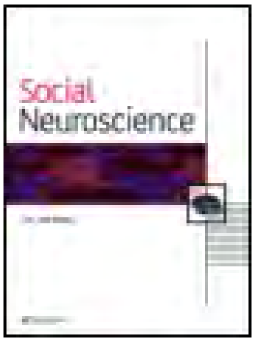

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Social Class Affects Mu-Suppression during Action Observation

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ABSTRACT

Socioeconomic status has been linked to differences in the degree to which people are attuned to others. Those who are lower in SES also tend to be more interpersonally attuned. However, to date, this work has not been demonstrated using neural measures. In the present EEG study we found evidence that lower SES was linked to stronger Mu-suppression during action observation. This finding adds to the growing literature on factors that affect Mu-suppression and suggests that the mirror neuron system may be influenced by one's social class.

Keywords: Mu-suppression, Socioeconomic Status, EEG

Socioeconomic status (SES) has been linked to a host of differences in how people think, feel, and behave (for a review see Kraus, Piff, Mendoza-Dutton, Rheinschmidt, & Keltner, 2012). One of the most striking findings from this body of research is that lower SES is linked to greater relational attunement. People who are lower in SES have greater empathic accuracy (Kraus, Cote, & Keltner, 2010), greater self-reported empathy and stronger physiological empathic responses (Stellar, et al., 2012), and show greater engagement during social interactions (Kraus & Keltner, 2009). In a similar vein, lower SES is linked to lower levels of narcissism and entitlement (Piff, 2014). Emerging evidence suggests that these social class differences may also be reflected in how the brain processes information about others. For example, a recent fMRI study by Muscatell and colleagues (2012) linked lower SES to greater activation in the mentalizing network when viewing pictures of others combined with social information. If working-class people are more attuned to others, might this attunement also be reflected in neural markers of motor resonance? To test this idea we measured the effects of SES on Mu-suppression during action observation using an EEG paradigm. We predicted that SES would be linked to increased power in the Mu frequency (i.e. less mu suppression) during action observation.

Mu-suppression is a reduction in power in the 8-13 Hz frequency band that is observed at central electrode sites over the motor cortex (C3, Cz, C4) in response to both the execution of actions and the observation of others' actions (Oberman, Hubbard, McCleery, Altschuler, Ramachandran, & Pineda, 2005). Mu-rhythms are distinct from alpha-rhythms, are present in human and other mammalian species, and it has been proposed that mu-suppression connects perception to action (for an excellent review, see Pineda, 2005). Mu-suppression is thought to reflect neural activity from the Mirror Neuron System (Perry & Bentin, 2009), an idea which is supported by EEG, fMRI, and simultaneous EEG-fMRI paradigms (Arnstein, Cui, Keysers, Mauritis, & Gazzola, 2011; Braadbaart, Williams, & Waiter, 2013).

An emerging body of research suggests that Mu-suppression is affected by individual differences as well as social context. For example, Mu-suppression is weaker in those with autism (Oberman, et al., 2004) and the experience of being mimicked (compared to social interaction without mimicry) enhances Mu-suppression (Hogeveen, Chartrand, & Obhi, 2014). Further, Mu-suppression is generally stronger for in-groups than for out-groups, but this effect is eliminated by perspective-taking (for a review see Gutsell & Inzlicht, 2013). To date however, there have been no studies exploring the effects of socio-cultural factors (such as SES) on Mu-suppression.

Methods

Participants

61 participants (27M, 32F, 2 gender unknown) took part in the study as volunteers. Informed consent was obtained from participants, and the research was approved by the Institutional Review Board at Arizona State University. Participants completed the study after taking part in one of several unrelated cognitive ERP experiments. Because previous findings on SES and relational attunement have come almost exclusively from studies of Americans, 5 participants (3 who indicated they were born outside the US and 2 for whom this demographic data was missing) were excluded from analysis, leaving a final sample of 56 participants (25M, 30F, 1 gender unknown).

