FUNCTIONAL DIFFERENCES IN NEURAL ACTIVATIONS OF LOW-SES INDIVIDUALS TO EMOTIONALLY-PROVOCATIVE IMAGES: RELATING SOCIOECONOMIC STATUS TO HEALTH OUTCOMES

by

Zohn Rosen

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Laura A. Rabin, Ph.D.

Date

Chair of Examining Committee

Maureen O'Connor, Ph.D.

Date

Executive Officer

Deborah J. Walder, Ph.D.

Laura Reigada, Ph.D.

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

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Advisor: Laura A. Rabin

Although material factors account for a portion of the relationship, cognitive factors likely explain much of the association between socioeconomic status (SES) and health. Functional MRI was used to explore differences in the processing of emotionally provocative images in a sample of low-SES versus high-SES individuals. Fifteen participants (8 low-SES, 7 high-SES) were presented with validated positive, negative, neutral, and poverty-specific images while performing a simple image/scramble identification task. Regions of interest investigated included limbic regions, as well as areas associated with modulating emotional control (i.e., frontal cortices), and regions associated with the transduction of emotional states into physiological changes (i.e., caudate, thalamus, and locus coeruleus). Results showed significant differences in each of the identified regions of interest, with low-SES individuals having increased activation of limbic and transductive regions when presented with negative images and images of poverty. In addition, low-SES individuals showed relative decreased amygdala activation in the poverty-specific condition, as well as increased insula activation coupled with

decreased activation in the anterior cingulate, fusiform, and frontal regions when presented with positive imagery. These results imply significant and meaningful processing differences for emotionally charged imagery in individuals at different levels of the socioeconomic spectrum. Additionally, results may help identify neural regions associated with the transduction of emotional information into somatic changes that cause the observed long-term health disparities seen in low-SES members of the community.

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Introduction

The observation that being poor is related to poor health has been commonplace throughout history. People who perform strenuous physical labor, lack basic resources, and have limited education and access to healthcare have been observed to live shortened and less healthy lives. Centuries worth of evidence has documented social inequalities in health, and observations to this effect appear in writings as far back as the Hippocratic corpus, ancient Chinese medical texts, and in writings from both ancient Egypt and Greece (Hippocrates, 1983; Sigerist, 1951, 1961; G. D. Smith, Carroll, Rankin, & Rowan, 1992; Syme, 1992; Wen, 1966).

In the past it was assumed that the abbreviated life spans associated with low status were due to hard living, insufficient diet, and a lack of access to almost any medical care. In more modern times, many of these factors no longer have a hold on the majority of society members (at least in first world countries), but the relationship between socioeconomic status (SES) and health remains (Link & Phelan, 1995). Efforts to elucidate the association between SES and health have targeted diet, increased risk behaviors such as smoking, and lesser use of medical services (especially preventive medicine), but research findings over the past quarter century indicate that these variables explain little of the relationship (Lantz et al., 1998). It therefore appears that the major causative factors have yet to be elucidated.

In this *Introduction*, we present evidence for the relationship between SES and health, and examine the mechanisms likely responsible for it. We begin with a review of the definition of SES and methods used for its measurement. We then review population-based and experimental evidence showing the robustness of the SES – health relationship

across multiple nationalities and cultures. Thereafter we explore the psychological underpinnings of low social status, and examine a recently proposed model that attempts to explain the interaction of many of the psychological and social factors involved. We then approach the issue from the physiological standpoint, and review the biological effects associated with low-socioeconomic status-induced stress. Finally, we execute an experiment designed to aid our understanding of the mechanisms underlying the SES/health relationship.

Measurement of Socioeconomic Status

A key question underlying research into the relationship between SES and health outcomes is what exactly is SES? SES is often conceptualized as simply income-related, although a significantly more complex set of factors determine one's status in society. When formal examinations of this topic began in the mid-1980s, a threshold measure – based on household income – was the primary gauge of SES. The threshold most commonly employed was the "poverty line," and analyses examining health outcomes used this dichotomized measure to conduct comparisons of low versus "normal" income participants. Conventional wisdom held that poor health was related to a lack of material resources and access to proper medical care, which are problems of the definitively poor. Thus, the poverty line was the obvious measure to define who fell into this category and presented a simple, dichotomous measure to be used in research on the relationship between SES and health. In general, threshold measures of SES had been commonly employed as a control variable in medical and sociological analyses, being treated much like gender in the way that it ubiquitously appears but is almost never used as an

explanatory variable (Marmot, Kogevinas, & Elston, 1987; Syme, 1992). The theory guiding this usage was that low SES participants could confuse results of studies performed on otherwise 'normal' individuals, and controlling for the potential confounds related to that group could alleviate such issues. By current standards this measure is an oversimplification of a highly complex topic, which has both material and psychological components.

Using poverty to measure SES lacks stability because poverty is both state and time-specific, and is subject to significant variation over time. For example, a study conducted from 1991-1993 found that approximately 20% of the U.S. population was "poor" in any given two months, but that only 5% of the population was in poverty for the entire 2-year period (Shea, 1995). The threshold model was challenged by findings from the first Whitehall study, which examined morbidity and 10-year mortality among 17,530 British civil servants at various stages of occupational grades (Marmot, Shipley, & Rose, 1984). This seminal study revealed an occupational gradient relating employment position and health outcomes. Findings showed that those at the bottom levels of the occupational grade had poorer health and higher mortality rates, and this trend continued all the way to the top occupational levels with improvement in health status being demonstrated at each successive stage of occupational status. This trend was found despite the fact that all participants in the Whitehall study were gainfully employed and had access to the British public health care system.

Whitehall study results had a profound effect on research into SES inequalities in health. These findings not only made clear that SES was related to health outcomes at all levels of economic and social standing, but also made a strong case that access to

resources alone could not account for the differences. Since all members of the Whitehall study had regular access to healthcare (due to the public healthcare system in that country), the argument that poor health was related to lack of access to medical resources no longer could explain the observed disparities. Although several other potentially confounding factors could partially account for the observed outcome (e.g., reduced health literacy related to lower education), the finding that SES was related to life expectancy at all levels of employment in the civil service fundamentally changed the argument that the relationship between SES and health was due solely to material factors. It is worth mentioning that findings from this study and many to follow in this literature review are predicated on a first-world view of SES in society. In places where the distribution of income is significantly more dichotomized (i.e., third-world countries), factors such as access to healthcare and basic resources are known to play a significant role in both morbidity and mortality.

Other studies conducted in the U.K. at around this time found similar results. Two such studies (Adelstein, 1980; Susser, Watson, & Hopper, 1985) using data from the British census found that a various conditions including infectious diseases, malignant neoplasms, and diseases of the respiratory, circulatory and digestive systems, in addition to all-cause mortality were related to SES based on civil-service occupational grade. One advantage of conducting this research in the U.K. was that a well-accepted measure of SES already existed (occupational grade) and was regularly documented, so large-sample analyses of SES and health were relatively easy to conduct. In order to examine these relationships in the U.S., new measures of SES were required.

It is important to note that SES is a "composite measure" that typically incorporates economic status (measured by income), social status (measured by education), and work status (measured by occupation) (Dutton & Levene, 1989). These three indicators arose during the 1980s to become the primary measures of SES. In the literature review that follows, each measure independently will be shown to have a significant relationship to health. Although often treated as interchangeable, each of the three indicators has specific social and temporal properties, representing overlapping components of overall SES.

Income

Income, both personal and household, has been widely considered to be the primary measure of SES because the amount of money available directly translates into access to resources for either basic necessities (e.g., food and healthcare) or luxuries, which then serve as external indicators of one's social status (e.g., an expensive car or fashionable clothing). Income though is a highly variable measure, and most social scientists feel that SES tends to be stable across the lifespan and intergenerationally (Lynch, Kaplan, & Salonen, 1997a). Although household income is likely to be more stable than individual income, the difference between the two is dependent on the secondary component of social support via family members or others sharing the same household and resources. Even if additional support is present, studies of income variance conducted during the economic recession of the 1980s showed that more than half of U.S. households experienced an increase of 50% or a decrease of more than 33% in monthly income (US Bureau of the Census, 1996). Further, members of households that experienced a single marked income drop experienced a 30% increase in mortality risk,

and those that experienced two or more such decreases had a 70% increase in mortality risk over a 5-year period (Duncan, 1996). This example shows the large potential variation associated with income as a measure of SES and its relationship with health outcomes.

Another potential issue with the use of income as the primary measure of SES when examining its relationship with health is reverse-causality. This phenomenon, often referred to as *social drift*, reflects the causal relationship between poor health and subsequent reduced SES. For example, there is evidence that individuals diagnosed with schizophrenia experience a trajectory of descending SES, often throughout the remainder of their lives (E. M. Goldberg & Morrison, 1963). Additional studies have found a relationship between poor health in childhood or young adulthood and reduced SES later in life (Wadsworth, 1986). Although some downward drift in SES accompanies poor health at almost any stage of life (with the possible exception of post-retirement), most researchers feel that this phenomenon is unlikely to play a major role in accounting for the overall observed SES-health relationship (Hann, Kaplan, & Syme, 1989; Wilkinson, 1986).

Occupational Status

A second, often used measure of SES is occupational status. Although highly correlated with personal income, an individual's occupation has ramifications far beyond the actual amount of earned income. Occupation is strongly tied to social standing, although measurement of this effect has been elusive and subject to change over time (Haug, 1977; Liberatos, Link, & Kelsey, 1988; Marmot et al., 1987; Nakao & Treas, 1994; Nam & Terrie, 1982). Researchers use a diverse set of measures for SES based on

occupation, and presently there is no agreed upon standard for relating SES to specific occupations. A further complication arises from the wide range of potential occupations that currently exist, and the growing number of new occupations spurred by technological and economic innovations (US Bureau of Labor Statistics, 2005). As a measure of SES, occupation has similar disadvantages as income in that both are subject to the effects of temporal instability. For example, anyone who is not currently working for pay is defined as "unemployed," even though this status can represent anything from a temporary shift from one job to another (or full-time attendance in school), to a permanent lack of gainful employment. Further, many members of U.S. society do not work for a variety of reasons (e.g., disability, retirement, homemaker, independently wealthy), making occupation an effective measure of SES for only a portion of the population. Finally, occupation also can be influenced by social drift, as health problems can affect the future development of one's career.

Education

Because of the potential influence of social drift and the temporal instability of both income and occupation, many researches have employed education as the primary measure of SES. One advantage of using education as a measure of SES is that most people complete their training by their early 20s, minimizing the potential influence of social drift (although childhood illnesses could have an influence on educational attainment). Second, after its completion, education typically remains stable throughout a person's life, thus avoiding the issues tied to fluctuating income or occupation status. Using education as a measure of SES also has the advantage of being well defined (at least within a single country's educational system) and easily captured as either number

of years or degree obtained. Finally, numerous studies have found a relationship between educational attainment and various health outcomes and mortality in the U.S. (Elo & Preston, 1996; Feldman, Makuc, Kleinman, & Cornoni-Huntley, 1989; Kitagawa & Hauser, 1973; Liberatos et al., 1988; Pappas, Queen, Hadden, & Fisher, 1993; Reis, 1991; C. E. Ross & Wu, 1995; Williams, 1990), as well as in Europe (Kunst, Geurts, & van den Berg, 1995; Kunst & Mackenbach, 1994) and developing countries (Behm, 1980; Grosse & Auffery, 1989).

Some have argued against the use of education as the sole measure of SES (Krieger & Fee, 1994). For example, lifetime stability of education may not always be an advantage, as use of education as the primary measure of SES obscures changes in SES in adulthood masking the relationship between changes in economic well-being and health (Liberatos et al., 1988; G. D. Smith, Hart, Hole, Gillis, & Watt, 1994). In addition, the commonly used and well-defined criteria of "years of education" may distort education's relationship with SES; in some cases, possession of specific credentials may have a much stronger relationship with employment and income. Researchers examining the relationship between education and health have found that degree obtained may serve as a good measure for educational attainment (Faia, 1981; Krieger & Fee, 1994; Liberatos et al., 1988). Further, the span of educational levels is far less than that of income, making it a less sensitive measure for evaluating inequalities in health outcomes (Krieger & Fee, 1994), and the distribution of educational attainment in the U.S. varies greatly by decade, with younger cohorts having overall higher education resulting in decreasing variability (Levy & Murnane, 1992; Liberatos et al., 1988).

Social Class

All the measures considered above involve a resource-based approach to the measurement of SES. A broader concept that reflects the social-interaction aspects of SES is "social class," a complex descriptor involving elements of both economics and social standing (Giddens & Held, 1982; Marx, 1967; Weber, 1978; Wright, 1989). Although defined in a variety of ways, social class is commonly used to refer to individual social groups that arise from interdependent economic-based relationships among people (Krieger, Williams, & Moss, 1997). In addition, other social elements (e.g., race and religion) can exert powerful influences that affect a group's position in society. As such, social class is a complex type of social relationship based on both the material and conceptual, and it is directly created by societies and their economic structures. Conceptualizing social position in this manner helps explain the changing economic and social well-being of the members of different social classes, and also why and how the well-being of one's social class is causally linked to the deprivation of other classes (Giddens & Held, 1982; Marx, 1967; Navarro, 1986; Townsend, 1993; Wright, 1989). Because of these complexities, several researchers have moved away from the term "socioeconomic status," instead preferring the term socioeconomic position (SEP), as SES is felt to blur the distinction between two conceptually separate aspects of socioeconomic position: (1) actual resources, and (2) prestige or rank-related social characteristics (Krieger et al., 1997). For the purposes of this work we will specifically focus on SES except where otherwise indicated.

Although social class may be more thoroughly descriptive of an individual's status in society – and therefore a more accurate predictor of subsequent health and life

expectancy – it is a difficult concept to measure in a scientifically useful manner. Despite its ubiquitousness in societies around the world, most terminology describing social class is vague and relativistic at best (e.g., working-class, middle-class, upper-class) and therefore lacks any absolute classification[1]. Moreover, social class has not been used to classify SES in most research examining the relationship between health and social status, so little data exist that relate SES to health or other outcomes.

Advanced Measures

All of the measures described within this section have been examined for their relationship with health outcomes, and several researchers have investigated the question of which SES measure is the most accurate predictor of health status. Using various statistical methods including multiple regression-based techniques, comparisons have been made of the strength of the relationship between measures of income, education, occupation, and health (Geyer & Peter, 2000; G. D. Smith, Hart, D., & al., 1998; Winkleby, Jatulis, Frank, & Fortmann, 1992). Overall, findings have been inconsistent, with some making a case that occupational position is the strongest predictor of socioeconomic differentials in health (Dahl, 1994; G. D. Smith et al., 1998), while others have found a stronger relationship for income (Blaxter, 1990; Geyer & Peter, 2000; Marmot et al., 1984), or education (Winkleby et al., 1992). An explanation for the discrepant findings is that the various indices of SES measure different aspects of social and economic position, and these are differentially related to the various health outcomes. For example, in a British study of 5,749 men aged 35 to 64 at baseline (between 1970 and 1973) followed over a 21-year period, participants who came from the *manual* social

[1] For a good attempt to classify such constructs see the work of E.O. Wright (Wright, 1966, 1985, 1989)

class had a significantly higher risk of all-cause mortality (G. D. Smith et al., 1998). This effect was further exacerbated by low-levels of education, which caused a significantly increased risk of death due to cardiovascular disease within the subclass.

Because of the inconsistencies involved in using income, occupation, or education as the index of SES to predict different health outcomes, some researchers have attempted to use advanced statistical methods to form a more consistent and stable measure. Using techniques such as confirmatory factor analysis, efforts have been made to form latent measures based on weighted combinations of some of the indices described above. For example, using data derived from Phase V of the Whitehall II study, Singh-Manoux, Clarke, and Marmot (2002), compared a straightforward multiple regression model using indices of education, occupation, and income to both a time insensitive and time-lagged latent measure combining all three indices to predict self-rated health and psychosocial health (i.e., hostility and hopelessness). Results showed that using a latent construct to measure SES produced significantly more accurate results than simply considering each of the indices in a multiple regression. There was no significant difference, however, between the time-insensitive model and the model that attempted to incorporate time-sensitive factors (Singh-Manoux, Clarke, & Marmot, 2002).

In another attempt to move beyond individual indices of SES, Sing-Manoux et al. (2003) explored the relationship between self-rated social status and health using a self-anchoring scale (Cantril, 1965) known as the psychosocial ladder. This measure uses an image of a ladder with 10 rungs, with participants being instructed to place an -'X'- on the rung that represents where they stand in society (details are presented below in the *Methods* section). Singh-Manoux argued that the ladder acts as a measure of subjective

social status, and therefore incorporates not only the material aspects of SEP, but the psychosocial ones as well. In his Whitehall II study of 6,981 London-based individuals, Singh-Manoux et al. (2003) found that the psychosocial ladder predicted five health outcomes: (1) diabetes, (2) respiratory illness, (3) angina, (4) depression, and (5) general health more accurately than any of the previously described indices of SES. The researchers also examined the relationship between this subjective rating of social status and conventional SES measures, as well as life-satisfaction and psychological well-being. Results showed that when 16 factors were considered, 51% of the variance in the psychosocial ladder was explained, and the variables with the lowest association were measures of psychological well being. Using statistical culling techniques (a technique where variables are systematically removed to achieve a more parsimonious model), a final model was developed that contained the five variables that best predicted the value of the subjective social status measure: (1) employment grade, (2) satisfaction with standard of living, (3) household income, (4) feeling of financial security, and (5) education. Based on these findings, Singh-Manoux asserted that subjective social status likely reflected an individual's SEP more fully than any objective measure of SES, and that this measure was relatively independent of current psychological well-being.

Economic Inequality

All of the previously mentioned measures refer to individual or household-level indices of SES. As will be explored later in this review, theories underlying the cause of the observed relationship between health and SES often are tied not to absolute levels of income, education, or occupation, but instead to level of *inequality* of these factors within a community, region, or country. By definition, measures of inequality require the

comparison of multiple individuals or households, and therefore form the basis of indices that can be used to compare the strength of the SES-health relationship across countries or at the level of nations and continents. The most common metric applied to the measurement of income inequality is the *Gini coefficient* (Gini, 1955), defined as the ratio of the area between the Lorenz curve (Lorenz, 1905) of the individual or household-level income cumulative probability distribution and the uniform income distribution curve (Dixon, Weiner, Mitchell-Olds, & Woodley, 1987; Gini, 1955). This index generates a value between 0, which corresponds to perfect equality (i.e., everyone in the measured region has the same income) and 1, which corresponds to complete inequality (i.e., one individual has all of the income while all others have none).

The Gini coefficient has several desirable properties when examining regional income differentials including scale independence (i.e., the coefficient does not consider the size of the economy and is independent of the absolute income values present within a region), population independence (i.e., population size has no effect on the metric), and anonymity (i.e., it makes no difference who the particular individuals are in the sampling frame). It also has the advantage of allowing calculations that follow the transfer principle, that is, the effect that transferring income from a higher-earning to a lower-earning group would have on the overall measure of inequality. Measures such as the Gini coefficient and comparative median incomes allow for an examination of the effects of income variance within and across regions at different scales (i.e., between states, national regions, countries, and continents). Using such a tool, investigations into the global effects of income differentials become possible, allowing researchers to examine the influence of changing global economies on the health and welfare of their populace.

Overall, accurate measurement of SES is still more of an art than a science. As this review shows, psychosocial measures of SES may have as strong a predictive relationship with health and life expectancy as material-based SES factors. We will now review how the variables described above are employed to examine the relationship between SES and various mental and physical health outcomes.

Socioeconomic Status and Health

Evidence of the Relationship Between Mortality/Morbidity and Socioeconomic Status

Since the findings of the initial Whitehall study (Marmot et al., 1984), researchers have been investigating the relationship between SES and health in an ever-expanding number of populations and regions. Although a considerable amount of variation exists between the methodologies and samples used for these analyses, the evidence in support of this relationship is overwhelming. Many of these studies employ large samples derived from census data, and examine mortality rates using death registries. Others focus on morbidity data, examining rates of major life-threatening health conditions such as cardiovascular disease or cancer. Still others employ income inequality data to perform large-scale cross-state and cross-national comparisons, thereby examining societies as a whole and the way their economies affect public health (generally through the use of the *life expectancy* metric).

U.S. Evidence

Sorlie, Backlund, and Keller (1995) employed a sample of over half a million participants (N=530,507) drawn from the Bureau of Labor statistics and the National

Longitudinal Mortality Study to examine the relationship between four measures of SES and death from any cause over an 11-year period in the U.S. Initial examinations compared mortality rates by income, education, occupation, and employment status within subgroups defined by race, gender, and age categories. Results showed that mortality risk consistently declined with increasing household income in all subgroups. Similar results were found for employment status (e.g., unemployed versus employed), employment category, as well as for years of education, which at its extremes represented a two- to threefold increase in mortality risk when comparing the lowest levels of education (less than 5 years) to the highest (17+ years). When the proportional hazard analyses (models describing how risk changes over time) were re-examined using the other SES predictors as control variables, the relationship between education and mortality and the observed link between occupation and mortality were both attenuated (although still significant), whereas the relationship between income and mortality was strengthened. These finding suggest that although socioeconomic factors such as income, education, and occupation are interdependent, household income accounts for the largest portion of the variance in mortality risk within this U.S. sample.

Other researchers have examined the predictive relationship between SES and health in the U.S. both at the individual level and by using aggregate measures (those which use community-level data such as Census tract-level information). Steenland et al. (2004) investigated both individual-level and area-level SES as it related to mortality in 179,383 adults in the American Cancer Society Nutrition Cohort. Individual-level SES was determined using educational level, while area-level SES was based on average house value, household income, education, and mean occupation level within census

blocks. Mortality resulting from vascular disease, cancer, or any cause was tracked over an 18-year period (1982 to 2000), and results showed that individual education was strongly and inversely associated with mortality from all causes. In addition, weaker but still significant results were obtained when the area-level SES measures were employed for all examined causes of mortality with the exception of cancer-related deaths. A similar study conducted in the same year in the U.S. examined the relationship between occupation and mortality in a cohort of 377,129 adults who participated in the National Health Interview Survey (Muntaner, Hadden, & Kravets, 2004). Results showed that non-professionals had a significantly higher risk of death from any cause than individuals with professional occupations.

Studies that make use of aggregate data in the U.S. have examined the relationship between health and SES at the county-level (McLaughlin & Stokes, 2002), state-level (Kaplan, Pamuk, Lynch, Cohen, & Balfour, 1996; Kawachi & Kennedy, 1997; Wolfson, Kaplan, Lynch, Ross, & Backlund, 1999), and across metropolitan areas (Lynch, Kaplan et al., 1998), as well as at the census-tract level (Steenland, Henley, Calle, & Thun, 2004). Many of these employ an income inequality metric as a means of cross-comparing areas while maintaining a consistent SES measure (i.e., unadjusted income may have a different effect on health outcomes across U.S. regions), although in many cases the measures of inequality are simple group comparisons as opposed to more standard metrics such as the Gini coefficient. The Gini coefficient is a standard measure of income distribution inequality. It is defined as a ratio with values between 0 and 1, where a low Gini coefficient indicates more equal income or wealth distribution. A Gini coefficient of 0 corresponds to perfect equality (everyone having exactly the same

income), whereas a 1 corresponds to perfect inequality (where one person has all the income, while everyone else has zero income).

For example, Lynch et al. (1998) examined metropolitan statistical areas across cities in the U.S. and concluded that higher income inequality was associated with increased mortality at all per-capita income levels. At the state-level, Kaplan et al. (1996) found that income inequality was significantly associated with both mortality and health-outcome trends, and Wolfson et al. (1999) showed that the observed state-level association between income inequality and mortality could not be completely explained by individual-level associations between income and mortality, implying a higher-order community-level effect. In further support of the above state-level findings, Kawachi and Kennedy (1997) employed a variety of measures of income inequality to determine if the observed relationship was dependent on the type of measure employed. Results indicated that choice of inequality indicator did not alter the conclusion that income inequality is linked to mortality and poor health.

Critics of the aggregate approach have raised the possibility that racial makeup of the regions compared may account for the findings as race and SES are often highly correlated (Mellor & Milyo, 2001). To address this issue, analyses were performed at the state level and results indicated that the association between health and income inequality was not confounded by race (Subramanian & Kawachi, 2003a, 2003b). In a further and more detailed examination of state-level income inequality and health, Ram (2005) determined that the health disparities observed in previous research were robust across a wide variety of research parameters. In addition, Ram found that the relationship between

income inequality and health was not significantly attenuated with the addition of the following explanatory variables: education, racial breakdown, or urbanization.

International Evidence

Research performed in other Western counties (e.g., Europe) has yielded similar results despite differences in governmental structures and social factors that affect income, educational attainment, available occupations, and access to health-related resources. For example, in a study of 84,814 German adults, the lowest income group had an almost 2-fold increase in all-cause mortality by age 65, even when the analyses controlled for occupation and gender (Geyer & Peter, 2000).

Another European study that used population data and measures of deprivation by electoral ward examined the relationship between deprivation and life expectancy across all of England and Wales (Woods et al., 2005). Results of this large-scale study indicated that people living in areas characterized by higher rates of deprivation had significantly shorter life expectancies than those in more affluent areas. The difference in life expectancy among women was nearly 4 years when comparing the most and least affluent areas, and more than 5 years for men. In a similar 1994 study, the approximately 57 million inhabitants of 95 Italian provinces were examined for their mortality risk as it related to income inequality using the Gini coefficient (Materia et al., 2005). For both genders, a positive association was found between income inequality and total mortality in provinces with a low per capita income, although the magnitude varied according to geographical region examined.

Moving beyond Western nations, studies examining the relationship between SES and health have recently been conducted in Asia. One example is a study of 578,756 male

Korean public servants aged 30 to 58 who were followed over an 11-year period (Song et al., 2006). The main finding was that SES had a significant inverse association with mortality, with the majority of this effect being due to myocardial infarction and stroke. These findings remained after statistical adjustments were made for cardiovascular risk factors (i.e., high total cholesterol, high blood pressure, BMI > 25, and smoking).

Cross-National Evidence

Finally, several researchers have performed cross-national comparisons examining the relationship between income inequality and mortality (Avendano et al., 2006; Rodgers, 1979; N. A. Ross et al., 2005; Wilkinson, 1992, 1996). Ross et al. (2005) pooled work-age mortality data from 528 metropolitan areas in Australia, Canada, England, Sweden, and the U.S. and found a significant relationship between income inequality and mortality. Within this pooled sample, it was determined that a hypothetical shift of 1% of income from the richest to the poorest half of the sample would result in a working-age decline of 21 deaths per 100,000.

