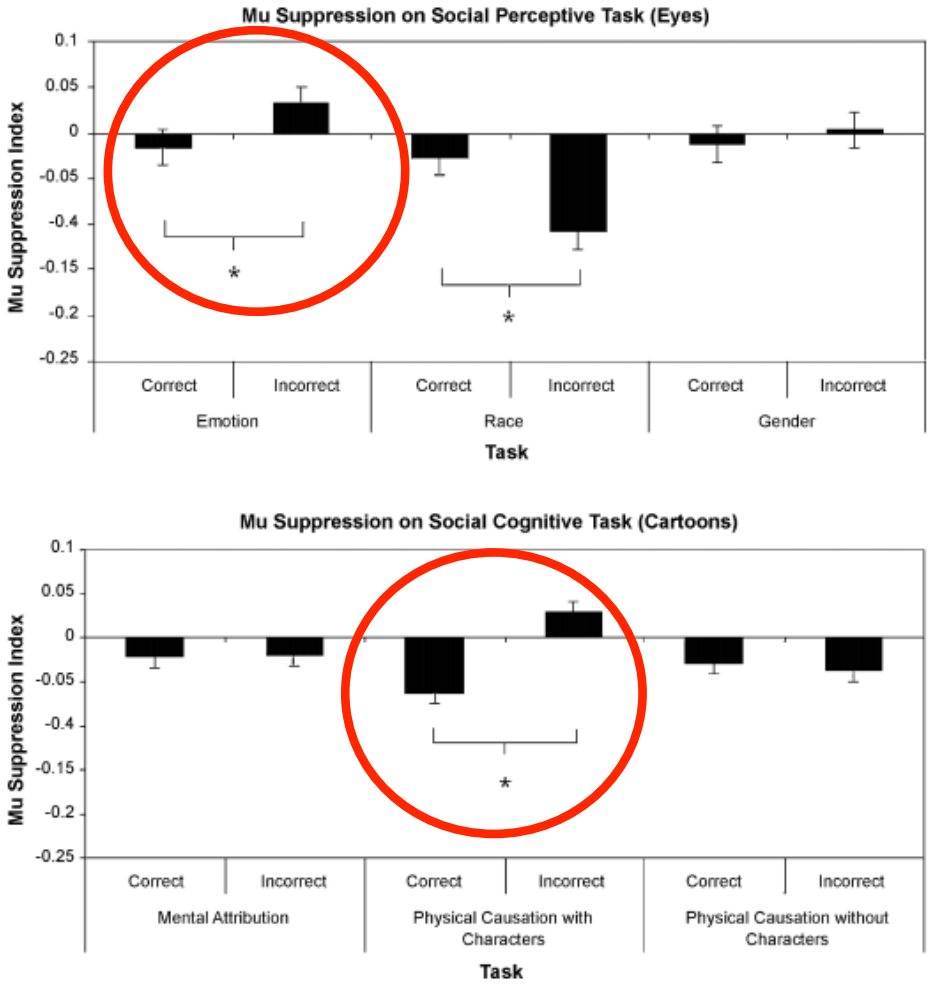
Difficulty of Task

- Least correct responses for Mental Attribution task in SC paradigm
- Least correct responses for Emotional Matching task in SP paradigm
- Both major tasks were the hardest within their paradigms
- The differential activity between SP and SC is not explained away by the difficulty of these tasks since both mental attribution and emotional matching tasks were the most difficult

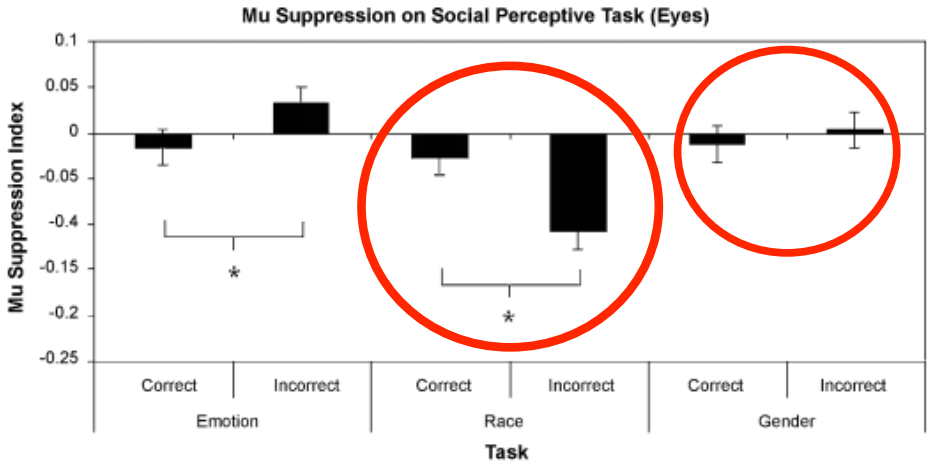
PC-C (SC) & Emotion Matching (SP)