Procedure

The procedure was adapted from Oberman's et al., (2004) and consisted of 6 blocks of 3 types: action observation, action execution, and a baseline condition in which participants viewed visual white noise (Figure 1). Each block lasted 80 seconds and was repeated twice. During the action observation (O) blocks, participants watched a right hand opening and closing while keeping fingers and thumb straight at a rate of one cycle per second. During the action execution (E) blocks, participants were instructed to open and close their own right hand in the same manner and at the same frequency as in the video while watching their own hand. No video was presented during the action execution blocks. During, the baseline (B) blocks participants viewed videos simulating television static. The order of the blocks was pseudorandomized such that participants could receive either OEBOEB or BOEBOE. This ensured that each action execution block was preceded by an action observation block in order to provide participants with a model.

Participants completed the 30-item version of the Self-Construal Scale (Singelis, 1994), the 6-item Cohen's R Scale (a measure of religiousness; Cohen, Malka, Rozin, & Cherfas, 2006), and answered demographic questions regarding gender, age, ethnicity, and the country of their birth. Included in the demographic questions was the MacArthur scale of Subjective SES, on which participants are asked to indicate their subjective status relative to other Americans by placing an "X" on a ladder with 10 rungs (Adler et al., 2000), as well as 6-point scales regarding the level of their mother's and father's education (1 = "did not complete high-school," 6 = "PhD, MD, or JD"). Participants were also asked to report their approximate family income on a 10-point scale (1 = "$0 - $24,999," 10 = "$250,000 or more"). A composite SES score was created by taking the standardized values for subjective SES, income, and highest parental education (whichever value was greater of maternal or paternal education).

EEG data recording

The EEG was recorded using a 32-channel cap with the average of the left and right mastoid electrodes as a reference on a NeuroScan system at 1000Hz bandpass filtered from .1Hz to 100Hz. Following acquisition, the data were resampled to 250Hz and data from the first and last 10 seconds of each block were removed in order to reduce the potential influence of changes in Alpha due to switching visual stimuli (c.f. Oberman et al., 2005). Following previous research on Mu-suppression data from C3, Cz, and C4, as well as O1, Oz, and O2, was epoched into 2000 ms segments.

Analysis

Following a procedure similar to that used by Hovegeen et al. (2014), for each participant we computed log-power of the FFT transformed data over central electrodes sites (i.e., C3, Cz, and C4) at four 2Hz windows between 8-13Hz, starting at 8, 9, 10, and 11Hz. For each participant, we selected the window that had the largest Mu-suppression in the action execution condition to use for all analyses involving that participant. Specifically, if Mu-suppression for a participant was -2.1, -2.12, -2.3, -1.8 for the 2Hz windows starting at 8, 9, 10, and 11Hz respectively, then we would use the 10Hz window for all measures involving that participant. We adopted this step to ensure that our measure of Mu-suppression was calibrated to potential individual differences in neural signatures of motor activity. That is, we did so to ensure that an individual's Mu-suppression score during action observation actually reflected activity in the same frequency band as activity during their own motor movements. Lastly, to ensure that the activity we observed at the central sites reflected changes in Mu-suppression as opposed to Alpha, we also compared power in the action observation and action execution conditions to power in the static baseline condition.

Results

Our sample contained participants from a wide range of social class backgrounds, ranging in subjective social status from 3 (near the bottom of the ladder) to 10 (the top of the ladder; M = 5.67, SD = 1.44), ranging in highest parental educational attainment from 1 (did not complete high school) to 6 (PhD, MD, or JD; M = 4.21, SD = 1.50), and ranging in annual family income from 1 (< $25,000) to 10 (≥ $250,000; M = 5.45, SD = 2.55).

Consistent with previous research using a similar paradigm (Oberman, et al., 2005) we compared log power in the Mu band at occipital (O1, Oz, O2) to log power at central (C3, Cz, C4) using a 2 (Electrode group: occiptal vs. central) x 3 (Electrode position: left, center, and right) x 2 (Condition: Action vs. Observation) repeated measures ANOVA, using the Greenhouse-Geisser correction when the assumption of sphericity was violated. There was a main effect of electrode group, there was greater mu-suppression over central sites (-.67 ± .11) than over occipital sites (-.04 ± .15), $F(1,55) = 28.68$, $p < .001$. There was also an electrode group by condition interaction, $F(1,55) = 21.78$, $p <.001$. Follow-up simple effects revealed that the interaction was caused by a difference between the action and observation conditions over central sites (-1.02 vs. -.36; $t(55) = 3.67$, $p < .001$) and no difference between these conditions over occipital sites (.08 vs. -.16, $t < 1$). There was also an electrode position by condition interaction, $F(1.41,77.26) = 4.74$, $p =.02$, indicating that the difference between conditions was larger over the left and center positions compared to the right position. Lastly, the 3-way interaction was marginally significant,