In an even larger cross-national study, Avendano et al. (2006) gathered data on SES and ischemic heart disease from nine European nations including Finland, Norway, Denmark, England/Wales, Belgium, Switzerland, Austria, Italy, and Spain. Results showed a relative risk of death from ischemic heart disease of 1.55 (95% CI 1.51-1.60) for low-SES versus middle and high-SES men aged 30-59, and 1.22 (95% CI 1.12-1.24) for low-SES versus middle and high-SES men aged 60 and older. For low versus middle or high-SES women, the relative risk of death from ischemic heart disease was 2.13 (95% CI 1.98-2.29) for women age 30-59, and 1.36 (95% CI 1.33-1.38) for women age 60 and older. Finally, Lenthe et al. (2006) examined the association between neighborhood

unemployment rates and mortality in six countries (U.S., U.K., Netherlands, Spain, Italy, and Finland). Results revealed increased rates of mortality associated with living in areas with high levels of unemployment.

Despite the large amount of evidence for the cross-country association between income inequality and population health, some researchers have questioned the validity of such findings (Deaton, 2003; Gravelle, Wildman, & Benzeval, 1998; Judge, Mulligan, & Benzeval, 1998; Mellor & Milyo, 2001). Attempts at replication using a variety of statistical methods have yielded inconsistent results leading researchers like Deaton (2003, pg. 139) to state the following: "Later research has cast considerable doubt on the robustness and reliability of many of these [cross-country] findings." In an attempt to settle this debate, Ram (2006) undertook the largest cross-national comparison to date, examining the relationship between income inequality and population health in 108 different countries using data from the last 25 years. Ram attempted to both re-estimate previous models using a more extensive data set and address issues raised by critics regarding the influence of variations within the populations studied (e.g., amount of ethnic heterogeneity or absolute level of poverty present). Findings strongly supported the negative association between income inequality and health across a range of nations, and indicated that this relationship exists even with statistical adjustment for population factors.

The Relationship Between Socioeconomic Status and Psychopathology

Studies examining the negative health effects related to low-SES go beyond physical health, and point to a relationship between low SES and increased risk of psychopathology (Costello et al., 1996; Costello, Compton, Keeler, & Angold, 2003; B.

P. Dohrenwend et al., 1992; Hollingshead & Redlich, 1958; Johnson, Cohen, Dohrenwend, Link, & Brook, 1999; Kohn, Dohrenwend, & Mirotznik, 1998; Martikainen, Adda, Ferrie, Smith, & Marmot, 2003; Muntaner, Eaton, Diala, Kessler, & Sorlie, 1998). The disorder most commonly examined in association with low SES is depression, and this relationship has been observed in both adolescent and adult samples (Gilman, Kawachi, Fitzmaurice, & Buka, 2002; Martikainen et al., 2003; Murphy et al., 1991).

Using the sample of 7,162 British civil servants obtained in the Whitehall II study, Martikainen et al. (2003) found that rates of depressive symptoms increased as household income decreased. The relative increase in depression as measured by the depression subscore of the 30-item General Health Questionnaire (GHQ) (Stansfeld, North, & White, 1995) was 2.04 (95% CI 1.37-3.04) for low-income men and 2.46 (95% CI 1.13-5.32) for low-income women (range 0 to 3) even after controlling for 12 covariates from an earlier time point including: age, baseline self-rated health, longstanding illness, 30-item GHQ depression and its squared value, employment status, number of economically active members of household, total number of people in the household, number of children, marital status, education, and employment grade. Similarly, a study of 1,132 adult offspring of mothers enrolled in the U.S. National Collaborative Perinatal Project, investigated the relationship between childhood SES, assessed from parental occupation, and depressive disorders, assessed using the Diagnostic Interview Schedule (Oliver & Simmons, 1985). Results showed that lower SES respondents had double the risk of a diagnosis of depression as those from higher SES backgrounds (Gilman et al., 2002).

Other investigators have examined a wider range of psychiatric disorders. In an 18-year longitudinal study of 736 families from New York State, Johnson et al. (1999) found that low family SES was associated with a significantly increased risk of offspring anxious, depressive, disruptive, and personality disorders, even after control for offspring IQ and parental history of psychopathology. Further, using a sample of 4,500 adolescents randomly drawn from an 11-county area of the southwestern U.S. (The Great Smoky Mountain Study of Youth), Costello et al. (1996) found that poverty was by far the strongest demographic correlate of the range of DSM-III-R (American Psychiatric Association, 1987) Axis I diagnoses (Costello et al., 1996).

A major question concerning the relationship between SES and psychopathology is its causal direction. The two primary hypotheses are *social selection*, which posits that individuals with psychopathology have a reduced ability to hold jobs and thus lower SES (referred to above as social drift), and *social causation*, which posits that people with low SES develop psychiatric disorders as a result of living with adversity. Evidence for psychiatric social selection has been demonstrated by a handful of studies in which early-onset psychiatric disorders (i.e., anxiety, mood, substance use, and conduct disorders) led to reduced educational attainment (Kessler, Foster, Saunders, & Stang, 1995), severe early-onset disorders like schizophrenia led to reduced income in adulthood (B. P. Dohrenwend et al., 1992; E. M. Goldberg & Morrison, 1963), and attention-deficit/hyperactivity disorder led to lower adult SES (Miech, Caspi, Moffitt, Wright, & Silvia, 1999). A problem with this research, however, is that many of the studies relating SES to psychopathology involved child/adolescent samples, making the likelihood of social selection in these cases low as individuals are too young to account for a

significant portion of their families' income (with the exception of the possibility of an indirect effect, in which child issues reduce parents' ability to maintain their income). More evidence exists in support of the social causation hypothesis (Catalano, Dooley, Wilson, & Hough, 1993; Dodge, Pettit, & Bates, 1994; Hamilton, Broman, Hoffman, & Renner, 1990; Johnson et al., 1999; Link & Phelan, 1995; Shaw, Winslow, Owens, & Hood, 1998), and longitudinal studies have investigated whether low SES precedes psychopathology or the reverse, with the overwhelming majority of results supporting the social causation hypothesis (Costello et al., 2003; Johnson et al., 1999; Shaw et al., 1998). It should be noted that a combined effect of both factors is likely at play in many cases, as psychopathology can manifest in a variety of ways and with different time courses.

Socioeconomic Status and Health Risk Behaviors

One theory underlying the observed relationship between low SES and poor health or premature mortality is that people of lower SES have a higher prevalence of health-risk behaviors. Health-risk behaviors and lifestyle factors such as substance use, obesity, and low physical activity are related to poor health outcomes and increased mortality risk. There is also evidence that low SES individuals are significantly more likely to lead sedentary lifestyles, be overweight, and consume cigarettes and alcohol (K. Liu et al., 1982; Osler, 1993; Wagenknecht et al., 1990; Winkleby, Fortmann, & Barrett, 1990). Lantz et al. (1998) examined a nationally representative sample of 3,617 adult men and women at three time points over a 7½-year period, and assessed the relationship of income, education, demographics, and health behaviors to mortality. Although Lantz found a statistically significant relationship between lower income/education and risky

health behaviors, the relationship between income and mortality remained basically unchanged when controlling for these behaviors. In fact, the four risk behaviors combined only accounted for 12% to 13% of the predictive effect of income on mortality. Results remained essentially unchanged when additional controls for Time 1 and Time 2 self-reported health status were added to the model. This finding shows that although lower income people are more likely to undertake risky health behaviors, this alone cannot account for the relationship observed between poverty and reduced life expectancy. In a follow-up study with the same sample, Lantz et al. (2001) examined health outcomes other than mortality. Again, participants in the lower income groups had significantly increased odds of moderate to severe functional impairment by the study's conclusion as compared to those in higher income groups, and this relationship was maintained even when accounting for the increased level of health-risk behaviors in the lower-income groups.

Similar results have been found in other samples despite differences in the techniques employed. For example, Smith et al. (1990) used data from 11,678 male British civil servants (originally sampled between 1967 and 1969 in the Whitehall Study), and examined whether the observed relationship between low SES and mortality could have been caused by pre-existing and behavior-related risk factors. Their analysis controlled for the behavioral factor of smoking, as well as the following physiological correlates of risky lifestyles and behaviors: plasma cholesterol concentration (a physiologic measure of unhealthy diet), glucose intolerance (a physiologic measure of diabetes, also associated with low SES), and blood pressure (a physical measure of heart disease and overall stress). Despite statistical control over these factors, the inverse

relationship between SES and mortality remained. This result was maintained when the addition of height, a marker for environmental factors present early in life, was added to the analysis.

Although further examples exist showing that the relationship between SES and mortality is maintained when controlling for behavioral and physiologic risk factors ((e.g., Duijkers, Kromhout, Spruit, & Doornbos, 1989; Haan, Kaplan, & Camacho, 1987), results of similar research conducted in first-world countries with low Gini-coefficients (i.e., Finland) shows that risky behavioral, psychological, and social factors account for a significant portion of the relationship in those settings (Lynch, Kaplan, Cohen, Tuomilehto, & Salonen, 1996). Because people living in low-SES circumstances are more likely to engage in risky behaviors (e.g., smoking, illicit drug use), which are related to health outcomes and mortality, the influence these factors exert on the link between SES and health becomes a question of degree. As the evidence shows, in cases where a relatively large disparity exists between rich and poor, increased risk behavior does not significantly attenuate the inverse relation between SES and health. However, in regions where this difference is smaller, the statistical importance of these behavioral factors is more strongly felt, thus changing the interpretation of their relative importance. In conclusion, smoking, obesity, substance use, and other health risk factors associated with low-SES do not explain the relationship between SES and health, and in many samples exert only a minor statistical effect upon the relationship. Therefore, other factors must be responsible that explain this relationship.

Psychological Theories Underlying the Link Between Socioeconomic Status and Reduced Health

The research described above establishes that low SES is related to increased mortality and morbidity – and the logical next question becomes what mechanism underlies this association? Since lack of access to healthcare and SES-linked health risk behaviors account for a small portion of the link between SES and health, another mechanism is likely contributing to the observed relationship. A leading explanation is that persons with low SES experience increased levels of stress, which in turn negatively impact their long-term health. The main thrust of this theory is physiological, where increased levels of stress hormones affect various body systems causing damage that accumulates over a lifespan. Stress, however, especially when long-term or cumulative, is not simply a physiological phenomenon.

Definitions of stress vary greatly, and due to its near ubiquitous use in popular literature, the term has expanded to include many factors both psychological and physical (McEwen, 1999a; McEwen & Seeman, 1999; Pacak & Palkovits, 2001). One of the most commonly accepted definitions from a psychological perspective (attributed mainly to Richard S. Lazarus) is that stress is a condition or feeling experienced when a person perceives that demands exceed the personal and social resources the individual is able to mobilize. This definition implies that stress is the result of the perception that one cannot sufficiently adapt to or cope with life's challenges. Multiple resource-based models have been developed to explain the relationship between low-SES and increased stress. These include the physiologically-based concept of allostatic load (D. S. Goldstein & McEwen, 2002; McEwen, 2000; McEwen & Seeman, 1999), and the psychological resource-based

reserve capacity model (Gallo, Bogart, Vranceanu, & Matthews, 2005; Gallo & Matthews, 2003). Both models are based on observations of the association between SES and either the psychological or physiological correlates of stress.

Socioeconomic Status and Negative Emotions

Psychological models involving the availability of stress-mitigating resources are based on research showing that people in high-stress/low-SES environments experience many psychological correlates of stress including increased negative attitudes, hostility, hopelessness, and depression (Adler et al., 1994; Kaplan & Keil, 1993; Matthews, 1989; Taylor, Repetti, & Seeman, 1997). These cognitive-emotional factors in turn relate to deteriorating health and premature mortality, elucidating their damaging effects on physical health.

In order to show that the relationship between SES and stress-related health issues is mediated by cognitive-emotional factors, the standard statistical definition for mediation needs to be applied (Baron & Kenny, 1986). For mediation to be tenable, the evidence must show that (a) SES is related to health, (b) SES is related to negative cognitions and emotions, (c) negative cognitions and emotions are related to health, and (d) when *a* through *c* is considered within the same model, the relationship between SES and health is significantly attenuated when the effects of negative cognitions and emotions are statistically controlled. Unfortunately, few studies have evaluated these four criteria allowing for a direct test of the mediation hypothesis. Although the handful of studies that do attempt to formally test this model will be discussed, we will first examine the copious indirect evidence for the association.

Depression and/or Hopelessness

The majority of research relating SES to negative emotional factors focuses on the following four factors: (1) depression, (2) hopelessness, (3) hostility, and (4) anxiety. Although available studies vary greatly in terms of measures and methodological strength, most extant findings support the low-SES/negative cognitions-emotions theory. A multitude of researchers have examined the relationship between SES and depression and/or hopelessness (Costello et al., 1996; Fiscella & Franks, 1997; Gilman et al., 2002; Johnson et al., 1999; Kaplan, Roberts, Camacho, & Coyne, 1987; Lynch, Krause, Kaplan, Tuomilehto, & Salonen, 1997b; Martikainen et al., 2003; Murphy et al., 1991; Salokangas & Putanen, 1998; Steele, 1978; West, Reed, & Gildengorin, 1998). Using 2,962 adults from the U.S. National Health and Nutrition Examination Survey (NHANES), Fiscella and Franks (1997) found that individuals with annual incomes below $10,000 had symptom scores that were 1.6-2.0 times higher than better-compensated individuals on measures of general well-being, depressive symptoms, and hopelessness. In addition, in two studies conducted in Finland, one with 2,674 men from the Ischemic Heart Disease Study and another with 1,643 patients drawn from community health centers, lower education, income, social class, and occupation resulted in higher depressive symptoms (and in the case of the Ischemic Heart Study, higher rates of hopelessness as well) (Lynch et al., 1997b; Salokangas & Putanen, 1998). In a study of 7,000 residents of Alameda County, California, lower level of education was associated with a significantly increased risk of depression over a 9-year follow-up period (Kaplan et al., 1987). Further, in a 16-year study of 593 adults where SES was assessed using an

index of material possessions, rates of depressive disorder were higher in individuals who possessed less over the study period (Murphy et al., 1991).

Such findings remain even when examining individuals who are middle-class or above. Using a sample of 134 upper- and middle-class residents from Connecticut, Steele (1978) found that belonging to the lower social class (middle class) was associated with higher rates of depressive symptoms than belonging to the upper class. Further, in a study of 2,025 older adults (> 55 years of age) living in Marin County, California, income was related to scores on the Centers for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977a), a well-validated measure of depressive symptoms (Radloff, 1977b; West et al., 1998). These results are particularly compelling as all of the participants lived in an affluent area, but their relative incomes still made a significant difference in overall level of depressive symptoms.

Although the studies reviewed above employed the more methodologically sound prospective approach, studies using cross-sectional methods have achieved similar results (Bebbington, Hurry, Tennant, Sturt, & Wing, 1981; Weissman, Bruce, Leaf, Florio, & Holzer, 1991; Wilson, Chen, Taylor, McCracken, & Copeland, 1999). One example involving a study of 8,098 U.S. residents aged 15–54 (drawn from the National Comorbidity Study or NCS), found that both lower income and lower education were associated with increased rates of major depressive disorder (Kessler et al., 1994). It should be noted that not all studies of SES and depression or hopelessness have yielded such consistent results. Some studies have found no statistically significant effects (Weissman et al., 1991), and others have found mixed results depending on the measure of SES employed (Comstock & Helsing, 1976; Craig & Van Natta, 1979; Regier et al.,

1993; Weissman & Meyers, 1978). Overall, variations in study methodology may account for the mixed results, but in a comprehensive review of this topic, Gallo and Matthews (2003) found that the majority of evidence supported the theory that low SES is related to increased rates of depression and hopelessness.

Anxiety

Although fewer studies have explored the association between anxiety and SES, available evidence also supports this relationship (Eaton, Kessler, Wittchen, & Magee, 1994; Eaton & Keyl, 1990; Himmelfarb & Murrell, 1984; Kessler et al., 1994; Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996; Regier et al., 1993; Warheit, Holzer, & Arey, 1975; Wells, Tien, Garrison, & Eaton, 1994). For example, two studies found that lower levels of education, income, and social class were related to a significant increase in anxiety symptoms (Himmelfarb & Murrell, 1984; Warheit et al., 1975). In addition, using 8,098 U.S. residents drawn from the NCS study, Eaton et al. (1994) found that the least educated group was four times more likely than the college-educated group to have experienced a panic attack, ten times more likely to have a diagnosed panic disorder, and seven times more likely to have a diagnosis of agoraphobia. In another study using the same sample, both income and education were inversely related to the lifetime and 12-month prevalence of any anxiety disorder as determined using the Composite International Diagnostic Interview (CIDI) (Kessler et al., 1994). Further, in a sample of 18,571 U.S. residents taken from the Epidemiologic Catchment Area (ECA) sample, lower SES participants had almost 2.5 times the prevalence rates of phobias and a greatly increased risk of panic disorder (Odds Ratio (OR) = 11.58) compared with high SES participants (Regier et al., 1993).

It should be noted that not all experimental results support the hypothesis that reduced SES leads to symptoms of anxiety and anxiety disorders. The term "anxiety" encompasses numerous disorders ranging from generalized anxiety and panic to phobias, of which many subtypes exist. Some studies have achieved mixed (Blazer, Hughes, George, Swartz, & Boyer, 1991; Eaton, Dryman, & Weissman, 1991), or null-results (Bruce, Takeuchi, & Leaf, 1991) when examining specific subtypes of anxiety disorders, but considering the great variability in methods employed it is not unexpected that some variation should appear.

Hostility

A final negative cognition/emotion commonly explored in relation to SES is hostility**.** Studies investigating this construct have utilized a variety of outcome measures, and overall have revealed strong evidence for the relationship between low-SES and the cognitive, affective, and behavioral components of hostility. Five such studies used the Cook-Medley hostility inventory (commonly referred to as the Ho), which is a measure of hostile cognitions (Cook & Medley, 1954), and found that low levels of income (Barefoot et al., 1991; Lynch et al., 1997a), education (Barefoot et al., 1991; Lynch et al., 1997a; Scherwitz, Perkins, Chesney, & Hughes, 1991), and occupation (Barefoot et al., 1991; Carmelli, Rosenman, & Swan, 1988), were related to hostility. Notably in the studies performed by Barefoot et al. (1991) and Scherwitz et al. (1991), separate analyses were conducted using the behavioral and affective subscales of the Ho, with similar findings achieved. In a study of 6,989 adult males living in the Netherlands, both low education and occupation were related to significantly higher scores on a multidimensional measure of hostility and anger (Ranchor, Bourma, & Sanderman,

1996). Finally, in a study of 541 women (aged 42-50 and living in Pittsburgh) that specifically examined anger as it related to education, increased levels of anger were associated with lower-levels of education (Matthews, Kelsey, Meilahn, Kuller, & Wing, 1989a).

The evidence presented above documents that SES, as measured using a variety of rating scales, is related to negative emotions and cognitions, notably depression, anxiety, hostility, anger, and hopelessness. Strong evidence also exits for the relationship between negative emotions and increased mortality and morbidity, supporting pathway (c) described above.

Negative Emotions and Physical Outcomes

An extensive amount of research has investigated the association between depressive symptoms, hopelessness, and formal diagnoses of depression – and increased risk for cardiovascular disease, stroke, cardiac events, and reduced life expectancy. In a community sample of 6,095 multiethnic U.S. adults, high rates of depressive symptoms were related to a 50% to 160% increase in stroke over the 22-year follow-up period (Jonas & Mussolino, 2000). Several researchers have presented detailed reviews of this topic (Glassman & Shapiro, 1998; Musselman, Evans, & Nemeroff, 1998; Rozanski, Blumenthal, & Kaplan, 1999; Wulsin, Vaillant, & Wells, 1999). For example, Rozanski et al. (1999) examined studies relating depression and hopelessness to risk of myocardial infarction (MI) and cardiac-related death, and found that the relative risk for depressed versus non-depressed individuals ranged from 1.5 times for depressive symptoms or symptoms of hopelessness to 4.5 times for major depression (Anda et al., 1993; Aromaa et al., 1994; Barefoot & Schroll, 1996; Everson et al., 1996; Ford et al., 1998; Pratt et al.,

1996). Further, depression was positively related to coronary heart disease (CHD) (Ahern et al., 1990; Carney, Rich, Freeland, & Sanai, 1988; Denollet & Brutsaert, 1998; Frasure-Smith, Lesperance, Juneau, Talajic, & Bourassa, 1999; Hermann et al., 1998), and a dose-response relationship emerged when examining hopelessness or depression and level of risk (Anda et al., 1993; Barefoot & Schroll, 1996; Everson et al., 1996; Pratt et al., 1996). In a review of studies relating depressive symptoms, major depressive disorder, and hopeless cognitions to cardiovascular outcomes, Musselman et al. (1998) found a strong and consistent relationship even when only examining studies that controlled for additional cardiovascular risk factors such as hypertension and smoking.

Research also supports the relationship between anxiety and poor health outcomes (Fleet & Beitman, 1998; Kubzansky, Kawachi, Weiss, & Sparrow, 1998; Rozanski et al., 1999). Rozanski et al. (1999) reviewed studies relating anxiety to cardiac-related mortality, MI, and CHD, and found that patients with high levels of anxiety had 2.5 to 4.9 times the risk of negative health outcomes (Amsterdam, 1990; Denollet & Brutsaert, 1998; Frasure-Smith, Lesperance, & Talajic, 1995b; Haines, Imeson, & Meade, 1987; Kubzansky et al., 1997; Lown, 1982; Moser & Dracup, 1996; Weissman, Markowitz, Ouellette, Greenwald, & Kahn, 1990). There was also evidence for a dose-response relationship between level of anxiety and reduced health (Kawachi, Colditz, Ascherio et al., 1994; Kawachi, Sparrow, Vokonas, & Weiss, 1994). Other reviews have yielded similar results, again with evidence for a dose-response relationship (Fleet & Beitman, 1998). Further, in a study of more than 18,000 U.S. adults, individuals with panic disorders (as assessed by a structured DSM-III interview) were more likely to have hypertension, heart attacks, or stroke (Weissman et al., 1990) than members of the

general population. In a study employing the New Haven ECA sample, individuals with a history of panic disorder were approximately three times more likely to die over the 9-year follow up period (Bruce, Leaf, Rozal, Florio, & Hoff, 1994) compared to individuals without a panic disorder diagnosis.

Finally, evidence for the relationship between hostility and health has been explored in two review articles (Miller, Smith, Turner, Guijarro, & Hallet, 1996; Rozanski et al., 1999). Although a portion of the findings showed mixed results, the overall evidence supported a positive relationship with high scores on the Ho predicting negative cardiovascular outcomes (Barefoot, Dahlstrom, & Williams, 1983; Barefoot, Larsen, von der Lieth, & Schroll, 1995; Kawachi, Sparrow, Spiro, Vokonas, & Weiss, 1996; Shekelle, Gale, Ostfeld, & Paul, 1983) and all-cause mortality (Barefoot et al., 1983; Barefoot, Dodge, Peterson, Dahlstrom, & Williams, 1989; Shekelle et al., 1983). Miller et al. (1996) performed a meta-analysis of 45 studies that examined the relationship between hostility and physical health, with studies divided by type of hostility measure employed and separate analyses performed for each set of studies. For studies that utilized an interview-based measure of hostility focused on hostile behaviors (e.g., verbal and behavioral aggressive behaviors), the weighted mean effect size was .18, showing a strong and significant relationship with CHD outcomes. When performing a similar analysis with studies that employed the Ho as their measure of hostility, a weighted mean effect size of .07 was found between hostility and CHD outcomes, which represents a weaker but still significant relationship. Finally, when examining studies that used the Ho as a measure of hostility and all-cause mortality as the endpoint, the

weighted mean effect size was.16, again showing a significant relationship between hostility and health/mortality.

As these results reveal, although behavioral measures of hostility have the strongest relationship with poor health, hostile cognitions (measured via the Ho) also had a significant and damaging effect on health and life expectancy. Other studies have supported these findings even when using health outcomes such as vascular disease as their endpoints. For example, in a study of adult Finnish men, high scores on a measure of anger expression predicted incident stroke, and for men with a history of cardiovascular disease, high anger-expression scores were related to a six-fold increase in stroke risk (Everson et al., 1999). These findings show that hostile cognitions, as well as hostile behaviors, have an effect on health outcomes.

Socioeconomic Status Effects on Health as Mediated by Negative Emotions

The research presented above makes clear that SES is related to negative emotions, and that these emotions are related to negative health outcomes. A handful of researchers have attempted to put both of these pathways into the same model to formally test the mediation hypothesis (Cohen, Kaplan, & Salonen, 1999; Fiscella & Franks, 1997; Lynch et al., 1996; Ruberman, Weinblatt, Goldberg, & Chaudhary, 1984). For example, Cohen, Kaplan, and Salonen (1999) used data from Finland and the U.S. to investigate the extent to which negative psychosocial characteristics contributed to the association between SES and poor perceived health. In the U.S. sample, low SES (measured via income and educational attainment) was associated with high levels of stress, anger, negative life events, as well as low personal control, low social support, and poor perceived health. After stratifying the sample by educational level and controlling for the

psychosocial variables, the odds ratio (OR) for poor health was reduced from 5.0 to 3.6 for the 8th grade education or less group, from 2.6 to 2.2 for the high school degree or less group, and from 1.6 to 1.4 for the college educated group. Similar results were obtained when stratifying the sample by income, and all differences found were statistically significant. In the Finish sample, income and education were again related to negative psychosocial characteristics, which in turn predicted poor perceived health. When stratified by education, ORs were reduced from 4.4 to 2.5 for the less than elementary education group, from 3.4 to 2.3 for the less than junior high school group, and from 2.9 to 1.7 for the high school education and above group. Again, similar results were seen for income, and the observed attenuations in the ORs were significant.

In a study based on the Beta Blocker Heart Attack Trial (BHAT) psychosocial factors were examined to determine the extent to which they modified the association between SES and cardiovascular outcomes in men recovering from myocardial infarction (Ruberman et al., 1984). When entered simultaneously into the model, life stress and social isolation predicted mortality rates, effectively bringing the relationship between education and health to a non-significant level. Further, in a study of the effects of SES on cardiovascular and all-cause mortality, Lynch et al. (1996) found that simultaneous adjustment for depression, hopelessness, social support, marital status, and social participation reduced the risk associated with the lowest income group by 52% for all-cause mortality, and by 57% for cardiovascular mortality over the 4 to 10 year follow-up period.

These results provide evidence for the mediation model presented above. Taken together with studies that examine the individual pathways relating SES to negative

emotions and such emotions to poor health, one could conclude that a significant portion of the SES/health relationship is mediated by these psychosocial factors. Further, negative emotions can be viewed as a proxy for stress, as they are an emotional reaction to the psychological adaptation required to handle the challenges brought about by stressors. The theory is that low-SES individuals are exposed to significantly more stressors than others, and that continuous challenges alter low-SES individuals both psychologically and physically rendering them more vulnerable to health problems.