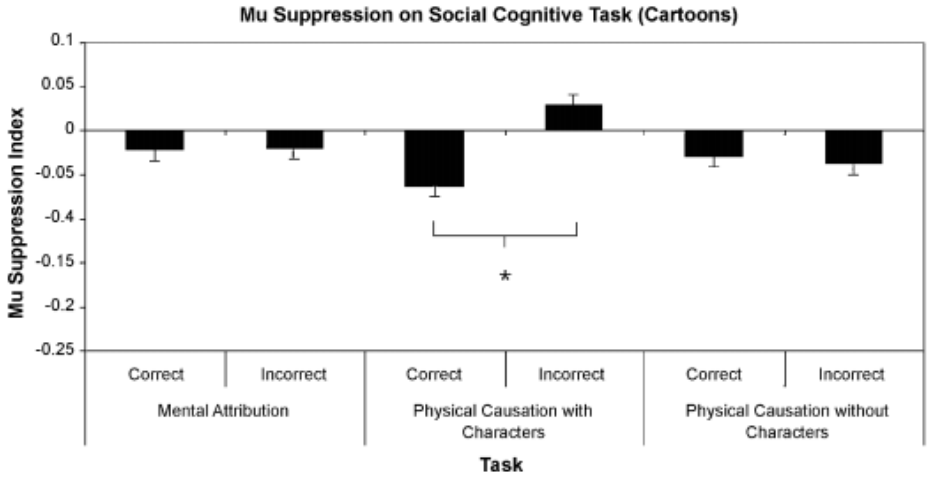
- Both exhibited a strong correlation between correctness and increased mu suppression
- This could be consistent with the idea that MNs (and Social Perception) encode for a more base human/biological perception, whereas mental attribution (Social Cognition) uses alternative mechanisms

Overlap


Mu Suppression on Social Perceptive Task (Eyes)
Mu Suppression Index
0.1
0.05
0
-0.05
-0.4
-0.15
-0.2
-0.25
*
*
Correct
Incorrect
Correct
Incorrect
Correct
Incorrect
Emotion
Race
Gender
Task
Mu Suppression on Social Cognitive Task (Cartoons)
Mu Suppression Index
0.1
0.05
0
-0.05
-0.4
-0.15
-0.2
-0.25
*
Correct
Incorrect
Correct
Incorrect
Correct
Incorrect
Mental Attribution
Physical Causation with Characters
Physical Causation without Characters
Task

Unexpected Results





-Consider the nature of each task

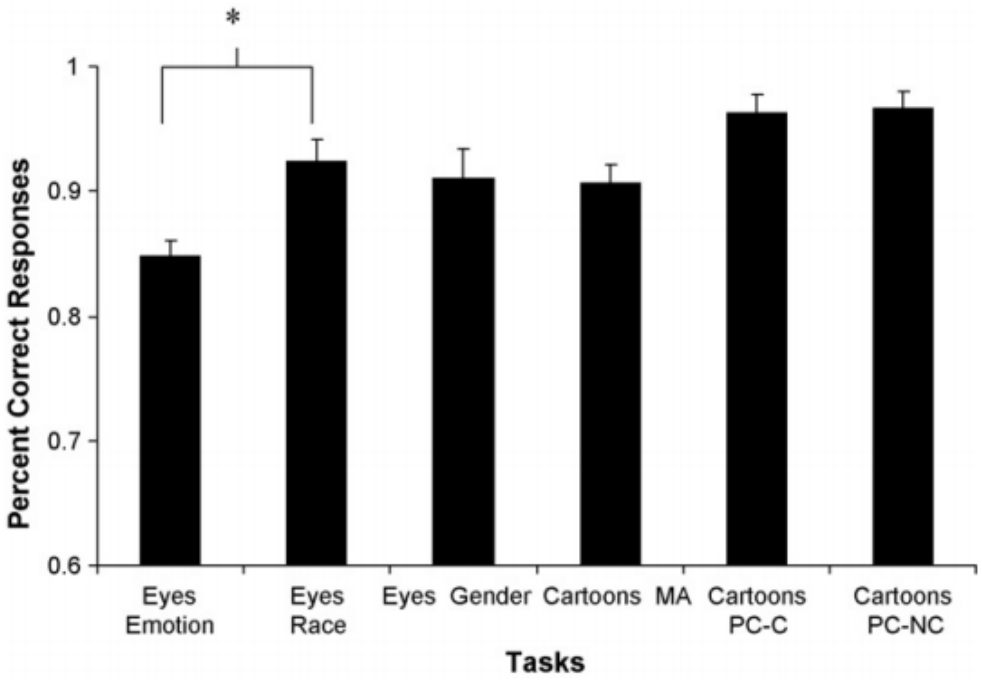
-Mu suppression greater for incorrect responses in the race (SP) task

Explanations….

Rebound effect?

-Mu suppression increases when error is realized

-Effect probably not significant since not observed across all tests, but were the participants more likely to realize error for certain tests leading to a stronger rebound effect?



Difficulty?

Difficulty can be further analyzed in terms of effort measured in reaction time. Perhaps, participants tried harder on certain tests due to social implications. Does uncertainty cause more intense mirroring?

Pros & Cons

Discussion of Paper

- What is the significance of the paper?
  - What does a correlation between Mu suppression and mirror neurons mean?
  - Does this paper augment the hypothesis that Mu suppression is indicative of mirror neuron activation?

Discussion of Paper Cont.

- What difference has this paper made?
  - Healthy Baseline
  - Possibility of separate but linked structures for SP and SC task resolution

Realism of SC Paradigm

- Lack of Realism in SC cartoon panels
- Could realism of characters change experimental results?
- Biological Cues?

SP Emotional Faces

- During Race and Gender testing, did not specify whether emotional faces were used or not (no examples given)
- The SP paradigm aims to study emotion perception
- Would confound the experiment if Race and Gender tests included emotional faces, alas the paper does not specify

Mental Attribution Cons

- Mental attribution through the Salley-Anne false belief task seems more directly relevant to mental attribution than cartoon panels
- Must have top-down knowledge of what a jail cell is, that the man is removing a window, that he wants to leave, etc.
- Salley-Anne false belief test seems more pertinent to inherent understanding of mental attribution

Race Matching (SP)

- Greater accuracy in Race Matching task correlated with *decreased* mu suppression (or increased mu response).
- What is the explanation for this?
- Could this imply that the mu rhythm measures something other than MNs (MNs are a more indirect causation of mu rhythm suppression)