$F(1.24,67.95) = 3.26$, $p < .07$, and driven by the fact that the difference between the action and observation conditions was much stronger over left/center positions at the central electrode sites compared to everywhere else. More specifically, we find no evidence of Mu-suppression over occipital sites, but see significant Mu-suppression over central sites (Figure 2). These results are consistent with this activity being associated with Mu rather than Alpha. Further, consistent with previous research we observed stronger Mu-suppression for action execution vs. action observation at the central electrode sites but not at the occipital sites (Figure 2). Taken together this suggests that the current paradigm did capture Mu-suppression.

To answer our central question of whether SES modulates Mu-suppression, we created a combined index of SES by standardizing and taking the average of 3 measures, participants' subjective social status, highest parental education, and family income (α = .55). Consistent with our predictions, higher SES was associated with greater power in the Mu-band (less Mu-suppression) at Cz ($r(54) = .28$, $p = .04$), and C4 ($r(54) = .25$, $p = .06$), however the effect at C3 although in the same direction was not statistically significant ($r(54) = .17$, $p = .22$)[1].

Given the high inter-correlations of Mu-suppression at these 3 sites (r's ranging from .45-.54), we also computed an average index (α = .77), which was correlated with our SES index in a similar fashion to the relationships observed at individual electrodes ($r(54) = .29$, $p = .03$, Figure 3). In addition we created a factor score for Mu-suppression based on the 3 central electrode sites using exploratory factor analysis using the maximum likelihood method, a minimum eigenvalue of 1, and a maximum of 25 iterations. The results suggested a single factor (eigenvalue = 1.96), which explained 65.3% of the variance, and factor loadings ranging from .62 to .73. Mu-suppression factor scores were also significantly correlated with our SES index, ($r(54) = .28$, $p < .04$, Figure 3).

Examination of the scatterplot in Figure 3 reveals a potential outlier shown as a star. Cook's Distance for this data point was .43, well beyond the 4/N=.07 cut-off recommendation (Bollen & Jackman, 1990). Furthermore, if we standardize Cook's Distance, this value is 6.73 SD units. Excluding this participant, the SES index remained correlated with the Mu-suppression average ($r(53) = .38$, $p = .005$), and the Mu-suppression factor scores ($r(53) = .37$, $p = .005$). Further, excluding this outlier, the SES index was correlated with Mu-suppression at each of the three individual electrodes (C3: $r(53) = .26$, $p = .05$; Cz: $r(53) = .31$, $p = .02$; C4: $r(53) = .34$, $p = .01$).

Gender was not significantly correlated with Mu-suppression ($|r\text{'s}| < .1$, ns), nor was Religiousness ($|r\text{'s}| < .17$, ns). Aside from a marginal correlation with the SCS Interdependence scale, such that Interdependence was associated with reduced power in the Mu band at C4 ($r(54) = -.23$, $p < .1$), there were no other relationships between the SCS scales and Mu-suppression ($|r\text{'s}| < .21$, $p\text{'s} > .1$). None of these variables were correlated with the Mu-suppression index created by collapsing across the 3 central electrode sites ($|r\text{'s}| < .21$, $p\text{'s} > .1$), or the Mu-suppression index created by factor analysis ($|r\text{'s}| < .12$, $p\text{'s} > .3$)[2].

Discussion

People who are lower in SES show greater Mu-suppression when watching others perform actions. Previous work using self-report and behavioral paradigms has suggested that working-class people are more attuned to others than are middle-class people. The present research provides the first neural evidence for a relation between Mu-suppression and social status. This work adds to the small body of research documenting the effects of SES on neural processes linked to social cognition (Ma, Wang, & Han, 2011; Varnum, Na, Murata, & Kitayama, 2012). These results also contribute to the small, but growing body of research on factors that are linked to individual differences in Mu-suppression. Given that SES is arguably a type of culture (Stephens & Townsend, 2013), these results also provide some of the first evidence that motor resonance and perhaps the Mirror Neuron System (MNS) may be culturally tuned.