Psychosocial Resources

Research supports the idea that low-SES individuals are exposed to increased daily hassles, dangerous and unsanitary environments, a lack of health and economic resources, and a greater number of stress-inducing life events (Almeida, Neupert, Banks, & Serido, 2005; Antonovsky, 1967; Baum, Garofalo, & Yali, 1999; Brady & Matthews, 2002; Goodman, McEwen, Dolan, Schafer-Kalkhoff, & Adler, 2005; Lantz, House, Mero, & Williams, 2005; Lynch, Smith, Kaplan, & House, 2000; Ross CE & J., 2001). It is not simply the amount or frequency of stressful events, however, but the resources one can mobilize to meet the challenges associated with these events that determines whether stress rises to the level of a health threat. A model of stress that emerged at the end of the 1980s, the *conservation of resources model*, proposes that stress results directly from the threat of lost resources, actual lost resources, or failed resource investment (Hobfoll, 1989, 1998). Hobfoll's definition of resources includes tangible elements such as financial reserves, as well as social and personal assets such as social support. In this model, low-SES individuals are defined by their lack of tangible resources (see the measurement of SES section above), but evidence has also documented the relative lack

of psychosocial resources available to these individuals. The major psychosocial resources that have been investigated include social support, optimism, and personal control, and evidence supports the idea that distribution of these resources is determined in part by SES (Taylor & Seeman, 1999).

Personal Control

Personal control, or sense of "person mastery," is the extent to which individuals believe they are able to influence events in their lives. Researchers have shown a positive relationship between higher education and/or income and an increased sense of personal control, mastery, and self-efficacy (Cohen, Kaplan et al., 1999; Gecas, 1989; Levinson, 1981; Mirowsky & Ross, 1986; Pincus & Callahan, 1995). In contrast, low-SES has been associated with greater powerlessness and anomie (Blauner, 1964; Mirowsky & Ross, 1986), and studies of the effects of downward-mobility highlight the relationship between reduced employment status and loss of personal control and self-efficacy (Gecas, 1989; Perlin, 1981). In addition, several studies have shown a relationship between personal control and both psychological health (Rodin, 1985) and physical outcomes such as incidence of CHD, mortality, and self-rated health (Karasek, 1982; Rodin & Langer, 1977; M. Seeman & Lewis, 1995). Finally, there is evidence that the association between belief in personal control and health may be moderated by SES, with the observation that differences in health outcomes associated with control beliefs are significantly greater at the lower end of the SES-spectrum (Lachman & Weaver, 1999).

Optimism

The continuum from optimism to pessimism has been explored for its relationship with SES and health. Initial interest in optimism was fueled by a model of behavioral

self-regulation proposed by Carver and Scheier (1981), referred to as a dispositional resource for reducing discrepancies between goals and present behavior/situations. In a recent study from the University of Helsinki on childhood and adult SES and optimism/pessimism, current adulthood SES was associated with overall optimism and pessimism, and childhood family SES predicted overall pessimism scores, even after controlling for adult SES (Heinonen et al., 2006). Further, in an analysis of four U.S. datasets, Taylor and Seeman (1999) found a significant relationship between SES and pessimism, although optimism subscores on the LOT-R (a 10-item measure of the optimism/pessimism construct) were not related to SES. Optimism also has been found to be related to better health habits, faster and more complete medical recoveries, and greater psychological well-being (Park, Moore, Turner, & Adler, 1997; Scheier & Carver, 1992), whereas in a 35-year longitudinal study pessimism predicted both poorer health and reduced life-expectancy (Peterson, Seligman, & Vaillant, 1988).

Social Support

Social support has been the most well explored psychosocial resource in terms of health and SES, and refers to the number of friends and family members one has, and the amount of support these individuals are willing and/or capable of providing. Social support generally has been divided into two major categories: emotional support and instrumental (material) support (Taylor & Seeman, 1999). Studies performed in the U.K., U.S., and Sweden all have found that social support is positively related to SES, with lower-SES individuals having fewer friends and relatives on which they can depend to help them achieve their goals or cope with negative life circumstances (Belle, 1982; Campbell, 1986; Huang & Tausig, 1990; Matthews, Kelsey, Meilahn, Kuller, & Wing,

1989b; Mickelson & Kubzansky, 2003; Pinquart & Sorensen, 2000; White, 1997). Research also supports the idea that social support is associated with physical health (Berkman, Glass, Brissette, & Seeman, 2000; Cohen, 1988; House, Landis, & Umberson, 1988; T. E. Seeman, 1996; Uchino, 2004) and mortality (Berkman, Leo-Summers, & Horwitz, 1992; Brummett et al., 2001; Frasure-Smith et al., 2000; Kaplan et al., 1988; Rutledge et al., 2004). The presence of supportive friends and family members affects health in several ways. First, instrumental support comes from one's social network and provides resources such as increased health monitoring, information, provision of direct care, and financial support. In addition, stronger social networks are associated with more positive psychological processes including positive moods, appraisals, and feelings of control (Barrera, 2000; Cohen, 1988; Gore, 1981; Lin, 1986).

Reserve-Capacity Model

In an attempt to bring all of the psychosocial elements associated with SES into a single model, Gallo and Matthews (2003) proposed the *Reserve Capacity model*. Overall it is rather complex (see Figure 1), involving six domains and twelve pathways designed to account for the direct effects as well as the mediating/moderating influences and feedback between domains when relating reduced psychosocial resources associated with low-SES individuals to negative health outcomes.

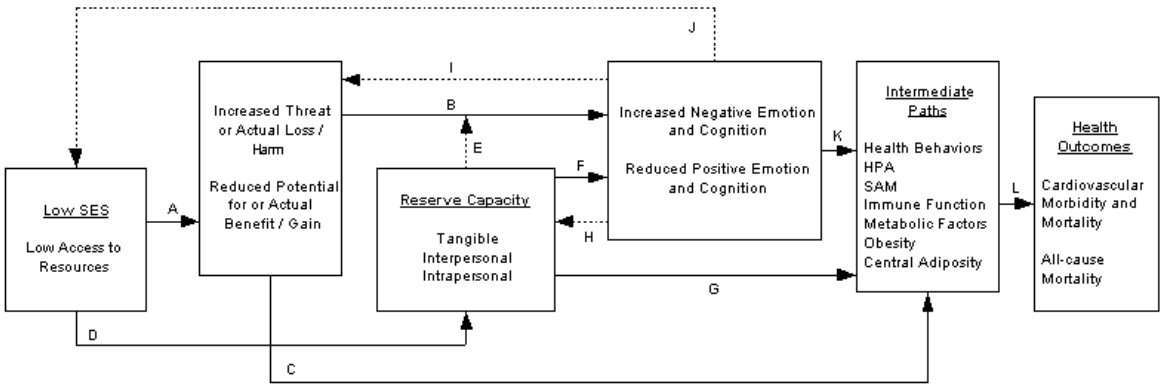

Figure 1. Reserve Capacity Model. From Understanding the association between socioeconomic status and physical health: Do negative emotions play a role? Gallo and Matthews (2003), Psychological Bulletin 129, p. 34.

The pathways in the model relate the lack of resources and increased negative life events associated with low-SES individuals and environments to the perception of increased threat of loss or harm and, conversely, to the reduced potential for benefit or gain (Arrow A). Evidence used to support this pathway includes studies showing that low-SES individuals encounter more frequent negative life events (B. S. Dohrenwend, 1973; Langer & Michael, 1963; McLeod & Kessler, 1990; Murrell & Norris, 1991; Myers, Lindenthal, & Pepper, 1974; Stansfeld, Head, & Marmot, 1998), and that such individuals interpret ambiguous events more negatively (Chen & Matthews, 2001; Flory, Matthews, & Owens, 1998; Matthews et al., 2000). The next pathway relates the increased perception of threat associated with SES-related stressors to negative cognitive and emotional experiences (Arrow B) (Alec, 1996; Ensel & Lin, 1991; Paykel, 1994; Stansfeld, North, White, & Marmot, 1995), which in turn are related to pathways affecting health outcomes (Arrows K and L) (McEwen & Stellar, 1993).

The key element of this model comes from studies revealing that at every level of stress, individuals with lower SES report more emotional distress than those with higher

SES, even after accounting for levels of prior stress exposure (Arrow E) (Brown & Harris, 1978; Kessler & Cleary, 1980; McLeod & Kessler, 1990; Turner & Noh, 1983). Overall, these studies have shown that stress reactivity varies by social class, with those on the low end of the SES-spectrum experiencing greater stress from the same stimuli compared to those on the higher end. To address the question of why this is the case, Gallo and Matthews (2003) proposed that low-SES individuals maintain a smaller bank of resources to contend with negative events than their higher-SES counterparts, and therefore have a deficient reserve capacity for handling stressors. The concept of *reserve capacity* emerged from the observation that resources tend to be present or absent in aggregate, suggesting a general protective influence or resource bank (Hobfoll, 1998, 2001; Rini, Dunkel-Schetter, Wadhwa, & Sandman, 1999; Turner, Lloyd, & Roszell, 1999). Gallo and Matthews proposed that low-SES individuals have a reduced capacity for handling stressful events because of the combination of increased exposure to situations requiring such protective influences (and thus draining them – Arrow D), and a reduced ability to develop and replenish such resources to keep in reserve. To support this view they referenced research showing that having few tangible or psychosocial resources exacerbated the effects of stressful events on health (Brown & Bifulco, 1990; Brown & Harris, 1978; Brown & Moran, 1997; Cohen & Wills, 1985; Hobfoll, 1989; Holahan & Moos, 1987, 1991), and once exposed to stress, individual resources deteriorate, rendering them more vulnerable to future negative events (Bolger, Foster, Vinokur, & Ng, 1996; Ensel & Lin, 1991; Holahan, Moos, Holahan, & Cronkite, 1999, 2000).

Within the model, the reserve capacity domain mediates the effect of stressors on both negative emotions and physiological responses to stress and health outcomes (Arrows F and G). Additionally, the negative emotions and cognitions associated with stress feed back to the reserve capacity domain, reducing both the tangible and intangible (emotional) resource reserve (Arrow H). Studies supporting this proposed pathway have shown that increased hostility and depression lead to reduced social support and greater social conflict (Barefoot et al., 1983; Houston & Kelly, 1989). Finally, the model proposes a pathway between cognitive/emotional states and the perception of threat via cognitive appraisal of external stimuli (Arrow I). Studies have shown that hostile individuals are more likely to interpret ambiguous stimuli in a threatening light (Chen & Matthews, 2001; Flory et al., 1998), and that depressed individuals may distort their perceptions to reinforce negative moods (Haaga, Dyck, & Ernst, 1991). Thus, the negative emotions and cognitions associated with stressful events could increase the level of threat perception, further reducing reserve capacity as even mild or non-threatening events then require resources for buffering their effect upon health.

With the reserve capacity model, Gallo and Matthews attempted to bring the diverse research relating low-SES to poor health outcomes into one integrative model. Their model only attempted to explain the psychosocial components of this relationship, but as such tied together the multitude of negative effects on both mental and physical health resulting from low-SES. Recently, an attempt was made to formally test the reserve capacity model (Gallo et al., 2005), using an ecological momentary assessment over a two-day period. Data were collected on a sample of 108 women in 40-50 minute intervals for all waking hours, and the psychosocial elements addressed within the model

were examined. Overall, results supported many of the pathways within the model, and provided evidence for the mediating effect of reserve capacity. Obviously research that addresses so many complex features of daily life is difficult to undertake, and future studies will need to further explore the various elements conceived within this model and their interrelations, before a final understanding of how these factors relate SES to health can be achieved.

Racial Factors and Discrimination

When examining the relationship between SES and health outcomes, potentially confounding issues such as ethnic group membership must be considered. For example, African Americans have been shown to have significantly higher rates of mortality for most of the 15 leading causes of death including heart disease, cancer, stroke, diabetes, hypertension, kidney disease, liver cirrhosis, and homicide (Kung, Hoyert, Xu, & Murphy, 2008). Further, many of these pathological factors linked to race continue to affect heath even when SES is controlled (Pamuk, Makuk, Heck, & Reuben, 1998). Several avenues have been explored to explain these findings including the stressful effects of perceived discrimination, genetic differences, increased risk-taking behavior, and differential access to societal goods and resources such as healthcare (Borrell, Kiefe, Williams, Diez-Roux, & Gordon-Larsen, 2006; Choi, Harachi, Gillmore, & Catalano, 2006; Ryan, Gee, & Laflamme, 2006; Smedley, Stith, & Nelson, 2003).

One of the most explored areas relating racial issues to health outcomes is perceived discrimination. Research has shown that the targets of discrimination are often aware of the behavior directed at them, and that perception of unfair treatment generates stress (R. Clark, N.B., Clark, & Williams, 1999). This discrimination-related stress is

thought to have negative health consequences. For example, data from the Metro Atlanta Heart Disease Study showed that perceived discrimination was only mildly related to hypertension unless the participants reported that it caused them significant stress, in which case there was a strong association (S. K. Davis, Liu, Quarells, Din-Dzietharn, & M.A.H.D.S.Group, 2005). An important component of the relationship between perceived discrimination and health may be the chronic stress associated with vigilance regarding anticipation of the occurrences of discrimination. Although somewhat difficult to investigate, approaches such as measurement of nocturnal blood pressure (Brondolo et al., 2008; Williams, Yu, Jackson, & Anderson, 1997) and self-report have been used, with racial-related vigilance shown to be related to physical outcomes such as arterial elasticity (R. Clark, 2006). Other factors considered include increased risk taking behavior in populations experiencing discrimination. Recent research has revealed that perceived discrimination is also associated with the use of substances including marijuana, inhalants, alcohol and cocaine in adolescent and young-adult samples (Borrell et al., 2006; Choi et al., 2006).

When considering the material risks associated with specific ethnic groups, factors such as segregation and access to/use of medical resources are often considered. Research has shown that residential segregation is linked to increased risk of illness and death (Acevedo-Garcia, Lochner, Osypuk, & Subramanian, 2003; Williams & Collins, 2001). Lack of access to healthy foods and healthcare-related services, physical concentration of economic hardship, concerns about personal safety, divestment of social resources from the government, weakened community structure, and increased environmental toxins have all been considered as possible causes for these findings

(Williams & Collins, 2001). In addition, recent studies have shown that there are large racial/ethnic differences in the quality and intensity of medical care for African Americans and other U.S. minority groups, who reportedly receive fewer medical procedures and overall poorer quality medical care than Caucasians (Smedley et al., 2003). This pattern appears to persist even when differences in health insurance, SES, disease severity, co-morbidities, and type of medical facility are taken into account.

Obviously ethnicity-based differences in health outcomes and issues of discrimination are highly complex, and not the primary focus of this review. These issues vary greatly by region, where the specific demographics and economics of the local population exert a profound effect on perception of discrimination and material factors such as housing and access to medical care. Further, racial issues and discrimination in particular are known to be related to SES, and have been shown to make an incremental contribution to SES when explaining health disparities (Williams & Neighbors, 2003).

Physiology Underlying the Link Between Socioeconomic Status and Reduced Health

In the previous section, we explored psychosocial factors that link negative emotions and lack of resources associated with low-SES to reduced ability to respond to various stressors and increased stress reactivity. Underlying the psychology of SES, however, are physiological systems that govern healthy functioning and that attempt to maintain homeostasis in the face of repeated challenges. Evidence for the negative health effects of long-term exposure to stress via living as a low-SES individual is robust, but a clear understanding of the underlying physiological mechanisms is still lacking. In the

upcoming section we review the evidence for the physiological processes underlying the link between SES-related stressors and negative health outcomes.

The Effect of Stress on Health

As discussed above, there is no scientific consensus regarding the definition of stress (Pacak & Palkovits, 2001). For the purposes of assessing the effects of stress on health outcomes, stress often is defined as an actual or perceived threat to homeostasis (Szanton, Gill, & Allen, 2005). The human body has a complex set of systems designed to adapt to challenges posed by external stressors such as hunger, perceived dangers, and infection (McEwen, 1998). These include the sympathetic nervous system, immune system, and the neuroendocrine system, especially the hypothalamic-pituitary-adrenal (HPA) axis (McEwen, 1998; McEwen & Seeman, 1999; McEwen & Stellar, 1993; Zhou, Kusnecov, Shurin, DePaoli, & Rabin, 1993). Included in the list of biological factors known to be responsive to stress are adrenalin, glucocoritcoids (especially cortisol), blood pressure, heart-rate, and components of the immune system such as the proinflammatory cytokines interlukin-1 and interlukin-6, natural-killer cells, lymphocytes (T-cells), fibrinogen, platelets, and C-reactive protein (Festa, D'Agostino Jr, Tracy, & Haffner, 2002; McEwen & Seeman, 1999; Owen & Steptoe, 2003; Segerstrom & Miller, 2004; Steptoe, Magid et al., 2003; Steptoe, Owen, Kunz-Ebrecht, & Mohamed-Ali, 2002).

In the short-term, these physiological responses are protective, and they act on systems throughout the body to prepare for fight or flight and increase natural (versus specific) immunity (McEwen, 2000; Segerstrom & Miller, 2004). For example, when exposed to a perceived threat, the body will immediately increase circulating levels of

glucocorticoids, which promote the conversion of protein and lipids to energy-providing carbohydrates. This essentially gives the body an immediate source of extra energy that could aid in escaping a dangerous situation, but also acts on the brain to increase locomotor activity and food-seeking behavior, thus modifying the energy-control systems (Leibowitz & Hoebel, 1997; McEwen, 2000).

When stressors become chronic or occur repeatedly over short time intervals, these adaptive changes can become damaging, leading to dysregulation of hormonal systems, increased stress-reactivity, and eventual tissue damage, especially in brain structures (McEwen, 1998; McEwen & Seeman, 1999). In the example above, if increased levels of glucocorticoids were maintained for an extended period of time, they might impede the action of insulin, and by extension glucose uptake (McEwen, 2000). The result of this interaction of reduced insulin function and increased glucocorticoids would be the promotion of adipose tissue formation, increased risk of diabetes, and the formation of atherosclerotic plaques that block coronary arteries leading to cardiovascular events (Brindley & Rolland, 1989).

Chronic, high levels of stress lead to hormonal changes, tissue damage, and reduced health outcomes. High levels of stress have been shown to be related to increased HPA axis activation (Kunz-Ebrecht, Kirschbaum, & Steptoe, 2004; Zhou et al., 1993), production of immune signaling hormones (Glaser et al., 1987), and risk of infection in controlled studies involving viral challenges (Cohen, Doyle, & Skoner, 1999; Cohen, Tyrrell, & Smith, 1991). In the past few decades many researchers have used this information to form the basis of a theory of how poverty "gets under the skin" to affect health (Lupien, King, Meaney, & McEwen, 2001). In this vein, several studies have been

conducted that relate low SES to indicators of increased physiological stress. Major markers addressed are cortisol (Cohen, Doyle, & Baum, 2006; Kunz-Ebrecht et al., 2004; Steptoe, Kunz-Ebrecht et al., 2003), catecholamines including epinephrine and norepinephrine (Cohen et al., 2006), C-reactive protein (Alley et al., 2005; McDade, Hawkley, & Cacioppo, 2006; Owen, Poulton, Hay, Mohamed-Ali, & Steptoe, 2003; Owen & Steptoe, 2003), and several markers from the immune system such as interlukin-1 and interlukin-6 (Steptoe et al., 2002), lymphocyte count (Owen et al., 2003; Owen & Steptoe, 2003), and platelet activation (Steptoe, Magid et al., 2003).

Most of the research relating SES to stress markers has focused on adult populations. Recently, researchers have included children and adolescents in an attempt to observe the developmental time-course of the physiological markers of stress. Studies of children raised in low-SES environments have found that as early as age 6, children show significantly higher levels of salivary cortisol than those raised in middle or high-SES environments (Lupien, King, Meaney, & McEwen, 2000; Lupien et al., 2001). In addition, in children afflicted with asthma, being raised in a low-SES environment was related to increased inflammatory immune markers leading to heightened disease processes (Chen et al., 2006). These findings are somewhat unexpected as the cumulative stress theory that underlies most of the modern SES-health literature relies on sufficient time and psychosocial insults to reach significant levels of physiological change. Children have less opportunity to accumulate negative events (stressors) due to limited time and life experiences, and therefore should not show such significant differences in their levels of stress markers. These findings may point to a critical period whereby the influence from the low-SES immediate environment has a profound effect on

physiological development, and such changes may be permanent. Some research supports this theory (Lupien et al., 2001), and in a study of 3,248 adults aged 32 to 47, childhood SES was related to significantly elevated C-reactive protein levels, even after controlling for adult circumstances and other potential confounds (Taylor, Lehman, Kiefe, & Seeman, 2006). More research is required to elucidate the specific environmental factors and developmental periods most critical to the observed physiological alterations in low-SES adults and children.

Stress Reactivity

Another important factor in the body's reaction to stress is the time it takes for a stressed individual to return to baseline conditions. This is referred to in the literature as *stress reactivity*, and involves the time-course associated with alterations in heart rate, blood pressure, HPA-axis activity and associated hormonal factors during and immediately following a stress challenge. Research has shown that low-SES individuals have significantly impaired stress reactivity as measured via heart rate variability (Cole, Blackstone, Pashkow, Snader, & Lauer, 1999; Lynch, Everson, Kaplan, & Salonen, 1998), blood pressure recovery (Steptoe & Marmot, 2006), and pro-inflammatory immune markers (Brydon, Edwards, Mohamed-Ali, & Steptoe, 2004; Cohen, Doyle et al., 1999; Maes, Song, & Lin, 1998; Steptoe & Marmot, 2006; Steptoe et al., 2002). Studies also have shown that SES interacts with specific genotypes such as serotonin transporter 5-HTT to affect serotonergic responsivity when individuals are exposed to direct neuroendocrine challenge (Manuck, Flory, Ferrell, & Muldoon, 2003).

Allostatic Load

Current understanding of the wide-ranging physiological effects of stress began in 1976 with the work of Hans Selye who proposed that stress-reacting "agents" had a "general effect on large portions of the body" (Selye, 1976). This orientation toward a general effect translated into the multisystem approach of subsequent researchers, leading Sterling and Eyer to propose the theory of allostatic load (Sterling & Eyer, 1981). Allostatic load is a concept derived from the term allostasis, which means maintaining stability (homeostasis) through change or adaptation. Adaptations are essential for the body to handle challenges, and healthy functioning requires ongoing adjustments by physiological systems such as the sympathetic nervous system, neuroendocrine system, and HPA-axis. Allostatic load refers to the price the body pays for making these adjustments, and represents the "wear and tear" associated with physiologically responding to repeated challenges (McEwen, 2000).

The concept of allostatic load was further developed by Bruce McEwen, who outlined the primary mediators (cortisol, adrenalin, noradrenalin, and dihydroepiandrosterone) that then affect secondary processes (systolic and diastolic blood pressure, serum high-density lipids, and glycosylated hemoglobin levels in blood plasma), leading to disease processes (McEwen, 2000). In general, the theory proposes that when the body responds to challenges, there are short-term changes that are protective and adaptive, but there are also long-term effects that can damage the body's systems. For example, within the cardiovascular system, catecholamines will adjust heart rate and blood pressure to adapt to the demands of physical exertion. Repeated surges in blood pressure or failure to return to baseline conditions will accelerate atherosclerosis

and interact with metabolic hormones leading to Type II diabetes (McEwen, 1998; Sterling & Eyer, 1988). Similarly, in the metabolic system, adrenal steroids promote allostasis in the face of challenges by enhancing food-intake and facilitating energy production and reserves, but overactivity of this system leads to insulin resistance, abdominal obesity, atherosclerosis, and hypertension (Brindley & Rolland, 1989).

The immune system and brain also are subject to potentially damaging effects when unable to quickly return to homeostasis. When high levels of HPA-axis activity operate in conjunction with an excess of excitatory amino acid neurotransmitters, allostatic load occurs and reduced neuronal excitability, neuronal atrophy, and cell-death (especially within the hippocampus) can occur (McEwen, 1997, 1999b). In the immune system as well, short-term activation upregulates many aspects of natural immunity by promoting trafficking of general immune cells (e.g., macrophages, natural killer cells) and related hormonal changes (cytokines, chemokines), while chronic activation leads to suppression of both cellular and humoral systems and decreased activity in both the natural and specific immune systems (McEwen et al., 1997; Segerstrom & Miller, 2004; Sternberg, 1997).

McEwen proposed four types of situations that may lead to allostatic load (McEwen, 1998, 2000; McEwen & Seeman, 1999). The first is high frequency of stressful events that require nearly continuous adaptation (allostasis). This situation is likely to occur when people live in highly stressful environments and is a probable mechanism for the relationship between low-SES and negative health outcomes. The second is a failure to habituate quickly to stressors (especially repeated stressors) resulting in a lag between challenge-related allostasis and return to baseline. A more

extreme version of the failure to habituate results is the third situation, in which the body undergoes a prolonged stress response and delayed shutdown of upregulated systems. The fourth allostatic load situation described by McEwen occurs when the hormonal stress response is inadequate or muted, resulting in excessive activity of other allostatic systems such as the inflammatory cytokines, which are normally controlled by elevated levels of cortisol and catecholamines. Although work in this area is ongoing, it is likely that prolonged exposure to the first type of allostatic load described (repeated insults) leads to reduced adaptability, resulting in one or more of the remaining three types of allostatic load situations described above.

Recent research has examined the relationship between SES and allostatic load. Seeman (2004) examined 1,189 initially healthy older men and women, and found that increased allostatic load accounted for 35% of the observed difference in mortality risk between high and low-SES individuals. Additionally, studies conducted in the U.S. and Taiwan found that low-SES predicted higher allostatic load (Kubzansky, Kawachi, & Sparrow, 1999; Singer & Ryff, 1999; Weinstein, Goldman, Hedley, Yu-Hsuan, & Seeman, 2003). Because both high-frequency physiological stress responses and inappropriate stress reactivity (both heightened and muted) are known to cause cardiovascular and other health-related problems, allostatic load appears to be a significant factor contributing to the observed relationship between SES and health. In many ways, this theory is the physiological equivalent of the reserve capacity model, where the combination of repeated exposure to stress and lack of coping resources interact to create an overtaxed physiology and reduced overall health.