Our findings are consistent with the idea low SES environments encourage greater attunement to others, whereas high SES environments encourage greater self-focus (Kraus et al., 2012). These differences are thought to reflect the constraints and affordances provided by different levels of SES. For example, high SES occupations tend to encourage self-direction, and high SES parenting practices reflect this orientation (Kohn & Schooler, 1969). In contrast, attending to and connecting more with others is a strategy to deal with low levels of resources and higher levels of threat found in low SES environments (Stellar et al., 2012). Given these differences in affordances and constraints as a function of SES, greater Mu-suppression might be useful to low SES individuals for several reasons. To the extent that activation of the MNS reflects mirroring, having a more reactive MNS should enable greater coordination and cooperation. To the extent that it may be linked to empathy, greater MNS activation may help strengthen social ties. And to the extent that it may be linked to mentalizing, greater MNS activation may help one to detect and appropriately respond to threats.

The present study was not without limitations. The effects of SES were stronger at Cz and C4 than at C3. We are not certain why this might be the case and we did not attempt an interpretation. Mu-suppression is typically stronger contralaterally but is also typically observed ipsilaterally as well as in the present data (Oberman, et al., 2005; Muthukumaraswamy, Johnson, & McNair, 2004). In addition, the relationship between self-construal and Mu-suppression was weak and generally failed to reach statistical significance. This is somewhat surprising given research suggesting that manipulating self-construal affects motor resonance such that priming independence reduces motor resonance and priming interdependence increases it (Obhi, Hogeveen, & Pascual-Leone, 2011), and that social interaction also increases motor resonance (Hogeveen & Obhi, 2012). It may be that motor resonance is more strongly affected by the momentary salience of different self-construals than trait self-construal. It is also the case that the paradigms used in these studies differed in other key ways, namely the use of TMS and EMG monitoring at the arm rather than EEG. In addition, the stimuli used were somewhat different (a hand grasping a ball vs. a hand opening and closing). Perhaps the effects of trait-level self-construal would be apparent if different stimuli were used, given that observing hands grasping objects has been shown to elicit greater Mu-suppression than observing hands making empty grasping motions (Muthukumaraswamy, et al., 2004).

In future research it would be interesting to examine downstream consequences of SES linked differences in Mu-suppression. Might such differences be linked to quicker social mimicry, enhanced coordination on cooperative tasks, or greater empathy? It would also be worthwhile to see if manipulating status affects Mu-suppression, given recent findings (using a TMS and EMG paradigm) that reminding people of a time they had power over others temporarily decreases motor resonance (Hogeveen, Inzlicht, & Obhi, 2014). Similarly, future research might manipulate the status of the target. On the one hand, prestige bias suggests people are more likely to imitate those who are high in status, thus we might predict greater Mu-suppression for high (vs. low) SES targets. On the other hand, previous work suggests greater Mu-suppression for in-group members (Gutzell & Inzlicht, 2013), thus it may be that people show greater Mu-suppression for targets who share a similar SES.

To the extent that Mu-suppression may index activation of the MNS, the present research suggests that one might expect parallel differences in MNS activation as a function of social class. Future researchers should test this possibility directly using fMRI. It would also be interesting to test the extent to which people in different societies might also vary in terms of MNS responsiveness.

Notes

1. Similar patterns of correlations were observed between the mu-suppression index and individual measures of SES although relationships were stronger for income ($r(54) = .27$, $p < .05$) and subjective social status ($r(54) = .24$, $p = .07$), than for parental education ($r(54) = .12$, ns).

2. Neither composite SES (r(54 = .13, ns), nor individual SES measures (r's ranging from -.01 - .17, ns) were significantly correlated with SCS interdependence, although they showed a slight trend toward positive correlations. Nor were these measures correlated with SCS independence (r's ranging from -.03 - .05, ns). This is consistent with previous research demonstrating SES differences in implicit and behavioral indicators of self-construal, but not on the more explicit self-construal scale (Na et al., 2010; Varnum, 2015).