Social Hierarchy

A component of SES not yet addressed in this review is the direct influence that social hierarchy has on stress, health, and immune function. The primary evidence for this association comes from the work of Sapolsky (1995) in his studies of free-ranging baboon populations in the Serengeti. Using an intimate knowledge of the life circumstances of individual baboons obtained through observation, he defined two major factors that led to variations in basal cortisol levels in the wild. The first of these factors was *rank*, in which higher social rank correlated with lower cortisol levels. The second factor was *social stability*, in which higher-ranking individuals showed increased cortisol levels when forced to defend their positions, and lower-ranking ones showed increased levels when held to their position by aggression or violence. Upon further observation Sapolsky also found that during times of social instability (e.g., with the introduction of a dominant male and an ensuing power struggle), lower-ranking baboons sometimes demonstrated reduced levels of cortisol similar to the higher-ranking individuals, as well as increased distraction and reduced focus on keeping lower-ranking members subordinate. Finally, Sapolsky observed that individual personalities and coping styles were also contributors to cortisol level, with baboons who could separate serious threats from transient ones showing healthier profiles.

When Sapolsky expanded his investigation to include other species that express social hierarchies (e.g., mongooses, African wild dogs, ring-tailed lemurs, and chimpanzees), he determined that the above-mentioned factors played a significant role in various non-human societies. Although direct evidence for the influence of position in the social hierarchy has not yet been obtained in human populations, ample research supports

the idea that SES is related to stress hormones in humans (see above). Further, experimental evidence has indicated that chronic social stress leads to reduced immune function and neuronal remolding in the hippocampus of non-human primates (Blanchard, McKittrick, & Blanchard, 2001; Cohen et al., 1997; McKittrick et al., 2000).

It is likely that similar mechanisms exist within human populations, as many elements of primate society are present in modern culture. Although human hierarchies are more complex and culturally-moderated than those of lower species, the profound evidence supporting the relationship between SES and health points to an important influence from the social hierarchy. As Sapolsky and others have observed, the disease consequences of being poor are often rooted in the psychosocial consequences of being made to feel poor by one's possessions and surroundings, and by comparison to the possessions and surroundings of (wealthier) others (Mackenbach, 2002; Sapolsky, 2005).

Posttraumatic Stress Disorder

Building on the physiological evidence for the effects of stress detailed above, researchers have employed neuroimaging techniques to observe structural and functional brain alterations. Recently, direct evidence for the damaging effects of stress on neural circuitry has been acquired using individuals diagnosed with Posttraumatic Stress Disorder (PTSD) (Bremner, 2003; Bremner et al., 1995; Liberzon et al., 1999; Rauch et al., 2003). PTSD is a psychiatric disorder that results from severe psychological trauma, and often occurs in war veterans and adults who suffered sexual abuse as children. As described by the DSM-IV-TR (American Psychiatric Association, 2000), PTSD is characterized by intense psychological distress and corresponding physiologic reactivity upon exposure to internal or external cues that symbolize or resemble an aspect of the

traumatic event. Symptoms of PTSD include intrusive memories, recurrent dreams, and flashbacks of the trigger event (American Psychiatric Association, 2000), and as such suggest abnormalities in the processing of emotionally-charged memories (Liberzon et al., 1999). In fact, altered information processing has been shown to be associated with PTSD, and imaging studies have shown differential functional neuroanatomical activity in diagnosed versus normal individuals (Bremner et al., 1999; Bremner et al., 2003; Bryant et al., 2008; C. R. Clark et al., 2003; Matsuo et al., 2003).

Evidence for structural changes in the brains of individuals diagnosed with PTSD was first discovered through the use of magnetic resonance imaging (MRI). Bremner et al. (1995) conducted a study comparing 26 Vietnam combat veterans diagnosed with PTSD with 22 matched controls. The experimental participants met criteria for PTSD on the basis of the Structured Clinical Interview for DSM-III-R (SCID), had a score of more than 107 (consistent with the diagnosis of PTSD) on the Mississippi Scale for Combat-Related Posttraumatic Stress Disorder, and were judged by consensus diagnosis of psychiatrists to meet criteria (Keane, J.M., & Taylor, 1988; Spitzer, Williams, & Gibbon, 1987). Also, exposure to combat was confirmed by official military records of service in Vietnam. Results showed a statistically significant 8% reduction in the right hippocampal volume of PTSD patients and associated deficits in short-term verbal memory as measured with the Wechsler Memory Scale (Iverson, Franzen, Demarest, & Hammond, 1993).

Since this landmark study, several other researchers using different populations and imaging techniques have explored physiological changes in individuals exposed to trauma carrying a diagnosis of PTSD. Studies mapping regional cerebral blood flow

(rCBF) using positron emission tomography (PET) also have found alterations in patients diagnosed with PTSD (Bremner et al., 1999; Liberzon et al., 1999; Shin et al., 1997; Shin et al., 1999). In a study of 14 Vietnam veterans diagnosed with PTSD, rCBF was significantly elevated in the left amygdala and the nucleus accumbens when participants were exposed to combat sounds as compared to 11 veteran controls (Liberzon et al., 1999). Other PET studies involving Vietnam veterans found increased rCBF in the ventral anterior cingulate gyrus and right amygdala, as well as in the posterior cingulate, precentral and inferior parietal cortices, and reduced rCBF in the medial prefrontal cortex and Broca's area (Bremner et al., 1999; Shin et al., 1997). In another study involving women with PTSD who were sexually abused in adolescence, recall of the abuse was related to increased rCBF in the orbitofrontal cortex and anterior temporal poles, and deceased rCBF was observed in the left inferior frontal gyrus and anterior cingulate (Shin et al., 1999) .

Overall, findings have been somewhat equivocal (Jelicic & Merckelbach, 2004). For example, in a twin study of combat veterans, no significant differences in hippocampal volumes were seen between monozygotic twin pairs with and without PTSD, and the authors concluded that smaller hippocampal volume was a premorbid risk factor for the development of PTSD rather than a consequence (Gilbertson et al., 2002). Given the limitations of studies exploring volumetric differences in PTSD and trauma-exposed individuals including small sample sizes and sample heterogeneity (Jelicic & Merckelbach, 2004), meta-analytic techniques have been employed to gain a more in-depth understanding of the relationship. Two meta-analyses performed in 2005 found evidence for bilateral hippocampal volume reduction in PTSD patients versus normal

controls (approximately 7.2% and 7.0% for left and right hippocampi, respectively), and to a lesser extent, bilateral hippocampal volumetric reduction in comparison to trauma exposed individuals (approximately 4.3% and 4.5% for left and right hippocampi, respectively) (Kitayama, Vaccarino, Kutner, Weiss, & Bremner, 2005; M. E. Smith, 2005). A third meta analysis conducted the following year also concluded that significantly smaller hippocampal volumes were present in patients with PTSD compared to controls with and without trauma exposure, and that significantly smaller anterior cingulate cortex volumes were observed in PTSD patients when compared with trauma-exposed controls (Karl et al., 2006).

The hippocampus is a component of the limbic region of the brain, and is known to be associated with memory and emotion functions. Other limbic structures include the amygdala, hypothalamus, thalamus, and the nearby "paralimbic" cortex, which includes the anterior cingulate, orbitofrontal cortex, insula, and the temporal poles (Mesulam, 1985; Nauta, 1982). Extensive animal research has shown that the limbic regions of the brain, especially the amygdala, play a central role in fear conditioning (Cahill, Weinberger, Roozendaal, & McGraugh, 1999; M. Davis, 1997; Kapp, Whalen, Supple, & Pascoe, 1992). Further, in human fMRI studies, ratings of emotional intensity to visual stimuli were significantly correlated with amygdala activation (Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). Studies have examined these areas as well in association with PTSD. Overall the findings indicate that observable physical alterations in the brain accompany PTSD, and that these changes involve direct physical damage to portions of the limbic region and modification of activity in supporting structures. Although there is variability between the specific study findings (likely due to varying procedures and

small sample sizes), PTSD activation paradigms tend to produce predictable changes in brain structures responsible for imbuing emotional content to stimuli, and show autonomic and neurohumoral changes consistent with the stress response (Vermetten & Bremner, 2002), which are known to also be elevated in highly stressed individuals without PTSD. The damage observed in PTSD patients is generally attributed to the neurotoxicity associated with extremely high levels of glucocorticoids (Sapolsky, 2002) which are known to also be elevated in highly stressed individuals without PTSD.

Although the current state of understanding precludes drawing conclusions about the direct effects of stress on structural and functional brain changes, available evidence suggests that neurological alterations associated with chronic stress are likely. The physiological differences between the intense episodic stress seen in PTSD sufferers and the chronic stress associated with low-SES have yet to be systematically examined, but it seems plausible that similar changes in the brain would be the result, although with a differing time course. Evidence presented in this section regarding dysregulation of stress-related systems associated with allostatic load and accompanying changes in hormonal and immune systems, imparts a physiological framework for long-term structural damage that could result from chronic stress. In conjunction with evidence from the previous section of increased depression, hostility, anxiety, and an increased likelihood to perceive situations as threatening, evidence of changes in the limbic structures of the brain are implied. What is currently lacking is a study that directly investigates whether PTSD-like changes in the brain are observed in low-SES versus middle or upper-class individuals.

Neuroimaging of Psychological Stress

Investigations of the physiological and neurological effects of stress have been on-going (see review above). Recently, neuroimaging techniques have provided a means of directly observing the effects of psychological stress on neural activations. A variety of techniques have been developed to induce stress under laboratory conditions including script-driven stimuli, color-word and emotional stroop tasks, simulated public speaking, serial subtraction and related tasks, and presentation of emotionally-laden visual imagery (Dedovic, D'Aguiar, & Pruessner, 2009). Each of these techniques is associated with strengths and weaknesses, and have been associated with a variety of outcomes – albeit with some similarities.

Until recently, pharmacobehavioral studies performed on humans and animals were the primary way to investigate physiological and neurological processes involved in stress (Brody, Preut, Schommer, & Schürmeyer, 2002; Fries, Hellhammer, & Hellhammer, 2006; Herman, Figueiredo, & Mueller, 2003; Herman, Ostrander, Mueller, & Figueiredo, 2005; Soderpalm, Nikolayev, & de Wit, 2003). These studies induced stress by chemical means, and then examined the resulting physiological effects. With the development of neuroimaging techniques such as PET and fMRI, noninvasive, real-time imaging of psychologically-induced stress became possible. These methods are significantly more desirable to researchers than those employed in the pharmacological challenge studies, which were artificial in nature and not representative of the normal human stress experience.

Script-driven stimuli experiments are one way to induce psychological stress. Such paradigms are generally tailored to the experiences of the individual subject, and

designed to elicit negative effective processing by either recalling traumatic experiences (common in PTSD studies), or by evoking emotional memory processing using self-reported stressful experiences (Britton, Phan, Taylor, Fig, & Liberzon, 2005; Dedovic et al., 2009; Hopper, Frewen, van der Kolk, & Lanius, 2007; Lanius et al., 2007; Lindauer et al., 2006). For example, working with a small group of subjects, Sinha et al. developed three personalized stress-inducing scripts and three neutral scripts on a per-subject basis, and presented them during an fMRI session (Sinha, Lacadie, Skudlarski, & Wexler, 2004). Results indicated significant activation of the medial prefrontal, anterior cingulate, caudate, putamen, thalamus, hippocampus, parahippocampal gyrus, and posterior cingulate regions during emotional distress relative to neutral-relaxing imagery.

Another way to induce psychological stress is through the stroop color-word interference task and emotional stroop tasks. In the classic stroop color-word interference task, subjects identify the color of a target word, which is either congruent or incongruent with the color that word names (e.g., the word "blue" written in red text is as an example of the incongruent condition). More recently, other interference tasks based on the original stroop have been developed, including the emotional stroop task. In this task, non-color words are presented that are either neutral or emotionally charged. Subjects name the color in which the word is written (essentially ignoring the word itself), and delayed reaction times result from words with greater emotional valence, hypothesized to be the result of a diversion of attention (i.e., interference) (McNally, Amir, & Lipke, 1996). One study used time pressure in the incongruent condition of the stroop color-word interference task to induce stress during an fMRI session. Results from 20 participants showed increased activation in the dorsolateral prefrontal cortex, basal

ganglia, thalamus, and cerebellum when the stress-inducing incongruent condition was compared to the congruent, control condition (Gianaros et al., 2005). The emotional stroop task has also been used to induce stress in neuroimaging studies. For example, in a study of Vietnam veterans with and without PTSD, combat-related, (general) negative-valenced and neutral words were used in an emotional stroop task presented during an fMRI session. Results showed that in the combat versus general negative comparison, the non-PTSD group exhibited significant fMRI blood oxygenation level-dependent signal increases in the rostral anterior cingulate cortex, but the PTSD group did not show such differences (Shin et al., 2001).

Another method for inducing psychological stress is through public speaking. One of the most established tasks to induce stress in this manner is the Trier Social Stress Test (TSST) (Kajantie & Phillips, 2006; Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004), which involves a 5-minute public speaking paradigm. Variations on this technique have been used to investigate social phobia. In two studies, PET scans were used to investigate neural activation when subjects were forced to speak about a vacation in front of a 6- to 8-member audience compared to a no-audience control condition (Tillfors et al., 2001; Tillfors, Furmark, Marteinsdottir, & Fredrikson, 2002). Results showed increased cerebral blood flow in the right amygdala and hippocampus of social phobics compared to normal individuals (Tillfors et al., 2001). In addition, anticipation of impending public speaking also induced changes in this group (due to the anticipatory stress response) in the right dorsolateral prefrontal cortex, left inferior temporal cortices, and left amygdala-hippocampus region (Tillfors et al., 2002).

Repetitive arithmetic tasks have also been used in neuroimaging studies to induce stress. For example, serial subtraction of 7s from a 4-digit number was used in a PET study to examine stress in healthy adult men (Ito, Kanno, Hatazawa, & Miura, 2003). Participants were pressured to perform the task as quickly and accurately as possible, and increased cerebral blood flow was observed in the right insular cortex, right superior temporal gyrus, bilateral inferior frontal gyrus, precentral gyrus, putamen, cerebellum, thalamus, and anterior cingulate cortex. In a similar study, researchers used perfusion fMRI to investigate psychologically-induced stress in 23 adults (Wang et al., 2005). Participants conducted serial subtraction of 13s from a 4-digit number while being prompted for faster performance and being required to restart if an error occurred. In this study, a positive correlation was observed between cerebral blood flow and perceived stress in the right ventral prefrontal cortex, amygdala, hippocampus, and right superior temporal regions, as well as the left insula-putamen.

Another arithmetic task used to induce stress in neuroimaging studies is the Montreal Imaging Stress Task (MIST). The MIST is composed of a series of computerized mental arithmetic tasks with an induced failure mechanism designed to produce equations slightly more difficult than the subject is capable of solving while providing continuous feedback (Dedovic et al., 2005). One study used the MIST to investigate brain activation changes associated with stress in a combined PET/fMRI study (Pruessner et al., 2008). Ten male subjects were scanned using PET methods, and 40 male and female subjects were scanned using fMRI techniques while performing the MIST. Results showed a significant deactivation of the limbic system and hippocampus

in subjects who demonstrated a significant stress response, and the level of deactivation in the hippocampus correlated with cortisol level changes.

Finally, standardized imagery has been used to induce psychological stress in neuroimaging research. This emotional imagery is generally divided into two categories: images with facial expressions and images without facial expressions. Research has shown that neural activations elicited by images differ when emotional faces versus non-face-based images are employed (Britton & Taylor, 2006; Hariri, Mattay, Tessitore, Frea, & Weinberger, 2003; Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). In terms non-facial stimuli, the most commonly used stimuli are derived from the International Affective Picture System (IAPS), a large set of standardized color photographs developed specifically for investigations of emotion and attention, which covers a range of semantic categories and content areas. The IAPS have been used in numerous studies of emotion. For example, one study used IAPS images in an fMRI session and then obtained post-scan ratings of valence and intensity for each image (Grimm et al., 2006). Results showed that valence correlated with the functional response in the ventromedial prefrontal and dorsolateral prefrontal cortices, and that image intensity correlated with ventrolateral prefrontal and dorsomedial prefrontal cortices. Further, IAPS stimuli were used in a study designed to distinguish emotional expectancy from emotional perception (Bermphol et al., 2006). Results indicated that emotional expectancy produced activation in the supracallosal anterior cingulate, cingulate motor area, and parieto-occipital sulcus, whereas emotional picture perception was related to activation in the amygdala, insula, medial and lateral prefrontal cortex, cerebellum, and occipitotemporal areas.

Each technique for inducing psychological stress has certain strengths and weaknesses associated with it. Script-driven stimuli have the advantage of being person-specific, and therefore are more likely to induce significant stress if properly prepared. Unfortunately, the development of such stimuli is very labor intensive, and the resulting stimuli have questionable reliability. Further, there is no way to guarantee consistency of stimuli across subjects – both the memory and perception of highly stressful experiences varies from individual-to-individual (and day-to-day), making these studies almost impossible to replicate.

The stroop color-word task uses standardized and well-validated stimuli and therefore avoids the complexities associated with script-driven stimuli. The stroop was initially designed to measure cognitive interference, however, and its use for inducing psychological stress represents a re-tasking of the instrument. It is unclear whether the stroop color-word task actually serves as a significant stressor as the task is not particularly difficult and bears little relationship to real-world tasks. As for the more recently developed emotional stroop, although it too provides consistent, well-controlled stimuli, it is not possible to ensure that the emotional words chosen will be equally stressful across subjects.

The TSST and other tasks involving speaking before an audience represent another paradigm for inducing psychological stress. Although this type of task appears to generate stress reliably in test subjects, there are several downsides to its use. First, whereas speaking before an audience is extremely stressful for shy individuals or someone diagnosed with social phobia, it may be minimally stressful for individuals skilled at public speaking (like politicians or teachers). Also, the choice of topic greatly

affects the level of stress induced by this type of task, and is variable across subjects (according to individual comfort level with the chosen topic). Finally, the requirement to speak for an extended period (and need for an audience) places constraints on the application of these tasks in fMRI and other scanning environments.

Like the stroop tasks, arithmetic-based stress-induction paradigms have the advantage of being highly structured and reproducible. Unfortunately, the level of stress induced by these tasks is questionable. Performing simple mathematical problems does not constitute a stressful task for most individuals, and other steps need to be taken (such as external psychological pressure from the experimenter) to ensure that the task is perceived as stressful. Such additional measures can be difficult to provide in a highly controlled manner, as they will tend to vary according to individual performance on the task. Further, the amount of stress provided by these tasks is dependent in part on the level of mathematic ability of the test subject, and therefore is confounded with educational attainment. Finally, responses to many arithmetic-based stress-inducing tasks must be provided verbally, which can lead to movement artifacts during scanning procedures.

The presentation of highly-valenced images is another commonly used way to induce both stress and emotion. Use of image banks such as the IAPS has the advantage of providing standardized stimuli to all participants in a neuroimaging study. These stimuli require only passive viewing, and should appear the same to all participants if they are presented in a standardized fashion to individuals with normal vision. The downside of such stimuli is that they are highly complex, and their potential to induce stress may depend on the prior life experiences of individual test subjects. Previous

exposure to scenes like those selected for a given study will affect an individual's reaction to the stimuli as will individual preference. Therefore it is difficult to ensure that the stimuli have the same "meaning" to all test subjects, and the expected stress response will vary across subjects.

To date, no paradigm has been developed that overcomes all of the problematic issues and reliably induces psychological stress in participants. Thus, researchers seeking to investigate the neuronal response to stress should develop or utilize tasks tailored to their specific goals and study participants. Also, when attempting to interpret findings from stress-induction experiments, an understanding of the stress-generating task is essential if one is to arrive at a clear understanding of the meaning of the obtained results.

Proposed Research: An fMRI Study of Limbic Structures and Associated Function in Low-SES Subjects

In this study we addressed the question of how SES is related to changes in functional neural activity. We presented emotionally-provocative images to a sample of adults raised and currently living in low-SES environments and compared their neural activations to those of a sample of middle-class individuals presented with the same stimuli. Using fMRI techniques, we examined functional differences using a block-design methodology similar to that employed in the PTSD studies discussed above. We presented both subject groups with emotionally-provocative visual stimuli designed to elicit strong emotions, drawn from the IAPS standardized image bank. The conditions explored included negative images, positive images, and a set of neutral comparison images. In addition, we prepared and presented a validated set of poverty images.

Our primary goal was to use IAPS to examine the relationship between SES and the image-induced neural response to elucidate a primary mechanism underlying the relationship between SES and health. Specifically, we sought to map differential activation of emotional-processing and higher cognitive neural regions by SES condition. We hypothesized that regions associated with visual processing (primary visual cortex, fusiform gyrus), emotional processing (limbic regions), and transductive circuits (e.g., insula, locus cerulei) would show differential activations between SES groups (Canli et al., 2000; Mesulam, 1985; Nauta, 1982; Shin et al., 1999). We determined these regions of interest (ROIs) based on previous research regarding neural responses to emotional and stressful stimuli. Unfortunately we are aware of no previous research investigating SES-based differences in neural activations, making this work highly exploratory.

If the limbic structures of low-SES individuals showed signs of differential processing of highly-valenced stimuli, then we would have initial evidence of the underlying relationship between SES and health outcomes (i.e., differential processing of emotional stimuli by SES group). Although we were unable to add physiologic measures of stress transduction such as galvanic skin response (GSR) or measures of the hormone cortisol to this study, finding differences in the processing of emotional stimuli would provide evidence of the initial step in the chain of events linking perception with altered physiology, and (indirectly) health outcomes. It is important to note that even if we achieve these findings, many questions will remain regarding the etiology of the observed differences, and longitudinal studies will be required to examine economic circumstances and life-events, as well as their impact on brain architecture.

In addition, we attempted to elicit self-appraisal of social position using a set of validated images of poverty. These images represent some of the worst elements of living in impoverished conditions (i.e., homelessness, squalor, crime), and we hoped they would invoke a self-reflective response from our low-SES participants. Although portions of this image set overlapped with the more generic validated IAPS negative images in theme, their specific focus and block-design presentation made clear that they represented negative elements associated with low-income environments. As the results presented below will reveal, these images evoked a large and differential response between SES groups, which represents a first attempt to explore how self-perception of social status influences neural responses.

Methods

Subject Recruitment and Characterization

We recruited and scanned 23 male and female African-American participants over the course of approximately one year. The primary criteria for inclusion were as follows: right-handedness, African-American descent, current age between 20 and 30, and appropriate classification into either our low or high SES groups. Participants were excluded if they had any significant prior head injury or a diagnosis of mental illness, as determined by a structured telephone screener.

Prospective participants were recruited using flyers approved by the Institutional Review Boards of the Mount Sinai School of Medicine and Brooklyn College of the City University of New York. The flyer specified the entry criteria and the compensation that would be provided for participation ($150). Flyers were distributed primarily in East Harlem and the Upper East Side areas of Manhattan. Flyers were placed in public areas adjacent to housing projects (targeting low-SES subjects), and on street-accessible public areas (e.g., light posts, phone booths) on the Upper East Side (targeting high-SES subjects). It should be noted that flyers were not placed in churches or community centers, as people who participate in religious or community activities tend to have greater social networks and, correspondingly, more available social support that could potentially influence the study's results (van Olphen et al., 2003). Copies of the flyers for both the high-SES and low-SES subjects are provided in Appendix A.

SES classification was determined using the flow chart presented in Figure 2. When selecting the sample, we sought to ensure that a participant's SES was consistent across his or her life span, and prospective subjects were asked about family income and

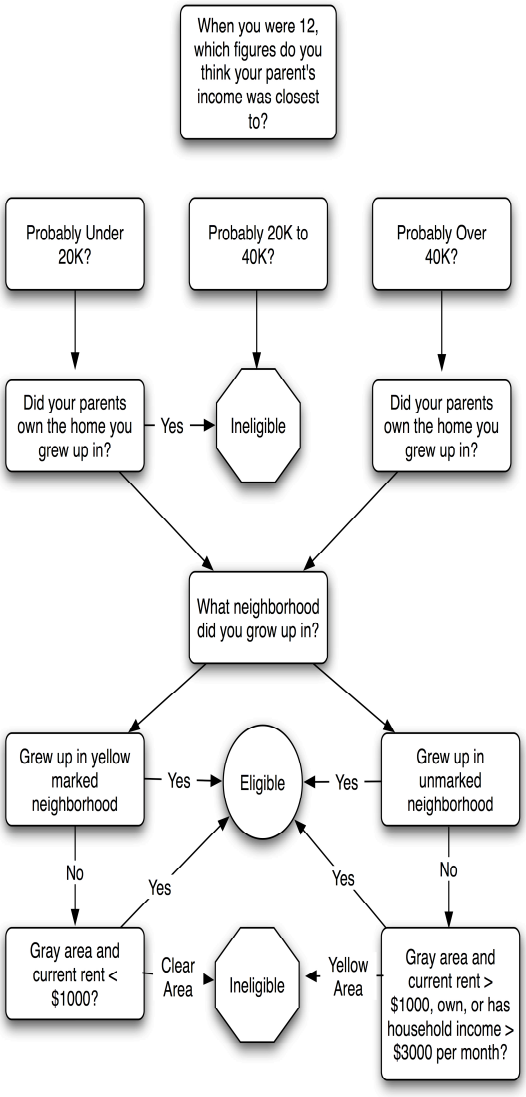

Figure 2. Classification Schema for SES Group

parental home ownership during childhood. The rationale for this includes evidence that childhood SES can influence adult health and perception of social status, which potentially could impact our findings especially considering our modest sample size (Pensola & Martikainen, 2003).

Childhood SES was determined by three factors: estimated family income at age 12, neighborhood in which the participant was raised, and family ownership of childhood home. Although children cannot be expected to report family income accurately, we asked prospective adult participants to estimate their family income as a means of placing them into a general SES category. Three categories were defined; less than $20,000, $20,000 - $40,000, and greater than $40,000 annual. Participants who reported estimated family income at age 12 to be less than $20,000 were considered eligible for classification into the low-SES group, and those who estimated family income as greater than $40,000 were eligible for classification into the high-SES group.

We then inquired about the neighborhood in which the participant was self-reported to have been raised. New York City neighborhoods were trichotomized into the

upper, middle, and lower third of recorded family income using the 2000 Census data (U.S. Census Bureau, 2000). To qualify for classification into the low-SES group, participants had to come from a neighborhood that was classified as belonging to the lower third of family income for New York City, with the additional criteria that their families did not own the home or apartment in which they were raised (Power & Matthews, 1998). In order to qualify for the high-SES group, participants needed to be raised in a neighborhood belonging to the upper third of family incomes, while childhood family home/apartment ownership was optional. Appendix B provides the neighborhood listing and classification package along with the screening information.

In order to determine adult SES category, the criterion of current rent was used. Current rent was employed as opposed to current income, as many potential participants of the appropriate age range were students, making actual income misleading (i.e., high-SES participants may have markedly lower incomes during this phase of their lives). Within urban areas, rent is highly correlated with SES, and many landlords use a simple rule-of-thumb calculation to determine the solvency of prospective tenants, a formula which we also followed -- a minimum of 40 times the monthly rent as annual income or a co-signer (generally a parent) who can guarantee that amount (Acitelli, 2007). This means that someone paying $1,000 in rent per month either has an annual income above $40,000, or a co-signer who can reliably guarantee such an amount. In order to ensure that high-SES participants with inexpensive rents were not excluded from the sample (possibly due to rent-stabilized, or rent-controlled apartments), we included a final criterion of monthly income of at least $3,000 as proof of high-status.

Classification into the low-SES category requires the following: estimated family income at age 12 less than $20,000, parents did not own the home in which they were raised, childhood neighborhood in the lower third of households at the time of the 2000 census, and current rent less than $1,000 per month. Similarly, to be classified into the high-SES group participants had to estimate their family income at age 12 as greater than $40,000, the neighborhood in which they were raised had to be in the top third of households at the time of the 2000 census, and their current rent must have been greater than $1,000 per month (or current income of at least $3,000 per month).

Upon contacting the study group, prospective participants were screened for history of mental illness, ability to abstain from illicit substance use, significant cigarette use, prior head injury, and appropriateness for entry into an MRI scanner (e.g., lack of metal in the body). As shown in Figure 3, we utilized a structured telephone screen administered by a trained research assistant.

History of mental illness was determined by asking if the prospective participant had ever been diagnosed with depression or other mental illness. Mental illnesses such as depression and schizophrenia have been shown to exert a significant influence on neural activations (Fitzgerald, Laird, Maller, & Daskalakis, 2008; Gross & Huber, 2008; Gur et al., 2007; Keller et al., 2008). The study designers felt that this single screener question was a simple and efficient way to eliminate potentially confounding subjects.

With regard to drug use, we attempted to screen out individuals with clinical levels of substance abuse or dependence by requiring an abstinence period of 10 days prior to entry into the scanner. Participants who passed the screening underwent a toxicology screen on the day of the scan to ensure that no participant was intoxicated

immediately prior to or during the study. Although the study designers felt it was necessary to ensure sobriety before scanning, complete abstinence from substance use within the population of interest was deemed unrealistic; therefore no attempt was made to ensure that participants had a "clean" history. Cigarette smoking may also influence neural activity in fMRI studies (Dager & Friedman, 2000; Lawrence, Ross, & Stein, 2002). Although it may have been desirable to exclude participants who reported any cigarette use, complete abstinence was deemed too restrictive a requirement for our target population. As such, our screener inquired whether prospective participants smoked greater than 5 cigarettes a day, a common classification to separate casual smokers from regular smokers (Brook, Duan, Brook, & Ning, 2007; Kawachi, Colditz, Stampfer et al., 1994); those who reported such use were eliminated.

Prior head injury was also assessed as significant head injuries have been shown to alter MRI results (Perlstein et al., 2004). Head injuries that result in extended periods of unconsciousness are generally considered serious, and our primary screener question defined a period of unconsciousness of 30 seconds or greater as an exclusion criteria. In addition, prospective participants who suffer from seizures were excluded as seizure disorders are associated with altered brain activity (Berl et al., 2005).

Potential participants were further screened to ensure that they met the standard criteria for entry into an MRI scanner. The presence of metal in the body, tattoos, non-removable jewelry, and metallic hair extensions were considered exclusion criteria, as was being pregnant for female participants. Finally, the dominant hand used by participants can affect lateralization of neural substrate activation; therefore only right-

handed participants were included in the sample. Left-handedness is a common exclusion criteria in fMRI studies (Cuzzocreo et al., 2008).

Inclusion/Exclusion Questions:	**Yes**	**No**
Have you been diagnosed with depression or other mental illness?		
Do you have seizures?		
Have you ever suffered a head injury where you lost consciousness for more than 30 seconds?		
Do you have any metal in your body?		
Do you smoke more than 5 cigarettes per day?		
Will you be able to refrain from using cocaine, marijuana, and other drugs for 10 days prior to the day of the experiment?		
Do you have hair extensions or metal in your hair you would not be willing to remove?		
Do you have a tattoo?		
Are you currently pregnant?		
Have you had unprotected sex since your last period?		
Would you describe yourself as African-American?		
Is English your native language?		
Would you be willing to provide a urine sample for pregnancy and drug testing?		
Are you between the ages of 20 and 30 years old?		
Are you right-handed?		
Females only: please explain that we only need this information because we are not yet sure if the magnet used in an MRI is safe for a fetus.		

Figure 3. Telephone Screening Questionnaire

The rationale for enrolling only African American participants comes from investigations into the psychological components of socioeconomic disparities, which show that they are deeply confounded with race (Krieger & Sidney, 1996; Ren, Amick, & Williams, 1999; Williams, 1999). Perceived discrimination is thought to be an independent risk factor for morbidity and mortality, and likely is a significant stressor that could confound our results. By holding race constant, we hoped to minimize this effect across SES groups. In addition, we were restricted to a small sample due to funding constraints. Therefore, issues of statistical power prevented us from recruiting a multi-ethnic sample as ethnicity subsets would contain too few participants for statistical analyses. We settled on an African American sample as this was the ethnic group most readily available in the Harlem/Upper East Side area that was native English speaking and appropriately spanned the SES spectrum. Future studies will include other ethnic groups to ensure that the findings are not race-specific.

In total, 66 participants were screened and 23 were deemed eligible for study entry according to the above criteria. The majority of the disqualifications (43 in total) were due to presence of tattoos, left handedness, drug use, inappropriate age, and racial ambiguity. One participant was improperly screened for age, and was removed from the final sample for being out of the pre-defined range.

Consent Process

Upon arrival at the Advanced MR Research Suite, participants were presented the Mount Sinai IRB approved consent form. The form explains the risks involved in this study, as well as the compensation provided. In addition, any questions posed by

participants were answered at this time, and the MRI safety screen was administered a second time orally to ensure the safety of all participants. All participants were asked to provide a sample of urine to conduct a toxicology screening to ensure sobriety at and immediately prior to the study. For female participants, a urine dipstick-based pregnancy screen was employed, as the fMRI scanner has not been safety approved for pregnant women. Finally, the Edinburgh Handedness Inventory was administered to all participants to ensure they met the criteria of being right handed (Oldfield, 1971).

Participants who gave written consent and met all entry criteria for the scanner moved on to the experimental portion of the study. At this point, participants were given the demographic and psychosocial questionnaires (see details below). Afterwards, participants were directed to a private space in which to change into a hospital gown prior to entry into the magnet. Scanning procedures, the activation paradigm, and all safety instructions were reviewed with each participant immediately prior to scanning. The MR technologist positioned the participant on a scanning gantry, attached a head coil, and set the display screen and hand controller apparatus in place.

Measures

Demographic and Psychosocial Questionnaires

The demographic and psychosocial portions of the study included a set of validated instruments: Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983), Perceived Neighborhood Stress (Martinez, Black, & Starr, 2002), Rosenberg Self-Esteem scale (Robins, Hendin, & Trzesniewski, 2001), Comprehensive Quality of Life Inventory, Version 5 (Cummins, McCabe, Romeo, & Gullone, 1994), and the MacArthur Psychosocial Ladder (John, 2001b). We further included measures developed specifically for this study: a set of demographic questions, perceived discrimination due to income, perceived social class, a measure of social support, and a short measure of negative life events. In general, participants completed the questionnaires upon arrival at the Mount Sinai School of Medicine laboratory facility. A copy of the questionnaire is available in Appendix C.

Standardized Instruments

Perceived Stress Scale: The perceived stress scale (PSS) is a 10-item scale used to assess the self-reported stress over the previous month. Responses are scored on a 5-point Likert type scale and range from "never" = 0" to "very often" = 4", with four items reversed scored. This measure has been validated for use in SES research and captures the primary, temporal, and adaptive domains involved in both internal states and external stressors. Previous studies have reported Cronbach alpha reliability as 0.88 (Cohen et al., 1983).

The perceived neighborhood Scale: (PNS) is a validated 13-item scale designed to assess both perceptions of neighborhood desirability and level of neighborhood-dependent external stressors. Responses are scored on a 4-point Likert type scale ranging from "not at all true" = 1" to "very true" = 4", with seven reversed scored items. Previous studies have reported Cronbach alpha reliability as 0.84 (Martinez et al., 2002).

Rosenberg Self-Esteem Scale: The Rosenberg Self-Esteem Scale (RSS) is a brief, unidimensional measure of global self-esteem. It is a validated 10-item scale, scored on a 5-point Likert type scale ranging from "strongly agree" = 1" to "strongly disagree" = 5", with five items reversed scored. The RSS has demonstrated good reliability and validity across a large number of different sample groups, and in previous studies has reported a Cronbach alpha reliability of 0.80 (Robins et al., 2001).

Comprehensive Quality of Life Inventory, Version 5: The Comprehensive Quality of Life Inventory (COMQOL), Version 5 is a multiple-item scale that captures a broad array of domains related to social functioning, care-seeking, employment, health, and other facets of daily life (Cummins, 1997; Cummins et al., 1994). The instrument is divided into six subscales including: material well-being, health, productivity, intimacy, safety, and emotional well-being. The instrument contains both factual information (e.g., "Where do you live?" – with responses being: "a house," "an apartment," or "a room"), and psychological questions (e.g., "How often can you do the things you really want to do"? – with responses ranging from "almost always" to "almost never." Also included is an assessment of time spent on various activities such as paid work, formal education, television viewing, and childcare, as well as the number of times per month the

participant performs certain activities such as going to church or a restaurant. Previous studies have reported Cronbach alpha reliability as 0.85 (McAlinden & Oei, 2003).

MacArthur Ladder: The MacArthur Scale of Subjective Social Class or the MacArthur Ladder is a validated measure of one's perceived social status within his or her community (Singh-Manoux, Adler, & Marmot, 2003). The measure is presented as a graphic of a 10-rung ladder, and subjects are instructed to place an 'X' on the rung of the ladder that corresponds to their status. The measure is presented with the following instructions:

> "Think of this ladder as representing where people stand in their communities. People define community in different ways: please define it in whatever way is most meaningful to you. At the top of the ladder are the people who have the highest standing in their community. At the bottom of the ladder are the people who have the lowest standing in their community. Where would you place yourself on this ladder? Please place an "X" on the rung where you think you stand at this time in your life, relative to other people in your community."

The measure has been shown to relate to health outcomes and has shown excellent reliability with a previously reported intraclass correlation coefficient of 0.79 (Goodman et al., 2001).

Instruments Developed for Use in the Current Study

Demographics: The following demographic data were collected for this study: age and date of birth, gender, educational attainment, estimated annual household income,

and number of people who sleep in the same abode on a regular basis. Educational attainment was scored on a 5-point ordinal scale where "less than high school" = 1, "high school graduate / GED" = 2, "some college / community college / business training" = 3, "college degree" = 4, and "graduate and/or professional training" = 5. Household income inquired about all members of the household (as a unit) and was recorded in estimated dollars.

Discrimination by Income: In an attempt to understand the effect that income had upon our participants' daily experiences, we asked two questions regarding perceived discrimination due to income. The following two questions had "Yes" and "No" as possible responses:

1. Do you feel that people discriminate against you because of your income?
2. Do you ever think that others see themselves as better than you because they earn more than you?

Responses were coded as "yes" = 1, "no"= 0, and response values were summed to obtain a total score on this measure.

Social Class Membership: We also inquired about the social class in which participants perceived themselves to reside. This question was placed directly after the MacArthur Ladder in an attempt to gain a more thorough understanding of the participant's perception of his or her social standing. The exact question asked was:

"In your community, do you see yourself as rich, middle class, or poor"?

Responses were coded from poor or "lower-class" = 1, to "rich" or "upper-class" = 3.

Social Support: A brief social support measure was developed with the following two questions:

1. Please fill in the total number of people in your life (friends/family) that you feel like you could rely upon to talk to you if you were having a difficult time.
2. If you needed $100, how many people close to you (friends/family) do you think would lend you the cash?

The value for this measure was the sum of the responses to both these items.

Negative Life Events Scale: A short assessment was made of recent negative life events. In total, three negative events were asked about, with "Yes" and "No" as possible answers. The instructions and questions are presented below:

Instructions: Over the past 2 years, have you experienced?

1. The loss of a romantic partner?
2. The loss of a job you wanted to keep?
3. A move to a neighborhood you didn't want to move to?

Responses were coded "yes" = 1 "no"= 0, and items were summed to obtain a total score for this measure.

Neuropsychological Activation Paradigm

After completing the questionnaire, participants were escorted to the fMRI suite and provided a private location in which to change into a hospital gown. A certified technician placed the participants into the scanner, and then checked for proper positioning using the imaging computer. Participants were provided with a finger-press

response device (and instructed on its proper usage) and instructions for the in-scanner task.

> "While in the scanner you will be shown a series of images. Every time you see a complete picture, press the button corresponding to your right index finger. Every time you see a scrambled picture, press the button corresponding to your right middle finger."

The task was initiated after the participant acknowledged understanding the image classification task instructions and completed one set of trials (employing a single image and scramble – see below).

While in the scanner, participants were exposed to stimuli designed to elicit an emotional response. The primary goal was to map differential activation of emotional-processing neural regions by SES group. We hypothesized that regions associated with visual processing (primary visual cortex, fusiform gyrus), emotional processing (limbic regions), and transductive circuits (e.g., insula, locus cerulei) would show differential activations between SES groups (Canli et al., 2000; Mesulam, 1985; Nauta, 1982; Shin et al., 1999).

Exposure to selected images was couched in a simple two-alternative, forced choice (2AFC) picture versus scrambled image judgment task. The explicit task involved an unscrambled image/scrambled image judgment wherein participants were instructed to perform a right index finger button-press immediately upon presentation of an unscrambled picture and to perform a right middle finger button press upon presentation of a scrambled image. Corresponding button presses were counterbalanced across

participants. Throughout the task, reaction time was individually recorded for each stimulus.

The stimuli for the activation paradigm consisted of three types of International Affective Picture System (IAPS) images: 1) those with positive content (e.g. a flower), 2) those with negative content (e.g., a snake running by a woman's foot), and 3) those with neutral content (e.g., a mushroom) (Lang, Bradley, & Cuthbert, 1995). In addition, we added a fourth condition, which included images of poverty (e.g., a homeless man sleeping on the street), which were independently validated (drawn from public sources). Positive, negative, and neutral images were balanced across valence and arousal categories as determined by the IAPS publication manual (Lang, Bradley, & Cuthbert, 1999). Poverty images were validated in a similar manner to the IAPS using 38 undergraduate students from Brooklyn College who were presented with each image and asked to rate how emotionally charged the image was on a scale of 1 to 5, ranging from "no feeling whatsoever" = 1 to "very strong feelings" = 5. Images with a mean value of 4 or above were included as stimuli.

Unrecognizable scrambled images were then generated from the IAPS images by random pixel placement to create color- and luminance-balanced scrambled visual stimuli. Scrambled images were randomly selected from the full stimulus set and created using Compositor Software (http://www.artlythere.com/compositor.shtml) using the PixalWhack/pixal randomizer command (5x). Visual stimuli were projected from an LCD projector onto a tangent screen directly in participants' line of view within the fMRI scanner. While being projected, the images extended across the entire screen subtending an average visual angle of approximately of 28 x 30 degrees.

Stimuli were presented in block design. Each block comprised a single emotional valence condition (negative, neutral, positive, poverty), and was composed of 10 visual stimulus trials. Between one and three scrambled images were presented among each block of 10 univalent images. Each of the four conditions (positive, negative, neutral, and poverty) was represented by ten blocks. The entire neuropsychological activation task thereby was comprised of 40 blocks presented as 5 runs of 8 blocks per run, and counterbalanced to control for order and time effects. Consequently, there were 100 trials per condition, and 400 total trials in the study session. Presentation of scrambled image stimuli was also counterbalanced across blocks.

Each stimulus appeared on the LCD projector screen for 1.5 seconds, followed by a jittered inter-stimulus interval averaging 1900 msec, for a total block duration of 34 seconds. Each block within a run was followed by 12 seconds of rest. In addition, each run was preceded and followed by 36 second rest periods. During rest periods, participants were instructed to view a cross at the center of the screen, with their minds either blank or floating freely. Stimulus presentation and response collection (accuracy and reaction time) were performed within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). Participants' reaction times to a stimulus trial (i.e., distinguishing image versus scrambled visual stimuli and signaling by button press) were collected within this environment. Corresponding button presses for the in-scanner task were counterbalanced across subjects.

We designed a factorial paradigm with a block (rather than event-related) design for several reasons: 1) to maximize operationalization of sustained emotional tone, 2) to facilitate factorial comparison of various permutations of emotion and response

conditions, 3) to exploit the imaging sensitivity bestowed by block design, and 4) to minimize potentially confounding extraneous cognitive-behavioral functions.

Equipment

The Advanced MR Research Suite at the Mount Sinai School of Medicine houses a Siemens Allegra 3T head-dedicated MRI scanner. In addition to the MR systems, the suite includes a patient waiting area, restroom, lockers and changing room, nurse's station, staff offices, and a small computer area for image viewing and processing. Gradient hardware consists of a 36 cm I.D. asymmetric gradient coil capable of imaging at ~60Mount/m with slew rates in excess of ~600 T/m/s at a duty cycle of 70% allowing single shot EPI at a sustained rate of 14 images/second. The system has a 15 kW RF amplifier and 8 RF preamp channels. The 3T suite is also equipped with dedicated peripherals for fMRI research: 1) 3 channel fiber optic response buttons with standard mouse interface, 2) scanner initiated trigger for synchronizing stimuli paradigms with MR data acquisition and, 3) in-room LCD rear projection system where paradigms can be presented. System linearity is monitored bi-weekly using a cylindrical uniform phantom, and intensity noise and drifts are kept within a 1% margin.

Imaging

Imaging was completed in a single session, approximately 85 minutes in duration per participant. The functional MRI session, which began with structural and localizer

anatomical scans and finished with functional EPI-BOLD scans, lasted approximately 70 minutes.

Structural MRI: We performed T1-weighted spoiled gradient (MP-RAGE) MRI whole brain scans (208 slices; 8 mm in-plane resolution, .8 mm slice thickness, contiguous slices) and T2-weighted Turbo Spin Echo (TSE) axial whole brain images (3mm slice thickness).

Functional MRI: T2* - Echo planar imaging - blood oxygen level dependent (EPI-BOLD) fMRI was used as an index of neuronal activity. Echo planar imaging was used as it allows rapid image acquisition, permitting scan sequence parameters to be set such that intrinsic changes in BOLD contrast can be detected. This technique enables generation of BOLD-related neural activation maps. Full brain EPI functional scans (32 slices; 3mm thickness; 1 mm gap) were performed with a TR of 2000 msec and TE equal to 30. This was the technique used during the neuropsychological activation paradigm. The first two time-points of each run, acquired for gradient stabilization, were discarded prior to analysis.

Post-Scan Procedures

Recognition

Immediately after imaging, participants were removed from the scanner and presented with a set of visual images on a touch screen monitor. These consisted of stimuli presented during scanning (targets) randomly interspersed with an equal number

of new images (distracters), divided equally across three of the stimulus categories (positive, negative, and neutral). Participants were asked to indicate which images were presented during the scanning session using a 2-alternative forced choice (2AFC) button press, and measures of accuracy were collected within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA).

Positive, negative, and neutral IAPS images not presented as stimuli during the in-scanner task served as distracters for the recognition task. Because the poverty images were taken from limited public sources, distracter images were not available for this condition and no recognition testing was performed.

Valence Rating

Participants were asked to rate the emotional valence of the stimuli presented during the in-scanner task. Images were displayed on a touch screen monitor in a counter-balanced fashion, and participants rated images on a Likert-like scale using the participative assessment mannequin (Backs, da Silva, & Han, 2005). Ratings ranged from strongly positive, to strongly negative (from "strongly positive" = 1, to "strongly negative" = 5).

Data Analysis

Demographic & Psychosocial Measures: Responses to questionnaire items were entered into a statistical analysis package. Standardized scales and newly developed measures were computed using the appropriate scoring algorithms described above. Subsequently, descriptive statistics were prepared for all demographic and psychosocial measures

(means, standard deviations). In addition, between-subjects tests of significance (t-tests) were calculated comparing the low-SES and high-SES samples for all demographic and psychosocial measures. Calculations were performed for the complete sample (all available data), and separately for the fMRI included subsample – defined as participants included in the neural imaging analysis (see below).

Neuropsychological Activation Paradigm: Reaction times were collected during the image classification task of the activation paradigm within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). The E-Prime software package outputs individual files for each participant into Microsoft Excel format, and mean reaction times, number of errors, and frequencies of response time-outs were determined. Errors were flagged when the button pressed did not match the stimulus condition (e.g., categorizing a scramble as an image). Response time-outs were a result of the programming of the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). This software was designed to record reaction times when participants responded within 1500ms while the image was being displayed. All responses later than this were not recorded, and were coded as time-outs. Mean reaction times for each of the stimulus conditions (positive, neutral, negative, and poverty) were computed for all stimuli in which a timely response was made. These results were then entered into the statistical analysis package (SPSS for Windows, Release 10.0.0 1999) for further analysis.

Between-subjects tests of significance (t-tests) were calculated comparing the low-SES and high-SES samples. Further, between-subjects tests of significance (t-tests) were performed to assess group differences in total errors and time-outs. In addition, within-subject statistical tests were conducted (ANOVAs) to examine differences in

reaction time across stimuli conditions (positive, neutral, negative, and poverty). These were performed within SES groups, as well as across the entire sample. All calculations were performed for the complete sample and separately for the f-MRI included subsample.

Neuroimaging

Neural Image Analysis: T1-weighted spoiled gradient (MP-RAGE) MRI whole brain scans and T2* - Echo planar imaging - blood oxygen level dependent (EPI-BOLD) fMRI images were obtained using the 1.5 Tesla scanner. Prior to statistical analysis, the first two volumes of each run were discarded to allow the MR signal to reach steady state. The remaining images in each participant's time series were then motion corrected using the MCFLIRT module of FSL (FMRIB's Software Library, v3.3) package (http://www.fmrib.ox.ac.uk/fsl). Images in the data series were spatially smoothed with a 3D Gaussian kernel (FWHM = 8x8x8 mm3), and temporally filtered using a high-pass filter (320 seconds). The FEAT (FMRIB's Expert Analysis Tool) module of the FSL package was used for these steps and subsequent statistical analyses.

Customized square waveforms were generated for each individual. These waveforms were convolved with a double gamma hemodynamic response function (HRF). For each participant, we used FILM (FMRIB's Improved Linear Model) with local autocorrelation correction to estimate the hemodynamic parameters for four explanatory variables/conditions (neutral, positive, negative, and poverty) and to generate statistical contrast maps of interest. The six movement parameters (i.e., translation and rotation of x, y, and z axes) were modeled as covariates.

Each of the five runs per participant was analyzed separately, and the average of these five runs was obtained through a higher-level analysis using the FLAME (FMRIB's Local Analysis of Mixed Effects) module (stage 1 only). Contrast maps were then warped into common stereotaxic space before mixed-effects group analyses were performed. The normalization procedure involves registering the average EPI image to the MP-RAGE image from the same participant, and then to the ICBM152 T1 template, using the FLIRT (FMRIB's Linear Image Registration Tool) module.

To identify the regions of brain activation, we defined the regions of interest (ROIs) by clusters of 30 or more contiguous voxels (Xiong, Gao, Lancaster, & Fox, 1995) in which there was also a significant difference in brain activity across conditions ($Z>2.81$, $p<0.005$ two-tailed). Using the Mintun peak algorithm (Mintun, Fox, & Raichle, 1989), we then located the local peaks (maximal activation) within each ROI. Additional ROI analyses were then performed using the average signals extracted from these clusters. Functional imaging contrasts of interest involved the interaction contrast of SES by valence condition, i.e., $[SES_{low} - SES_{high}]$ X [negative – neutral].

Final activation tables were then created using the Talairach Daemon, a free piece of shareware created and developed by Jack Lancaster and Peter Fox at the Research Imaging Center of the University of Texas Health Science Center San Antonio (http://www.talairach.org/index.html). This software is designed to match activation/deactivation locations with known neural regions and generate a table. The software was run in 2 modes: 1) using a 3mm cube-range search starting from the center of a significantly active region (of at least 30 voxels), and 2) using an algorithm designed

to locate the nearest grey matter (within a maximal range of 11mm). These tables were then combined to ensure maximal confidence in neural region identification.

Images were then selected from these tables and saved as Jpeg files using MRIcro (Version 1.40, build 1) developed by Chris Rorden at the University of South Carolina (http://cnl.web.arizona.edu/mricro.htm). All images are presented in neurological convention.

Post-Scan Recognition: The post-scan image recognition task was run within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). The E-Prime software package outputs individual files for each participant into Microsoft Excel format. For each stimulus condition (positive, neutral, negative, and poverty) accuracy was determined, and standard signal-detection algorithms were performed generating figures for sensitivity (d') and bias. These figures were then entered into our statistical analysis package (SPSS for Windows, Release 10.0.0 1999), and between-subjects tests of significance (t-tests) were calculated comparing the low-SES and high-SES samples. All calculations were performed for the complete sample and separately for the f-MRI included subsample.

Post-Scan Valence Rating: The post-scan valence rating task was also run within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). The E-Prime software package outputs individual files for each participant into Microsoft Excel. For each stimulus condition (positive, neutral, negative, and poverty) average valence was determined, and entered into our statistical analysis package (SPSS for Windows, Release 10.0.0 1999). Between-subjects tests of significance (t-tests) were calculated comparing the low and high-SES samples. In addition, within-subjects statistical tests were

performed (ANOVAs) to assess for differences in valence across stimuli condition (positive, neutral, negative, and poverty). These were performed within SES group and across the entire sample. All calculations were performed separately for the complete sample and the fMRI-included subsample.

Statistical Power

Psychosocial and Behavioral Measures: This study was designed to be sufficiently powered to compare neural activations across two groups, taking into account limitations in funding and time. Therefore, this study was under-powered to detect group differences in psychosocial measures and behavioral measures such as reaction time. Although we designed the study with these limitations in mind, we decided to include the psychosocial measures in order better understand the populations under study and to inform future research. Because we expected to find few significant differences within this small sample, we did not employ statistics to correct for multiple comparisons within the psychosocial and behavioral testing. As such, the significant results should be treated as preliminary, and future research should be sufficiently powered to explore these important areas.

Due to our limited sample size we employed a blocked design for this study. Blocked designs have the advantages of enhancing power and providing a favorable signal-to-noise ratio, with a short scanning time – an important consideration for our population of interest (Amaro & Barker, 2006; Chee, Venkatraman, Westphal, & Siong, 2003; T. T. Liu, 2004). Further, this design is often used to examine previously

unexplored theories as it offers excellent detection power when used in a properly designed study (T. T. Liu, Frank, Wong, & Buxton, 2001).