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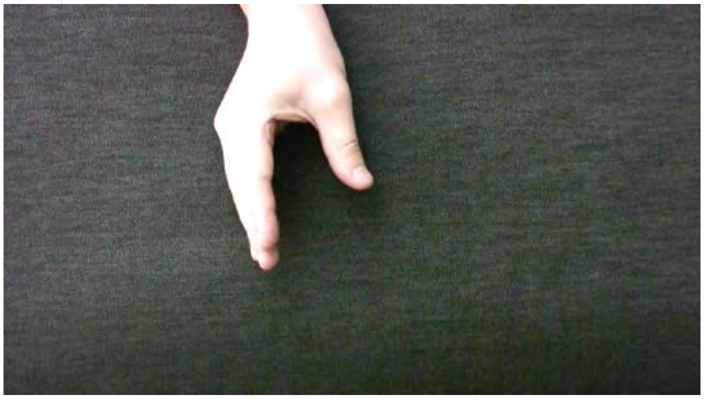
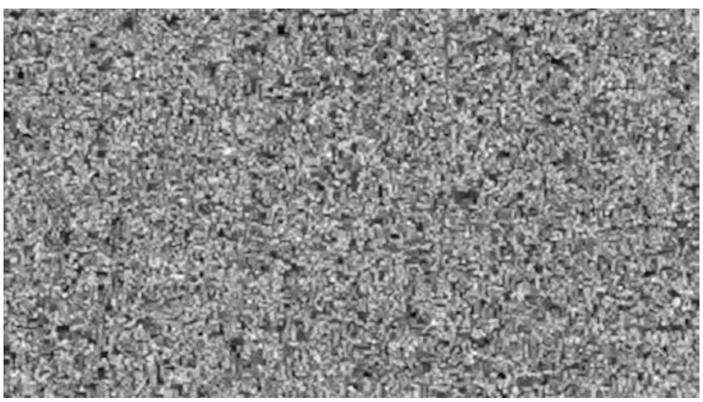
Figure 1. Still frames from videos presented to participants in the (a) action observation blocks, and (b) baseline blocks of the experiment.



(a)



(b)

Figure 2. Log-power in Mu-band (8-13Hz) at Occipital and Central sites. The results suggest that 8-13 Hz activity observed at the central sites reflected Mu- rather than Alpha-rhythms.

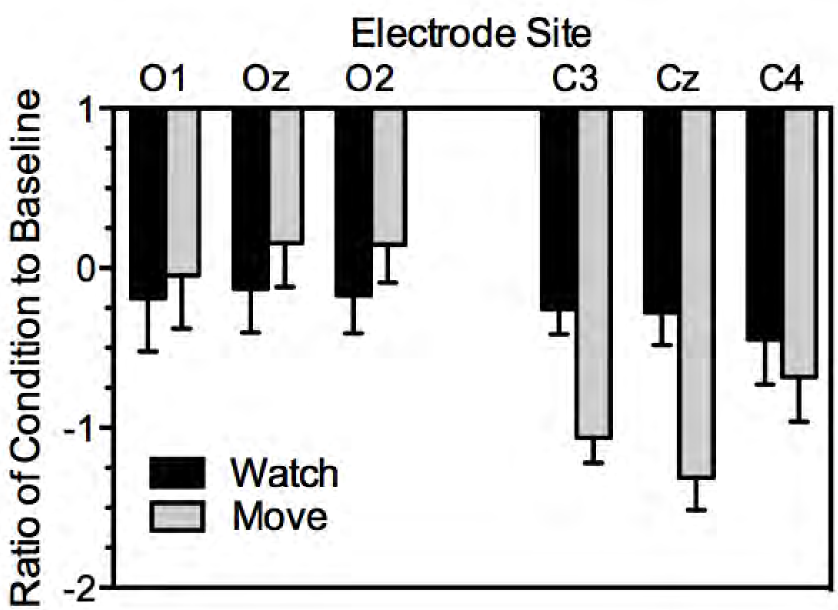


Figure 3. Scatterplots showing the correlations between composite SES and (a) Mu-suppression index averaged across C3, Cz, and C4, and (b) Mu-suppression factor scores. Higher scores = greater power in the Mu-band, indicating weaker Mu-suppression. The outlier is depicted as a star and is not used in the regression calculation.