Neural Imaging: The issue of statistical power in standard neuroimaging analyses is complex and remains a concern among fMRI researchers, as standards have not been well defined. A handful of published papers directly address the issue of sample size and statistical power in fMRI. In one such paper, Desmond and Glover (2002, pg. 128) concluded that: "for a liberal threshold of 0.05, about 12 participants were required to achieve 80% power at the single voxel level for typical activations. At more realistic thresholds, after correcting for multiple comparisons, the number of participants must be doubled to maintain this level of power". As described below in the *Results* section, our final sample included 15 participants with minimal head motion, and proved adequately powered to detect many SES group differences.

Results

Participant Characteristics

Sixty-nine individuals were screened via telephone for entry into the study; of those, 47 did not meet the inclusion criteria, leaving a total of 22 participants. Participants' demographic characteristics are detailed in Table 1, which shows mean values, standard deviations, and between-groups tests of significance. Notably, the low SES participants had significantly lower household incomes and lower educational attainment as measured by highest degree obtained.

Table 1: Demographic Characteristics of the Complete Sample by SES Group

Measure	**Low SES Sample (n=11)**	**High SES Sample (n=11)**	**t-test, p-value**
Gender	6 Male (55%) 5 female (45%)	3 Male (27%) 8 female (73%)	--
Age	23 (2.68)	25 (2.32)	t=1.87, p=.076
Education[a]	2.55 (1.04)	3.91 (0.70)	t=3.62, p=.002**
Current Household Income	$28,632 ($16,022)	$48,591 ($23,960)	t=2.30, p=.033*
Number of people who sleep in home	3.00 (1.41)	2.18 (1.33)	t=1.40, p=.177

Note. Data are mean (SD) except where indicated.

[a] Education was measured on a 5-point scale with a higher value indicating a greater level of education (<H.S., H.S. Diploma, Some College, College Degree, Graduate/Professional Education)

* p<.05, ** p <.01

Of the 22 participants, 7 were excluded from the final fMRI image data set due to excessive head movement while in the scanner (> 1 mm in x, y, or z plane) or for not completing the paradigm. The remaining sample included 15 participants: 8 low-SES

participants and 7 high-SES participants. It should be noted that a sample size of 15 is not uncommon in fMRI research. Unfortunately, due to financial constraints, we were unable to scan additional participants to replace those lost to movement artifact and/or prematurely exiting the study. The demographic characteristics of the fMRI-included subsample are shown in Table 2. As before, the low SES group had a significantly lower level of household income and educational attainment. For the purposes of completeness, where possible, all results will be presented for both the complete sample of 22 and the fMRI-included subsample of 15.

Table 2: Demographic Characteristics of fMRI Included Subsample by SES Group

Measure	**Low SES Sample (n=8)**	**High SES Sample (n=7)**	**t-test, p-value**
Gender	4 Male (50%) 4 female (50%)	2 Male (29%) 5 female (71%)	--
Age	22.63 (2.77)	25.57 (2.51)	t=2.15, p=.051
Education†	2.62 (1.06)	4.14 (0.69)	t=3.23, p=.007**
Current Household Income	$29,956 ($14,543)	$56,714 ($24,464)	t=2.53, p=.031*
Number of people who sleep in home	3.13 (1.55)	2.14 (1.35)	t=1.30, p=.216

Note. Data are mean (SD) except where indicated.

† Education was measured on a 5-point scale with a higher value indicating a greater level of education (<H.S., H.S. Diploma, Some College, College Degree, Graduate/Professional Education)

* p<.05, ** p <.01

Twenty participants completed the psychosocial measures. Two high SES participants did not complete the questionnaires due to scheduling constraints. Table 3 shows that mean values, standard deviations, and between-groups tests of significance for all psychosocial measures.

Table 3: Psychosocial Measures of Complete Sample by SES Group

Measure	Low SES Sample (n=11)	High SES Sample (n=9)	t-test, p-value
Perceived Stress Scale	18.27 (5.50)	15.22 (4.94)	t=1.29, p=.213
Perceived Neighborhood Stress	30.82 (8.04)	34.44 (5.48)	t=0.83, p=.416
Rosenberg Self Esteem	18.73 (7.43)	15.33 (4.09)	t=1.22, p=.237
COMQOL: Material Well-Being	8.64 (1.96)	9.55 (1.51)	t=1.15, p=.265
COMQOL: Health	13.45 (1.29)	14.33 (0.50)	t=1.92, p=.071
COMQOL: Productivity	12.73 (2.83)	15.00 (1.87)	t=2.06, p=.054
COMQOL: Intimacy	12.00 (2.57)	13.78 (0.83)	t=2.16, p=.051
COMQOL: Safety	11.40 (2.17)	11.78 (1.39)	t=0.45, p=.662
COMQOL: Emotional Well-Being	9.09 (1.76)	11.00 (1.22)	t=2.75, p=.013*
MacArthur Psychosocial Ladder	5.32 (2.26)	6.20 (1.72)	t=0.10, p=.331
Discrimination by Income	0.91 (0.70)	1.00 (0.71)	t=0.28, p=.777
Social Class Membership	2.28 (0.44)	1.89 (0.42)	t=1.92, p=.072
Social Support	10.20 (8.00)	19.11 (11.75)	t=1.95, p=.068
Negative Life Events	0.80 (0.92)	0.67 (0.87)	t=0.32, p=.750

Note. Data are mean (SD) except where indicated.

* $p<.05$

As shown in Table 3, scores on most of the psychosocial measures were comparable between groups. As described in the *Methods* section, this is likely due to the reduced statistical power associated with the small sample size. Nonetheless, a significant difference was detected in the Emotional Well-being scale of the Comprehensive Quality

of Life Inventory, Version 5 (COMQOL), with high SES participants reporting higher rates of well-being. Measures that approached significance included the COMQOL Health, Productivity and Intimacy scales, as well as our short measure of social support. Interestingly, although not statistically significant, low-SES participants reported being in a higher social class (closer to middle class) than the high-SES sample.

Table 4 presents the psychosocial measures for the fMRI-included subsample. Again, only one significant result was detected, the COMQOL Productivity score with high-SES participants reporting greater productivity. Measures that approached significance included the Material and Emotional Well-being scales of the COMQOL.

Table 4: Psychosocial Measures of the fMRI-Included Subsample by SES Group

Measure	Low SES Sample (n=8)	High SES Sample (n=7)	t-test, p-value
Perceived Stress Scale	17.38 (5.78)	16.14 (5.27)	t=0.43, p=.675
Perceived Neighborhood Stress	30.50 (9.18)	33.00 (6.14)	t=0.61, p=.553
Rosenberg Self Esteem	17.75 (8.48)	16.00 (4.32)	t=0.49, p=.631
COMQOL: Material Well-Being	8.63 (1.60)	10.00 (0.82)	t=2.05, p=.061
COMQOL: Health	13.38 (1.51)	14.29 (0.49)	t=1.53, p=.151
COMQOL: Productivity	13.00 (1.85)	15.43 (1.72)	t=2.62, p=.021*
COMQOL: Intimacy	12.38 (2.26)	13.86 (0.90)	t=1.62, p=.130
COMQOL: Safety	11.50 (2.20)	11.43 (1.27)	t=0.08, p=.941
COMQOL: Emotional Well-Being	9.00 (2.07)	10.86 (1.35)	t=2.02, p=.064
MacArthur Psychosocial Ladder	4.88 (2.23)	6.00 (2.04)	t=1.01, p=.330
Discrimination by Income	0.87 (0.64)	1.00 (0.58)	t=0.39, p=.700
Social Class Membership	2.14 (0.38)	1.79 (0.39)	t=1.73, p=.109
Social Support	12.14 (8.61)	20.86 (12.95)	t=1.48, p=.164
Negative Life Events	0.71 (0.95)	0.71 (0.95)	t=0.01, p=.999

Note. Data are mean (SD).

* $p<.05$

Of particular interest in both Table 3 and 4 is the lack of difference observed in the MacArthur Psychosocial Ladder scores when comparing high and low-SES participants. Although in both the complete and fMRI-included subsample high-SES participants reported higher perceived social status on average, the differences were slight

and several low-SES participants reported higher values than high-SES participants. In fact, the kendall's tau-B correlation between scores on the MacArthur Ladder and observed SES was only r=0.19, p=.318. Further, Pearson correlations between the MacArthur ladder scores and household income showed a weak relationship, r=-0.15, p=.508, as did the relationship between the MacArthur Ladder and education, r=0.22, p=.328.

Neuropsychological Activation Paradigm

Reaction Time

As described in detail in the *Methods* section, participants were exposed to either emotionally-valenced images or scrambled images in the scanner, and were asked to perform a button-press image classification task. Reaction times were collected and averaged by stimulus condition (positive, neutral, negative, and poverty) for each participant.

All data collected for this portion of the study were collected within the E-Prime environment (Psychology Software Tools, Inc., Pittsburgh, PA). This software records reaction times only when participants respond while the image is still present on the display screen, i.e., for 1.5 seconds per image. All responses later than this are not recorded, and henceforth will be described as time-outs. Several participants had high-rates of time-outs, possibly due to a lack of complete understanding of the task. Outliers were eliminated by calculating the standard deviation of time outs (SD time-outs = 60.45) and removing all scores 2 SDs or above from the analyses (≥ 121). A total of 2 participants (both high-SES) reached this level and were removed from the analyses. In

addition, 2 low-SES and 1 additional high-SES participant were not included in the analysis due to not completing the scanning procedure (insufficient data), leaving a total of 9 low-SES and 8 high-SES participants in the reaction time sample.

The high and low-SES groups were then compared for the number of reaction time trials missed within each group (time-outs) and errors made. These analyses included all subjects who completed the task - that is, outliers were included in these analyses. For both groups, the error rate was zero. For both the complete sample as well as the fMRI-included subsample, the time-out rate was not significantly different between SES groups (full sample $t=1.27$, $p=0.220$; f-MRI included subsample $t=0.72$, $p=0.483$).

ANOVAs were performed to examine reaction times across the four conditions (positive, neutral, negative, and poverty). For all participants who completed the reaction time task and were determined not to be outliers in terms of missed trials, no significant differences were seen across the four conditions, $F(3,64)=0.215$, $p=0.886$. When performed within SES group, the results were similar (Low-SES group: $F(3,32)=0.233$, $p=0.873$; High SES group, $F(3,28)=0.086$, $p=0.967$). These tests were then repeated using only the participants who were not outliers and were included in the fMRI sample, (f-MRI included subsample $F(3,48)=0.210$, $p=0.889$; Low-SES group $F(3,28)=0.236$, $p=0.870$; High-SES group $F(3,16)=0.047$, $p=0.986$).

Mean reaction times, standard deviations, and between-groups tests of significance are shown for the available sample in Table 5.

Table 5: Reaction Time Means for the Complete Sample by SES Group

Condition	Low SES Sample (n=9)	High SES Sample (n=8)	t-test, p-value
Positive	730.08 (120.59)	586.62 (138.67)	t=2.28, p=.037*
Neutral	716.30 (108.46)	604.00 (124.18)	t=1.99, p=.065
Negative	765.91 (154.42)	621.35 (154.24)	t=1.93, p=.073
Poverty	737.88 (132.45)	602.81(127.50)	t=2.14, p=.050*

Note. Data are mean (SD) except where indicated.

* $p<.05$

Table 5, shows that reaction times were significantly longer for low-SES participants when identifying positive-stimulus and poverty-stimulus images. This finding is consistent with research showing that emotionally provocative stimuli extend reaction time (Broadbent, 1971; Welford, 1980) and that people on the lower end of the socioeconomic spectrum react more slowly, overall, in experimental settings (Buckhalt, El-Sheikh, & Keller, 2007).

Table 6 shows the mean reaction times, standard deviations, and between-groups tests of significance for participants who were included in the final fMRI sample. A total of 8 low-SES and 5 high-SES participants completed the reaction time task and had sufficiently low rates of head movement to be included.

Table 6: Reaction Time Means for the fMRI-Included Subsample by SES Group

Condition	Low SES Sample (n=8)	High SES Sample (n=5)	t-test, p-value
Positive	742.86 (122.21)	604.72 (157.13)	t=1.78, p=.102
Neutral	732.62 (103.45)	613.75 (149.88)	t=1.70, p=.116
Negative	783.86 (154.73)	639.72 (172.47)	t=1.57, p=.146
Poverty	755.13 (130.34)	625.98 (145.80)	t=1.66, p=.124

Note. Data are mean (SD) except where indicated.

As shown in Table 6, no significant differences were observed in reaction time when only the fMRI-included subsample was used in the analysis. This is likely due to the low statistical power associated with a sample size of 13.

Recognition

After the scanning procedure, participants were tested for stimulus recognition using a 2-alternative forced choice (2AFC) button press target/distracter task. Signal detection methodology was used to calculate the sensitivity, bias, and accuracy of identification for each participant. As described in the *Methods* section, only three conditions were tested for image recognition (positive, neutral, and negative).

Not all participants completed the post-scan tasks. Participants who exited the scanner prematurely were not asked to participate in the image-recognition testing, and others were lost due to scheduling issues. In total, 9 low-SES and 8 high-SES participants completed the task. Their mean sensitivity, bias, and accuracy scores are shown in Table 7, along with between-groups tests of significance.

Table 7. Recognition Signal Detection Sensitivity, Bias, and Accuracy Values for the Complete Sample by SES Group

Condition	Low SES Sample (n=9)			High SES Sample (n=8)			t-test, p-value		
	Sen	Bias	Acc	Sen	Bias	Acc	Sen	Bias	Acc
Positive	.781	.270	68.06%	.838	.530	73.59%	t=1.63 p=.123	t=1.66 p=.117	t=1.49 p=.157
Neutral	.752	.195	69.86%	.864	.529	77.19%	t=2.7 p=.016*	t=2.37 p=.031*	t=1.75 p=.10
Negative	.759	.008	66.67%	.807	.137	72.66%	t=1.27 p=.224	t=0.45 p=.662	t=1.73 p=.105

Note. Sen=Sensitivity; Acc=Accuracy

* p<.05

Table 7 shows that there were only minor differences in detection accuracy, sensitivity, and bias between the two groups. In the neutral-stimuli condition, low-SES participants had significantly lower sensitivity and bias scores compared with high-SES participants, but levels of accuracy were essentially equivalent.

Table 8 reports the same measures, but for the fMRI-included subsample. Only 12 participants met the criteria of having completed the recognition task and the scan procedure with low head movement. Note that 1 low-SES participant was removed from the data pool due to distraction during the recognition task.

Table 8. Recognition Signal Detection Sensitivity, Bias, and Accuracy Values for the fMRI-Included Subsample by SES Group

Condition	Low SES Sample (n=7)			High SES Sample (n=5)			t-test, p-value		
	Sen	Bias	Acc	Sen	Bias	Acc	Sen	Bias	Acc
Positive	.807	.334	70.36%	.837	.557	82.64%	t=0.80 p=.445	t=1.41 p=.200	t=0.68 p=.511
Neutral	.748	.182	71.4%	.862	.535	76.50%	t=2.01 p=0.72	t=2.26 p=0.48*	t=1.05 p=.320
Negative	.780	.108	68.21%	.224	.743	86.17%	t=1.36 p=.205	t=0.66 p=.527	t=1.67 p=.125

Note. Sen=Sensitivity; Acc=Accuracy

* p<.05

Table 8 shows a similar pattern of results as Table 7. The only significant difference detected was again in the neutral-stimulus condition, where low-SES participants showed a lower detection bias than high-SES participants. It should be noted that the accuracy scores are somewhat higher for the fMRI-included participants than for the complete sample, likely due to better compliance with experimental procedures overall in this subject pool.

Valence Rating

Immediately after completing the post-scan recognition task, participants were asked to rate the valence of the stimuli presented in the scanner. The participants who completed this task were the same as those completing the recognition task, with the exception of 1 high-SES participant who left prior to completion. Table 9 shows the mean and standard deviations of the valence ratings, as well as between-groups tests of significance for each of the four stimulus conditions.

Table 9. Valence Ratings for the Complete Sample by SES Group

Condition	Low SES Sample (n=9)	High SES Sample (n=7)	t-test, p-value
Positive	1.76 (0.47)	1.93 (0.33)	t=0.82, p=.428
Neutral	2.60 (0.74)	2.62 (0.13)	t=0.08, p=.942
Negative	4.30 (0.54)	4.24 (0.27)	t=0.28, p=.785
Poverty	3.94 (0.82)	4.07 (0.33)	t=0.39, p=.705

Note. Data are mean (SD) except where indicated.

As shown in Table 9, on average, all stimuli groups were rated appropriately; that is images from the positive stimuli condition were rated as the most positive (nearest to "1"), while negative stimuli received the most negative scores (closest to "5"). Neutral scores were rated very close to the midpoint between the two ends of the scale (2.5), and poverty-related images on average were seen as somewhere between negative and neutral. No significant differences between SES-group were detected.

ANOVAs were then performed to test differences in valence across the four stimuli conditions (positive, neutral, negative, and poverty). For all participants who completed the valence task, significant differences were found in valence across conditions, $F(3,60)=80.73$, $p<.0001$. Bonferroni post-hoc tests showed significant differences between all conditions ($p<.0001$), with the exception of Negative and Poverty stimuli ($p=.78$). When these tests were performed within SES group, similar findings emerged (Low SES group: $F(3,32)=29.03$, $p<.0001$; High SES group: $F(3,24)=115.80$, $p<.0001$). Bonferroni post-hoc tests showed significant differences between all conditions ($p<.0001$) with the exception of Negative and Poverty (low-SES: $p=0.99$; high-SES: $P=0.99$). In addition, within the low-SES group, the valence ratings of the Positive and Neutral stimuli were also found not to be significantly different ($p=.063$).

These analyses were repeated for participants in the fMRI-included subsample. Table 10 shows the mean and standard deviations of the valence ratings for the fMRI-included subsample, as well as between-groups tests of significance for each of the four stimulus conditions.

Table 10. Valence Ratings for the f-MRI Included Subsample by SES Group

Condition	**Low SES Sample (n=7)**	**High SES Sample (n=4)**	**t-test, p-value**
Positive	1.89 (0.43)	1.92 (0.31)	t=0.12, p=.905
Neutral	2.89 (0.49)	2.58 (0.11)	t=1.2, p=.253
Negative	4.51 (0.40)	4.30 (0.30)	t=0.90, p=.391
Poverty	4.25 (0.54)	3.97 (0.25)	t=0.95, p=.368

Note. Data are mean (SD) except where indicated.

The results shown in Table 10 mirror those found in Table 9. Again stimuli were appropriately perceived, and no significant differences were seen between SES group for any condition. In addition, the ANOVA analysis testing differences in valence across the four stimuli conditions was repeated with participants in the fMRI-included sample. The pattern of findings was similar, with $F(3,40)=94.07$, $p<.0001$. Again Bonferroni post-hoc tests showed significant differences between all conditions ($p<.0001$) with the exception of Negative and Poverty stimuli ($p=.61$). When these tests were performed within SES group, the findings followed course (low-SES group: $F(3,24)=47.73$, $p<.0001$; high-SES group: $F(3,12)=78.13$, $p<.0001$). Bonferroni post-hoc tests showed significant differences between all conditions ($p<.0001$) with the exception of Negative and Poverty (Low SES: $p=0.99$; High SES: $P=0.55$).

Neuroimaging Results

The following section presents the results of the fMRI imaging contrasts, SES by valence condition, i.e., [SES_{low} - SES_{high}] X [valence contrast]. The primary valence contrasts of interest in this study were: Negative imagery versus Neutral imagery, Poverty imagery versus Neutral imagery, Negative imagery versus Poverty imagery, and Positive imagery versus Neutral imagery. For each condition we present the difference images that were a minimum of 30 contiguous voxels and best matched our hypothesized ROIs. In addition, a table of all significant activation differences where $p<0.05$ is presented for each valence condition comparison. Note again that all images are presented in neurological convention.

Negative versus Neutral

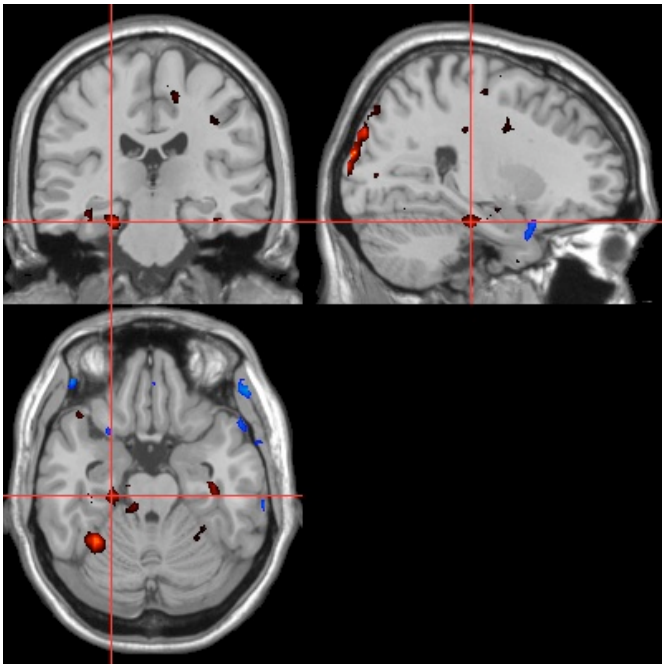

Figure 4. Region indicated shows greater parahippocampal gyrus activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

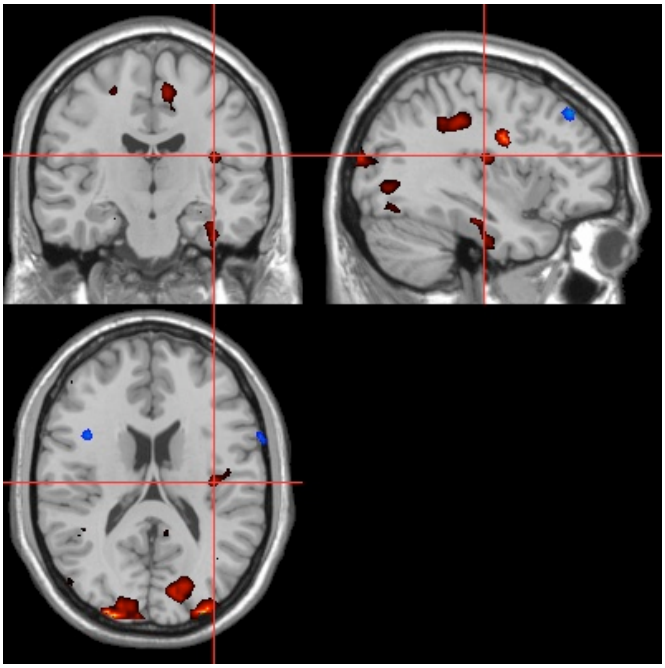

Figure 5. Region indicated shows greater insula activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

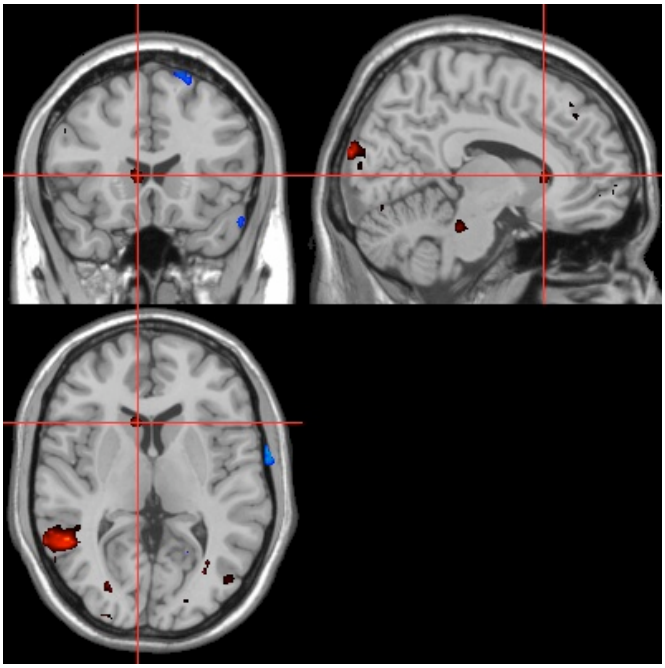

Figure 6. Region indicated shows greater caudate activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

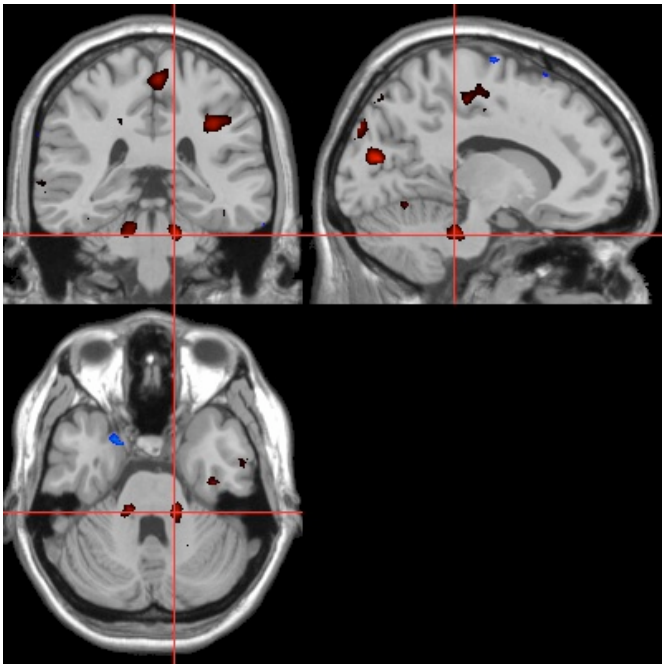

Figure 7. Region indicated shows greater bi-lateral pons activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

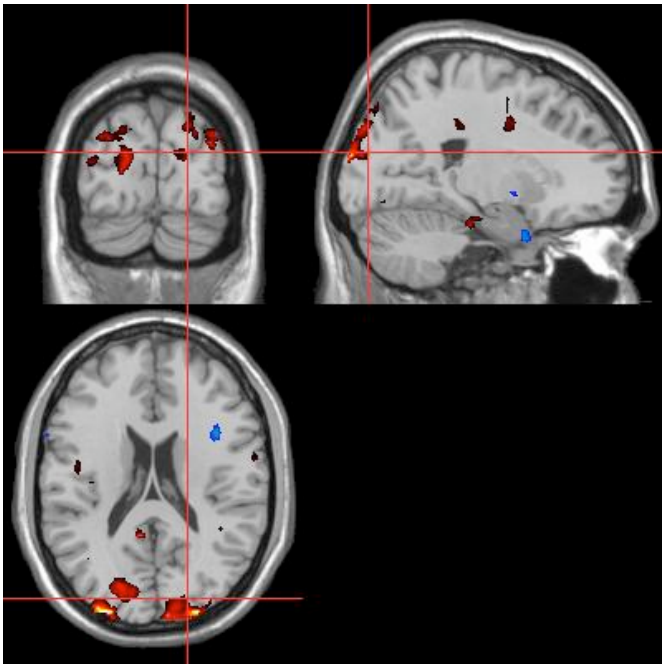

Figure 8. Region indicated shows greater bi-lateral occipital gyrus activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

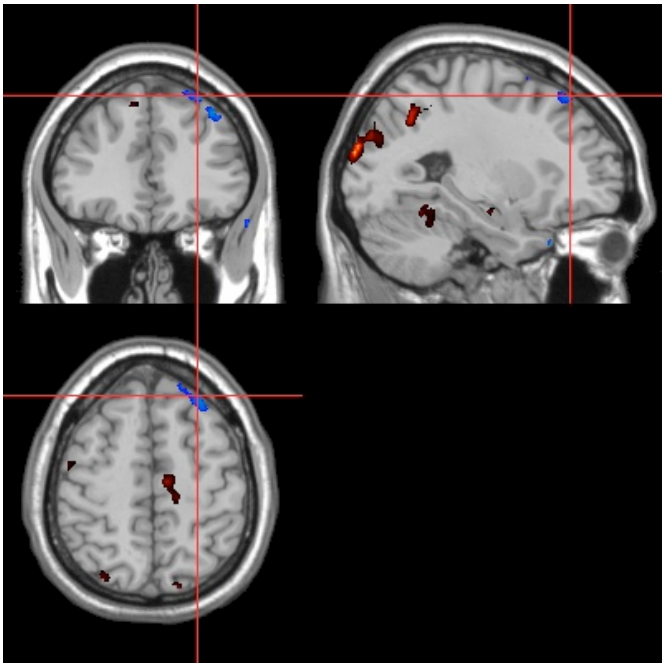

Figure 9. Region indicated shows reduced superior frontal gyrus activation by low-SES as compared to high-SES participants for the negative versus neutral contrast

Table 11. Neural Regions with Significant Differences in Activity for Low versus High-SES Participants - Negative versus Neutral Valence Conditions

Brain Region	Side	Size	Coordinates			Z Score
Activations			**X**	**Y**	**Z**	
Superior Temporal Gyrus	Left	31	-30	4	-44	2.36
Middle Temporal Gyrus	Left	47	-46	4	-40	2.68
Uncus	Right	84	34	-18	-30	2.89
Inferior Temporal Gyrus	Right	33	52	-4	-32	2.7
Pons	Right	73	12	-34	-30	2.99
Parahippocampal Gyrus	Left	73	-26	-24	-22	3.08
Cerebella Culmen	Left	135	-38	-54	-22	3.51
Cerebella Culmen/Declive	Right	84	26	-50	-18	2.45
Fusiform Gyrus	Left	33	-40	-26	-20	2.32
Lingual Gyrus	Right	142	34	-72	-4	2.85
Middle Temporal Gyrus	Left	804	-60	-48	0	4.3
Inferior Occipital Gyrus	Left	91	-36	-74	-2	2.84
Medial Frontal Gyrus	Left	72	-16	56	-2	2.37
Inferior Frontal Gyrus	Left	37	-48	30	0	2.75
Caudate	Left	30	-12	20	4	2.47
Middle Occipital Gyrus	Left	657	-24	-90	26	4.1
Middle Occipital Gyrus	Right	850	22	-86	20	4.42
Precentral Gyrus*	Right	348	40	-6	26	4.5
Precentral Gyrus	Left	57	-60	4	26	2.18
Cingulate Gyrus	Left	119	-24	-2	38	2.46
Postcentral Gyrus	Right	288	36	-36	38	2.71
Precentral Gyrus	Left	132	-54	-6	48	2.89
Brain Region	**Side**	**Size**	**Coordinates**			**Z Score**
Deactivations			**X**	**Y**	**Z**	
Superior Temporal Gyrus	Right	97	66	2	8	3.74
Middle Frontal Gyrus	Right	54	34	36	42	3.38
Superior Frontal Gyrus	Right	69	24	32	52	3.43
Superior Frontal Gyrus	Right	64	16	16	66	3.01

Note. Images 1 - 5 above are shown in bold.

*Presented insula activation is a component of the larger precentral gyrus activation, with crosshairs centered at (-36, -16, 18)

Poverty versus Neutral

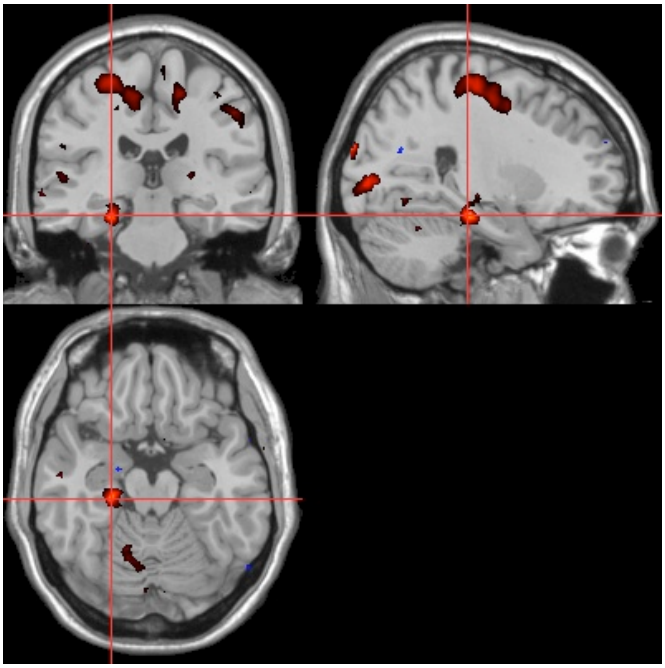

Figure 10. Region indicated shows greater parahippocampal gyrus activation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

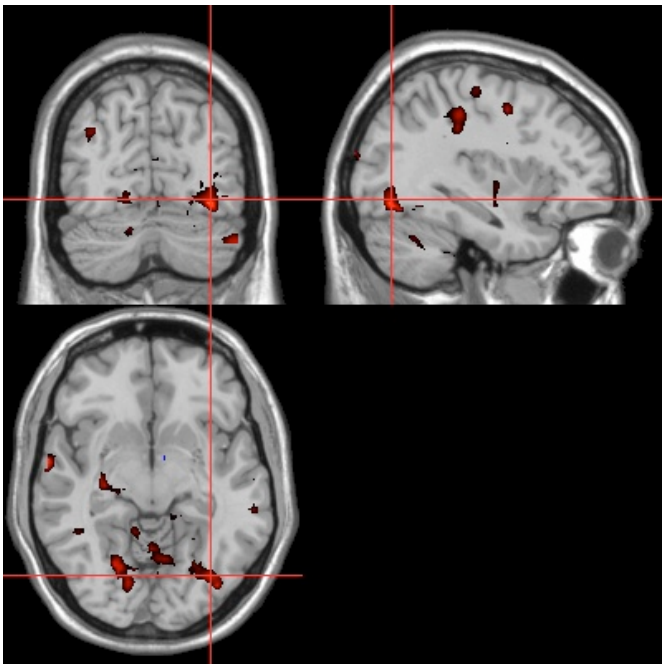

Figure 11. Region indicated shows greater bi-lateral fusiform activation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

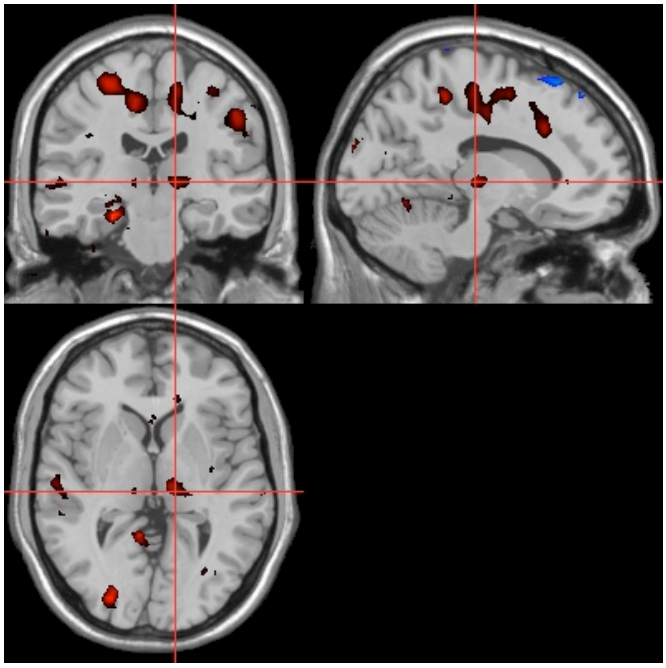

Figure 12. Region indicated shows greater thalamus activation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

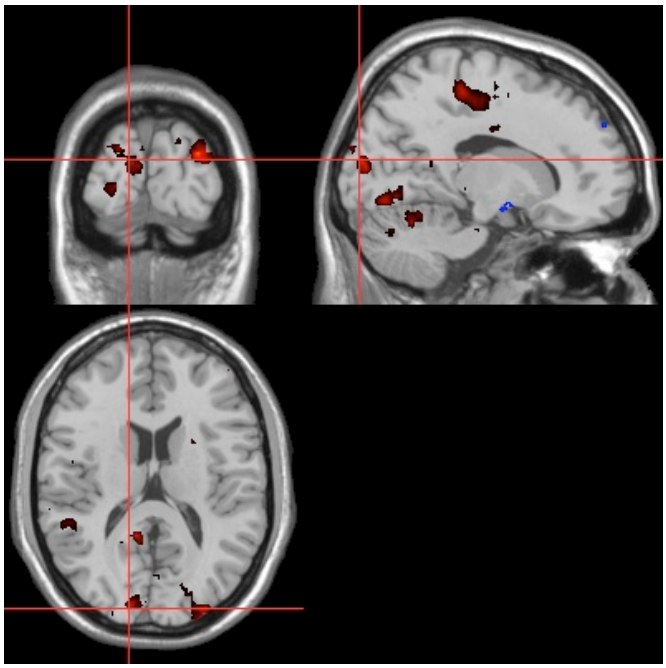

Figure 13. Region indicated shows greater bi-lateral middle occipital gyrus activation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

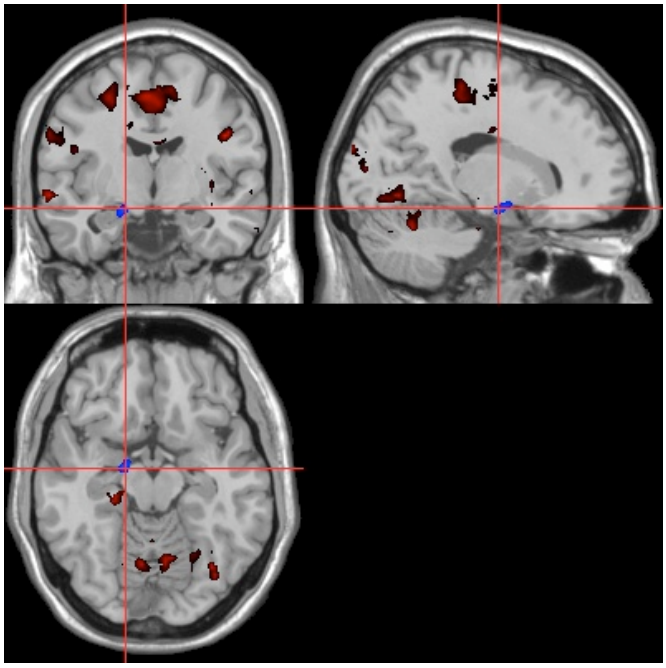

Figure 14. Region indicated shows reduced amydgala deactivation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

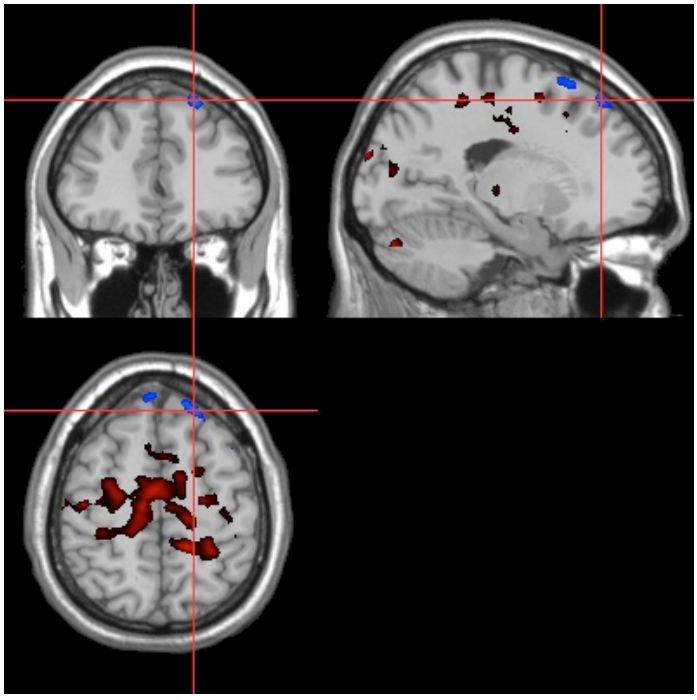

Figure 15. Region indicated shows reduced superior frontal gyrus deactivation by low-SES as compared to high-SES participants for the poverty versus neutral contrast

Table 12. Neural Regions with Significant Differences in Activity for Low versus High-SES Participants – Poverty versus Neutral Valence Conditions

Brain Region	Side	Size	Coordinates			Z Score
Activations			**X**	**Y**	**Z**	
Fusiform Gyrus	Left	307	-18	-68	-14	2.93
Parahippocampal Gyrus	Left	200	-28	-24	-16	3.92
Posterior Cingulate	Left	393	-6	-56	-2	3.52
Fusiform Gyrus	Right	292	30	-70	-8	3.67
Middle Temporal Gyrus	Left	395	-58	-26	2	3.3
Middle Temporal Gyrus	Right	78	54	-34	-6	2.68
Middle Occipital Gyrus	Left	106	-28	-88	0	3.1
Thalamus	Right	93	12	-22	2	2.72
Caudate	Left	48	-4	22	4	2.71
Middle Occipital Gyrus	Left	201	-16	-92	16	3.62
Middle Occipital Gyrus	Right	225	22	-92	18	3.86
Precentral Gyrus	Left	4673	-4	-16	46	3.02
Middle Temporal Gyrus	Left	112	-40	-60	28	3.28
Cingulate Gyrus	--	56	0	-12	26	2.66
Precentral Gyrus	Right	50	40	-8	28	2.91
Middle Frontal Gyrus	Right	32	32	-2	46	2.66
Brain Region	**Side**	**Size**	**Coordinates**			**Z Score**
Deactivations			**X**	**Y**	**Z**	
Amygdala	Left	34	-20	-6	-14	2.75
Superior Frontal Gyrus	Right	47	16	38	52	3.36
Superior Frontal Gyrus	Right	112	12	22	62	3.43

Note. Images 1 - 6 above are shown in bold.

Poverty versus Negative

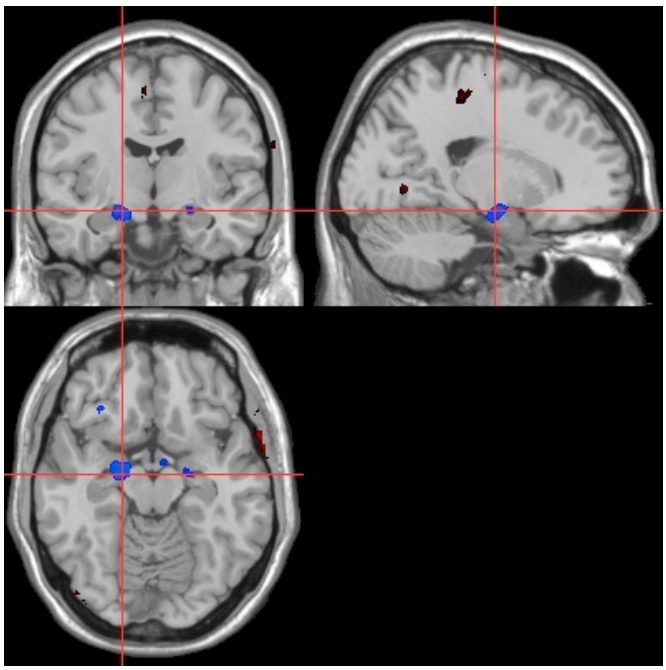

Figure 16. Region indicated shows reduced parahippocampal gyrus and amygdala activation by low-SES as compared to high-SES participants for the poverty versus negative contrast

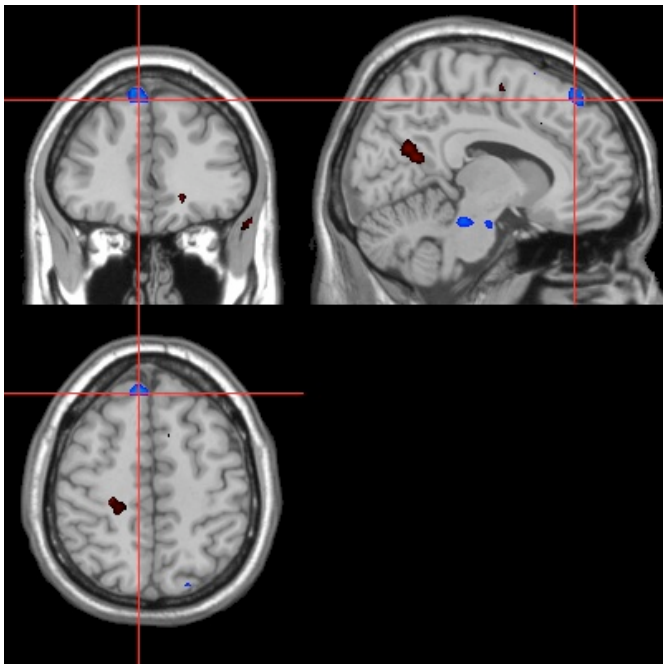

Figure 17. Region indicated shows reduced superior frontal gyrus activation by low-SES as compared to high-SES participants for the poverty versus negative contrast

Table 13. Neural Regions with Significant Differences in Activity for Low versus High-SES Participants – Poverty versus Negative Valence Conditions

Brain Region	Side	Size	Coordinates			Z Score
Activations			**X**	**Y**	**Z**	
Superior Temporal Gyrus	Left	67	-66	2	-4	4.06
Precuneus	Left	111	-14	-62	24	2.58
Cingulate Gyrus	Left	42	-2	-30	26	2.87
Postcentral Gyrus	Right	37	70	-18	30	2.28
Cuneus	Left	35	-2	-76	30	2.39
Cingulate Gyrus	Left	55	-2	16	32	2.4
Precentral Gyrus	Left	120	-26	-26	58	2.75
Brain Region	**Side**	**Size**	**Coordinates**			**Z Score**
Deactivations			**X**	**Y**	**Z**	
Parahippocampal Gyrus / Amygdala	Left	108	-20	-10	-14	3.19
Middle Temporal Gyrus	Left	40	-54	-48	0	2.86
Middle Temporal Gyrus	Left	124	-32	-54	12	3.25
Superior Occipital Gyrus	Left	35	-32	-90	28	3.03
Superior Frontal Gyrus	Left	89	-10	38	52	3.45

Note. Images 1 - 2 presented above are shown in bold.

Positive versus Neutral

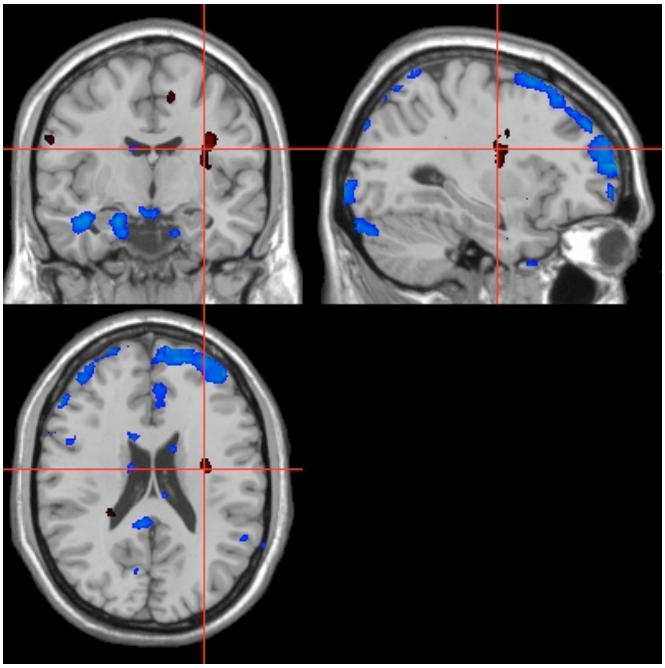

Figure 18. Region indicated shows increased insula activation by low-SES as compared to high-SES participants for the positive versus neutral contrast

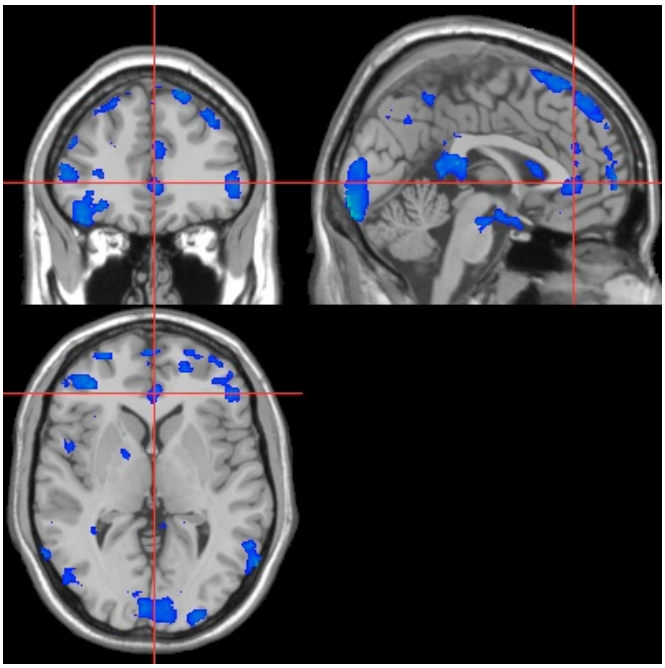

Figure 19. Region indicated shows reduced anterior cingulate activation by low-SES as compared to high-SES participants for the positive versus neutral contrast

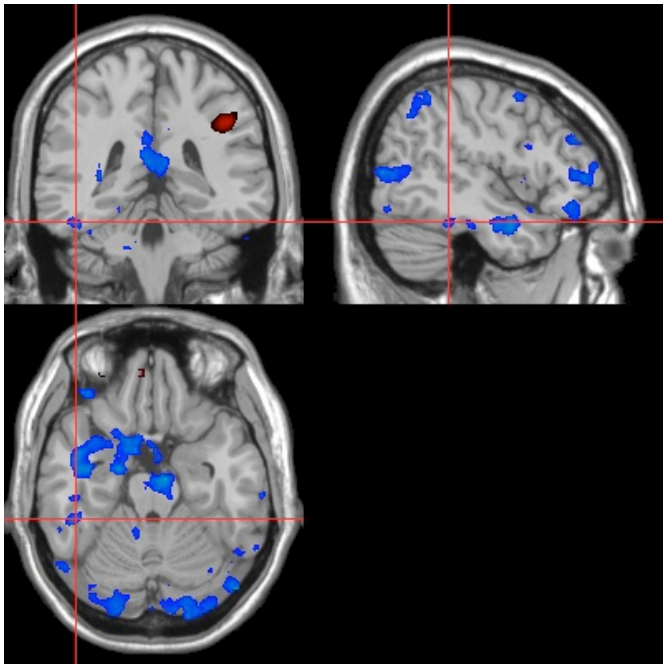

Figure 20. Region indicated shows reduced fusiform gyrus activation by low-SES as compared to high-SES participants for the positive versus neutral contrast

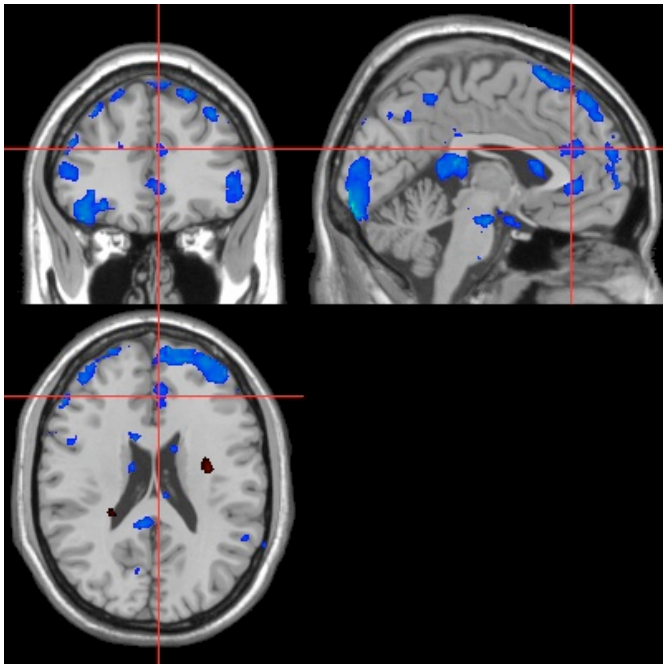

Figure 21. Region indicated shows reduced medial frontal gyrus activation by low-SES as compared to high-SES participants for the positive versus neutral contrast

Table 14. Neural Regions with Significant Differences in Activity for Low versus High-SES Participants – Positive versus Neutral Valence Conditions

Brain Region	Side	Size	Coordinates			Z Score
Activations			**X**	**Y**	**Z**	
Insula	Right	115	30	-8	22	2.45
Precentral Gyrus	Left	34	-64	-6	26	2.29
Precentral Gyrus	Left	86	-34	-20	66	2.66
Brain Region	**Side**	**Size**	**Coordinates**			**Z Score**
Deactivations			**X**	**Y**	**Z**	
Superior Temporal Gyrus	Left	1306	-32	-2	-24	3.66
Middle Temporal Gyrus	Right	427	58	-58	-12	3.41
Fusiform Gyrus	Left	47	-46	-26	-26	2.66
Lingual Gyrus	Right	2079	10	-92	-10	4.59
Fusiform Gyrus	Left	56	-48	-38	-24	3.18
Inferior Temporal Gyrus	Left	420	-62	-60	-8	3.61
Superior Frontal Gyrus	Right	5696	2	44	26	4.04
Anterior Cingulate	--	99	0	36	-2	3.13
Middle Occipital Gyrus	Left	191	-50	-74	6	3.47
Superior Temporal Gyrus	Left	37	-52	6	2	2.46
Caudate	Left	47	-36	-44	6	2.91
Caudate	--	69	0	14	10	3.13
Medial Frontal Gyrus	Right	76	2	36	22	2.81
Caudate	Left	37	-14	-4	24	3.07
Precuneus	Left	47	-34	-66	32	2.89
Precuneus	Right	173	10	-66	38	3.04
Superior Temporal Gyrus	Right	33	50	-58	32	2.8
Middle Frontal Gyrus	Left	64	-52	8	46	3.13
Superior Frontal Gyrus	Left	109	-18	12	68	3.13

Note. Images 1 - 4 presented above are shown in bold.

Discussion

Sample

The final sample included 22 participants, 15 whose movement within the fMRI scanner was less than 1 mm in any direction. Of the 15 participants included in the fMRI sample, 8 met criteria for the low-SES group, and 7 met criteria for the high-SES group. The remaining 7 participants completed most or all of the study, but were excluded from the neural imaging analyses due to excessive movement. Results were reported for every participant who completed a particular task, and then results were reported separately for the fMRI-included subsample only. It should be noted that due to a variety of circumstances during the experimental procedures, several participants did not complete one or more of the measures. Therefore the sample size for each analysis was noted in the tables presented above.

Demographics

For both the full sample (n=22) and the fMRI-included subsample (n=15), significant differences were observed for current household income and highest degree obtained when comparing low and high-SES groups. This finding was expected as income was a component of the selection criteria for SES-group assignment. The differences observed in educational attainment were also expected (although not specifically selected for) as education has been shown to be highly correlated with SES (Krieger et al., 1997). The demographic measure of number of people who sleep in the home was not significantly different between socioeconomic groups, although low-SES participants reported greater numbers overall. Finally, participants in the low-SES group

were slightly younger than high-SES participants, but this difference did not reach significance.

Psychosocial Questionnaire

In general, measures obtained from the psychosocial questionnaire did not show significant differences between the low and high-SES groups at the $p<0.05$ level. This was an expected outcome as the sample size was too small to show significance except where the group differences were most extreme. We undertook the exercise of collecting the questionnaire data in order to gain a better understanding of the participants in our study and to inform future research in socioeconomic disparities. When comparing the entire sample of participants, only the emotional well-being scale of the COMQOL Version 5 showed a significant difference between low and high-SES groups. Members of the high-SES group reported significantly higher emotional well-being within the quality of life instrument than low-SES participants ($t=2.75$, $p=0.013$).

Additionally, several other measures showed a trend toward significance including the health and productivity subscales of the COMQOL, as well as our measures of social support and social class membership. In all cases, high-SES participants self-reported higher scores on these measures with the notable exception of our measure of social class membership. Low-SES group members reported, on average, being in a higher social class than high-SES group members. This finding, coupled with the lack of observed relation between the MacArthur Psychosocial Ladder and objective SES, points to an interesting phenomenon regarding self-reported comparative social status. Although this concept needs to be explored systematically, it appears that higher-SES participants (who in reality are more middle-class than upper-class) were significantly more critical of

their status than members of the lower class, and therefore more likely to rate themselves as lower on the social hierarchy. Although speculative, it may be that higher-SES participants have more exposure to the upper-class lifestyle (and therefore know there is much they cannot afford) as compared with lower-SES participants who tend to limit their exposure to areas where they do not "fit in" economically. Future research should explore this concept more thoroughly, as perception of SES has psychological, neurological, and/or health consequences similar to those observed when comparing members of objectively different socioeconomic statuses.

Results from the fMRI-included subsample were similar to those seen in the entire sample, but due to the loss of statistical power, the overall p-values obtained generally were higher. Again, only one measure achieved significance - the productivity subscale of the COMQOL Version 5. High-SES participants reported higher quality of life-related productivity than low-SES participants. Two other measures showed a trend toward significance: the material well-being and emotional well-being subscales of the COMQOL, both with low-SES participants self-reporting lower quality of life in these areas. Although below the threshold of significance, lower-SES participants again reported higher social class membership than high-SES participants, and no relationship was observed between scores on the MacArthur Psychosocial Ladder and objective socioeconomic group status.

Reaction Time to Neuropsychological Activation Paradigm Images

As described in the *Methods* section, participants were exposed to emotionally-valenced images while in the scanner, and were asked to perform a button-press image

classification task identifying complete images from image scrambles. Reaction time was measured for all participants, although several had an excessive number of time-outs, defined as responding to the image (by pressing a button) more than 1500 ms after its presentation. All participants having a large number of timed-out trails (i.e., > 2 standard deviations and above the mean) were removed from the analysis. It should be noted that most participants only timed-out on a handful of trials (range 0 to 197 time outs; mean=38.7), which indicates the possibility that a subset of the participants did not fully understand the instructions. Although it could be argued that only removing participants who timed-out on 30% of the trials or greater (the equivalent of 2 SDs) was not restrictive enough, this cut off point was selected to retain at least a portion of the limited statistical power associated with our sample size.

When analyses were performed on the reaction time data for each of the valence conditions (positive, negative, neutral, and poverty), no significant differences emerged. This held true when performed across groups as well as within SES group (and within the fMRI-included subgroups). When the complete sample was analyzed comparing high and low-SES group means on each condition separately, significant differences were observed for the positive-valenced and poverty-valenced stimuli. In both cases, low-SES participants had longer reaction times on average than high-SES participants. When these analyses were performed with the fMRI-included subsample of participants (with less than 2SD > mean time-outs), the differences observed were no longer significant for any condition.

It should be noted that across conditions, low-SES participants had longer average reaction times than high-SES participants, although in general these differences rarely

reached significance. Previous studies have shown that level of arousal affects reaction times (Broadbent, 1971; Welford, 1980), and in this study we hypothesized that low-SES participants would have greater arousal to images with strong negative valence (negative and poverty conditions) than high-SES participants. In addition, we felt that positively-valenced stimuli might also provoke greater arousal in the low-SES participants, possibly due to anger or jealousy. If we had greater statistical power for these analyses it is likely that these hypotheses would have been borne out.

Post Neuropsychological Activation Paradigm Image Recognition

After the participants were removed from the scanner they were asked to complete a stimulus recognition task using a 2-alternative forced choice (2AFC) button press technique. For three of the four valence conditions (positive, negative, and neutral), images shown in the scanner were presented in random order interspersed with an equal number of distracter images. Using standard signal detection formulae for 2AFC tasks, accuracy, sensitivity, and bias were calculated for each participant. Group averages were then determined for each measure, and between-groups comparisons were performed.

When the entire participating sample was examined, differences in sensitivity and bias were observed for only the neutral-valenced condition. This means that high-SES participants did a better job of separating presented stimuli from distracters, but were more likely to say that an image was a target (part of the stimuli presented in the magnet). When the fMRI-included subset was examined, only the measure of bias for the neutrally-valenced stimuli was significantly different between SES groups.

Overall, both groups showed approximately equivalent performance on this task, although low-SES participants had slightly lower accuracy rates than high-SES participants across all conditions. None of these differences reached significance, and in general both groups performed the task with acceptable accuracy.

Post Neuropsychological Activation Paradigm Image Valence Rating

The final task involved rating the valence of the images presented in the scanner. Images were presented one at a time in random order, and participants rated them from positive to negative. Several observations can be derived from the results. For both the entire sample and the fMRI-included subsample, all stimuli were assigned appropriate valence scores (on average). Positive images were given the most positive ratings, whereas negative and poverty stimuli were given negative ratings. On average, neutral images were rated closest to the neutral value, although these were seen as slightly more positive possibly due to their contrast with the highly-valenced negative and poverty images. ANOVAs performed both between and across groups supported the hypothesis that participants perceived the categories of valence-coded stimuli as significantly different.

These findings were further explored using Bonferroni post-hoc tests. For both high and low-SES participants each stimulus condition was seen as different from the others, with the exception of the negative and poverty-valenced conditions. This was an expected finding as both conditions involved highly aversive images and were expected to receive negative valence ratings.

In addition, when analyzing the results from the entire participating sample, low-SES participants did not significantly distinguish the positive and neutral-valenced stimulus conditions ($p=0.063$). Although these results approached significance, it may be that members of the low-SES sample were hypo-responsive to positive imagery, making their valence ratings closer to the neutral stimuli. It should be noted that when this analysis was performed with the fMRI-included subsample, the difference between the positive and neutral valenced conditions reemerged. This finding suggests that the lack of difference seen in the complete sample was not due to poor statistical power, although the instability of the findings sheds doubt on its robustness.

Neural Activations

As can be seen from the images presented in the *Results* section, large differences in neural activation were obtained when comparing low and high-SES participants exposed to emotionally-valenced visual stimuli in the scanner. Many of the significant differences shown were present in the hypothesized ROIs (i.e., limbic regions), as well as in areas indicating differences in both high-level executive functions (e.g., frontal cortex) and low-level processing of stimuli (e.g., occipital cortex). It should be noted that throughout the *Discussion* section, we use the term "deactivation" to denote instances when the low-SES group demonstrated significantly reduced activity in a neural region compared with the high-SES group. While this terminology may be considered a misnomer by some, it is in keeping with the comparative language employed throughout this section and should be understood in a relative sense (Pruessner et al., 2008).

Negative versus Neutral Conditions

Significant differences in levels of activation were recorded across multiple neural regions when contrasting low versus high-SES participants exposed to negative images in the negative versus neutral contrast condition (see Table 11). Limbic, frontal, and lower-level processing regions all showed activation differences when presented with aversive images.

Low-SES participants demonstrated significantly greater ventral limbic activation, specifically right antero-medial hippocampal/parahippocampal, during processing of negatively-valenced stimuli. This region has been extensively studied and implicated to mediate complex emotional memory associational processing (Britton & Taylor, 2006; Daselaar et al., 2008; Gillath, Bunge, Shaver, Wendelken, & Mikulincer, 2005; Medford et al., 2005; G. D. Smith, Henson, Dolan, & Rugg, 2004). The differences seen here suggest that the low-SES participants had significantly increased emotional responses to negative stimuli compared to high-SES participants. We hypothesize that this was related to greater cumulative exposure to negative environmental stimuli prior to participation this study.

Further, low-SES participants showed greater activity in the right insula during negative visual stimulus processing. Several lines of evidence implicate the insula as a key cortical relay and integration center for heteromodal sensory, visceral, autonomic, and limbic information processing (Cabeza & Nyberg, 2000; Eickhoff et al., 2006; Mesulam & Mufson, 1982a; Schienle et al., 2006). The insula receives highly processed association cortex input, and is richly interconnected with subcortical limbic and autonomic regions. The insula is therefore poised to serve as a neural substrate mediating

reciprocal modulation of cognitive, emotional, and cerebrogenic autonomic control (Mesulam & Mufson, 1982a, 1982b). Such integrative modulatory function has significant relevance for understanding both normal mentation and disturbed homeostatic processes (Nagai, Kishi, & Kato, 2007). The insula is believed to process convergent information to produce an emotionally relevant context for sensory experience. Functional imaging experiments have revealed that the insula plays an important role in pain and the experience of a number of basic emotions including anger, fear, disgust, and sadness (Mataix-Cols et al., 2008; Stark et al., 2007). The increased activity observed in response to negative versus neutral stimuli may represent the intensity with which the low-SES participants experienced the negative images, and may represent the primary relay to increased somatic activation.

In addition, greater activation was seen in the caudate. The caudate sits astride the thalamus and has been demonstrated to be directly involved in stimulus-response (S-R) learning, especially feedback processing (Graybiel, 2005; Packard & Knowlton, 2002). The caudate has been shown to be activated during the recognition of items that were encoded within a negative emotional context (Erk, Martin, & Walter, 2005). Several studies have dissociated the role of the basal ganglia in stimulus-response learning from that of a cognitive or declarative medial temporal lobe memory system that includes the hippocampus as a primary component. Evidence suggests that during learning, basal ganglia and medial temporal lobe memory systems are activated simultaneously (Packard & Knowlton, 2002). In the case of the low-SES participants in this study, both of these regions were simultaneously activated in response to negative versus neutral imagery. This reinforces the theory that these participants have a higher overall exposure to

negative stimuli in their daily environment, so much so that they may have developed a S-R basic behavioral response to that imagery. The likely somatic responses to such stimuli include increased HPA-axis activity (associated with heightened cardiovascular activation) and physical stress associated with that state.

Low-SES participants also demonstrated enhanced bilateral pontine activity during processing of negatively-valenced visual stimuli. Although the local activation maxima localize to the dorso-lateral region of the mid-pons, the nearest nuclei providing potential sources for these activations are the locus cerulei. The locus ceruleus is the principal source of noradrenergic neurons in the CNS, and has been extensively implicated in both diffuse CNS modulation and efferent autonomic outflow (Chrousos, 2000; Devilbiss, Page, & Waterhouse, 2006; Jankovic, Jovanova-Nesic, & Nikolic, 1993; Sterpenich et al., 2006). Further, the locus ceruleus has recently been identified as an important component of the anxiety circuitry (Itoi, 2008). That the locus cerulei would show greater activity in low-SES participants during negative information processing suggests that these neurons provide a pathway by which negative stimuli can affect both central processing and somatic states, especially in conjunction with increased hippocampal and insula activation. If the activity in these regions is increased with high frequency, the likely result would be amplified allostatic load, and the damage associated with spending excessive time in that state (D. S. Goldstein & McEwen, 2002; McEwen, 2000). This may be a key relay transducing the increased emotional response to negative stimuli into deleterious somatic activation.

Unexpectedly, low-SES participants showed greater activation of the middle occipital gyrus, a sensory cortical area in the medial and lateral portions of the occipital

lobe. This area is part of the extrastriate visual cortex that surrounds the primary visual cortex, and is known as a visual association area, with feature-extracting, shape recognition, attentional, and multimodal integrating functions (Hyvarinen, Carlson, & Hyvarinen, 1981; Orban, Dupont, Vogels, Bormans, & Mortelmans, 1997). Although differential activity in this region was not hypothesized, it is interesting that differences were seen, as this region is involved in low-level visual processing prior to integration with higher-level cognitive and emotional circuits. Although speculative, this finding suggests that low-SES participants are initially processing negative images differently than high-SES participants.

Turning to the higher-order functions, a significant deactivation was seen in low-SES participants in the superior frontal gyrus at Brodmann area 8 during processing of negatively-valenced visual stimuli. This area has been shown in an fMRI study to be involved in the management of uncertainty, and with increasing uncertainty there is increasing activation (Volz, Schubotz, & von Cramon, 2005). Also, this region has been shown via lesion studies to be involved in higher cognitive functions such as working memory (du Boisgueheneuc et al., 2006). An alternative interpretation is that this activation in frontal cortex encodes hope, a higher-order expectation positively correlated with uncertainty (Chew & Ho, 1994), as well as emotional expectancy (Bermpohl et al., 2006).

The combination seen here of deactivation in the superior frontal gyrus and increased hippocampal and caudate activation has been previously observed in a study of simulated negative face-to-face interactions, which showed that such activity was correlated with subjective emotional responses (Prohovnik, Skudlarski, Fulbright, Gore,

& Wexler, 2004). Because stimuli in our study were presented in a blocked design, it is possible that an expectancy for negative imagery was created during negative blocks, coupled with enhanced negative emotions in the low-SES sample. This increased expectation of negative stimuli (and consequent reduction in hope) appears to profile the state of being for the low-SES participants, with increased expectation of and response to negative stimuli.

Taken together, these results show that low-SES participants have an overall more negative experience when exposed to aversive stimuli than higher-SES individuals. Evidence for increased emotional response as well as emotional memory when shown similarly-valenced images points to a greater familiarity with negative elements in the daily environment. Further, an increased response in integrative and relay circuitry strongly implies a somatic component when exposed to negative stimuli, which when combined with a greater frequency of such stimuli, may be a component connecting SES and morbidity/mortality as seen in epidemiological studies (Kawachi & Kennedy, 1997; Lynch, Kaplan et al., 1998; Ram, 2006; Sorlie, Backlund, & Keller, 1995).

Poverty versus Neutral Conditions

Several of our hypothesized ROIs showed significant activation differences when contrasting low versus high-SES participants exposed to images of impoverished circumstances in the poverty versus neutral contrast condition (see Table 12 above). Once again, differences were observed in limbic, frontal, relay, and lower-level processing regions, although in a different overall pattern than seen in the negative versus neutral contrast.

Low-SES participants demonstrated significantly greater hippocampal/parahippocampal activation during presentation of poverty stimuli than high-SES participants. This may indicate increased mediation of emotional memory associational processing during poverty-specific stimuli trials (Britton & Taylor, 2006; Daselaar et al., 2008; Gillath et al., 2005; Medford et al., 2005; G. D. Smith et al., 2004). These differences again indicate that low-SES participants have an increased emotional response to negative stimuli, with large differences seen for the poverty-centric stimuli.

Also, a significant increase in activation was observed in the fusiform gyrus bilaterally. The fusiform gyrus is considered a key region of visuo-linguistic (Pernet, Celsis, & Demonet, 2005), visuo-emotional (Kensinger, Garoff-Eaton, & Schacter, 2003), and other complex higher visual associational processing (Simons, Koutstaal, Prince, Wagner, & Schacter, 2003; Sugiura et al., 2005). Increased activation the of fusiform gyrus has also been associated with individual assessment of extreme valence (Gerber et al., 2008) and encoding of negative information (Kensinger & Schacter, 2008). This finding is coupled with the observation that low-SES participants showed significantly greater activation in the middle occipital gyrus. Once again, differential activity in this region was not hypothesized as it is generally regarded as a low-level preprocessing region, but in combination with fusiform activation suggests a linkage of the visual imagery associated with poverty and higher-order visual and emotional processing.

Further, increased activation in the thalamus was observed in low-SES participants. Historically, the thalamus has been considered a relay point within the cortex, transmitting peripheral sensory information and subcortical information to higher-

order regions, but more recently it has been hypothesized that the thalamus also plays a significant role in relaying higher-order information (Sherman, 2007). New research points to the fact that many of the driver afferents to the thalamus have branches innervating extrathalamic subcortical sites including the midbrain, pons, and spinal cord (Bourassa & Deschenes, 1995; Bourassa, Pinault, & Deschenes, 1995), implying that the thalamus works in parallel coordinating higher and lower-order neural information (Sherman, 2007). It is likely in this case that the thalamus and fusiform gyri are acting to coordinate lower-level visual information from the occipital cortex with higher-level emotional processing in the limbic regions. This processing is most likely linked to highly-charged emotional memory (probably via increased prior exposure to poverty circumstances), and may have an effect on somatic functioning via the thalamus through subcortical connections to homeostatic maintenance systems (e.g., via the pons, and spinal cord).

Unexpectedly, significant deactivations were seen in the amygdala of low-SES participants when exposed to poverty versus neutral stimuli relative to the high-SES participants. The amygdala has long been implicated in the encoding and retention of memories for events that signal threat, and in the learning and consolidation of fear memories. For example, ratings of emotional intensity to visual stimuli have been shown to be significantly correlated with amygdala activation (Canli et al., 2000), although other research has shown that reduced activity in the amygdala accompanies increased arousal to expressive faces (Gerber et al., 2008). The amygdala also interacts with cortical regions to mediate other aspects of emotional memory including encoding and consolidating unpleasant arousing events into long-term memory, the narrowing of focus

on central emotional information, retrieval of prior emotional events and contexts, and the subjective experience of recollection and emotional intensity during retrieval (Labar, 2007; LeDoux, 1993). This finding may show a hypo-responsivity to poverty-related visual images in low-SES participants, although it also may mean that high-SES participants had a spike in activity when shown images of severe poverty. Although this finding is counter to our original hypothesis, it is likely that images of poverty are more threatening to high-SES than to low-SES individuals, who are exposed to similar imagery on a regular basis, possibly accounting for the relative decrease observed in the low-SES versus high-SES sample.

Significant deactivations were observed in the low-SES participants in the superior frontal gyrus during exposure to this contrast condition. The superior frontal gyrus and surrounding region are known to contribute to higher cognitive and executive functions as well as working memory (Boisgueheneuc et al., 2006). Goldberg and colleagues provided evidence that the superior frontal gyrus is involved in self-awareness, in coordination with the action of the sensory system (I. Goldberg, Harel, & Malach, 2006).

Taken together, these findings appear to map the neural circuits involved in emotionally-valenced image processing from initial visual processing of the poverty-specific stimuli to both higher-order emotional activation and executive function. Low-SES individuals showed an increased emotional response to images of poverty (as seen through increased hippocampal/parahippocampal activation), but a relatively reduced threat response (via reduced amygdalae response) and depressed self-awareness. Although hypothetical, these findings may represent the pattern of neural activity present

in individuals who have undergone a prolonged period of increased allostatic load, showing both emotional hyper-responsivity to provocative but familiar stimuli, coupled with relative hypo-responsivity in systems registering fear and threat. Further, these responses were coupled with deactivation in the superior frontal cortex, possibly indicating a "distancing" of the self from the stimulus – potentially a coping mechanism or habituation to continued exposure to poverty environments.

Poverty versus Negative Conditions

An important study goal was to show that poverty stimuli were not simply a subset of negative imagery, but represented a different category with corresponding neural activations in low-SES populations. Indeed, when we investigated neural responses as participants viewed poverty versus negative images, several significant differences were observed (see Table 13).

Significant deactivations were seen in the parahippocampal gyrus and amygdala in low-SES participants when comparing poverty and negative stimuli. This finding appears counterintuitive, as these brain regions are generally activated when encoding and remembering emotionally-valenced stimuli (Britton et al., 2006; Canli et al., 2000). One possibility is that this finding is related to a dysfunction of the neural systems in participants regularly exposed to poverty-related conditions. In a study of adolescents with antisocial behavior, a reduction in amygdala and hippocampal activation was observed when patients were exposed to images with strong negative valence after correcting for symptoms of anxiety and depression (Sterzer, Stadler, Krebs, Kleinschmidt, & Poustka, 2005). The authors suggested that these findings reflected an impairment of both the recognition of emotional stimuli and the cognitive control over

emotional behavior in patients with antisocial behavior, with the result being an increased propensity for aggression. Although aggressive and antisocial behaviors were not investigated in this study, they are observed with higher frequencies in low income samples (Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006). Although we would not hypothesize that growing up in a low-SES environment is necessarily related to violent and antisocial behavior, the similar pattern of findings observed by Sterzer et al. implies that repeated exposure to negative circumstances leads to similar dysfunction in emotional information processing as in our low-SES sample. This is a potential avenue for future research, and the differential processing of poverty versus general negative images needs to be more thoroughly explored.

Alternatively, many of the negative IAPS images may have been novel to an urban, low-income population (e.g., a snake in the grass) whereas the poverty images were likely familiar to this group. It is possible that for the low-SES participants, the negative images were unfamiliar and thus more provocative than the poverty images. Conversely, images of poverty and impoverished circumstances may be highly threatening and aversive to a higher-SES population, increasing the activations seen in the limbic regions within that group. Further, a significant deactivation was seen in the superior frontal gyrus in the low-SES versus high-SES participants when examining the poverty versus negative condition. Again this may represent a "distancing" of the self from the poverty stimuli, showing greater frontal activations to the more novel negative images.

Positive versus Neutral Conditions

The final contrast condition analyzed was positive versus neutral stimuli. This contrast was selected to determine whether low-SES participants showed exaggerated responses to negative stimuli only, or also had reduced responses to positive stimuli. Several ROIs showed significant activation differences when contrasting low versus high-SES participants exposed to positive versus neutral IAPS images (see Table 14). Overall, most of the significant differences were deactivations, and included areas such as the anterior cingulate, fusiform gyrus, and frontal regions, with a few notable exceptions.

One exception was the significantly increased activation in the insula of low-SES versus high-SES participants when viewing positive versus neutral images. As described above, the insula is a key cortical relay and integration center for heteromodal sensory, visceral, autonomic, and limbic information processing (Cabeza & Nyberg, 2000; Eickhoff et al., 2006; Mesulam & Mufson, 1982a; Schienle et al., 2006), and imaging experiments have shown that the insula plays a major role in the experience of anger, fear, and disgust (Mataix-Cols et al., 2008; Stark et al., 2007). This finding implies that low-SES participants may be having an intense negative reaction to positive imagery, potentially showing signs of disgust to pictures with highly positive valences.

Low-SES participants showed decreased activation in the anterior cingulate cortex (ACC). The ACC has been shown to have executive, evaluative, and emotional functions (Bush, Luu, & Posner, 2000). The ACC is connected to the prefrontal and parietal corticies, as well as to the motor system and frontal eye fields (Posner & DiGirolamo, 1998), making it a central station for processing top-down and bottom-up stimuli and assigning appropriate control to other areas in the brain. The ACC is thought

to be involved when effort is needed to carry out a task such as in early learning and problem solving (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001). Studies attribute functions such as error detection, anticipation of tasks, motivation, and modulation of emotional responses to the ACC (Allman et al., 2001; Bush et al., 2000; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001). The deactivation seen in this region may represent modulation of a positive emotional response resulting in an increased negative evaluation of these images. Further, this finding may represent reduced motivation when exposed to positive imagery in the low-SES sample.

In addition, low-SES participants showed decreased activation in the left fusiform gyrus when exposed to positive images. The fusiform gyri have been implicated in visuo-emotional (Kensinger et al., 2003), and other complex higher visual associational processing (Simons et al., 2003; Sugiura et al., 2005). This may be coupled with the finding of significant deactivation in the medial frontal gyrus in low-SES participants when viewing positive images. The medial frontal gyrus is implicated in adaptive goal-directed behavior, involving the monitoring of ongoing actions and performance outcomes, and then subsequent adjustments of behavior and learning (Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Evidence suggests that the detection of unfavorable outcomes, response errors, response conflict, and decision uncertainty elicits largely overlapping clusters of activation foci in the medial frontal cortex (Gehring & Fencsik, 2001; Rushworth, Walton, Kennerley, & Bannerman, 2004). Since the 2AFC button press task employed in this study was designed to be easy to complete (which was confirmed by the lack of recorded errors), it is unlikely that the deactivations observed were tied to task performance. Instead, it is likely that we observed an increase in

evaluative emotional conflict with repeated exposure to positive images in the low-SES sample.

As can be seen in the images presented in this contrast condition and Table 14, large portions of the frontal and temporal gryi were significantly deactivated in the low-SES sample compared with the high-SES sample when viewing positive stimuli. Such sweeping differences may imply clinical-level dysfunction in the low-SES sample akin to that seen in depression or PTSD. Studies of patients diagnosed with major depression have shown simultaneously altered activation in the ACC and frontal cortex, which is considered to be a key feature of this disorder (Frodl et al., 2007). Further, in a script-imagery study of patients diagnosed with PTSD, reduced ACC and frontal activation was seen in conjunction with increased insula activation in PTSD-diagnosed subjects, approximating our findings (Lanius et al., 2007). Although we cannot claim that low-SES individuals are by definition traumatized or depressed, these findings strongly suggest that living in an impoverished circumstance has an overarching effect on the processing of positive-valenced imagery.

Conclusion

We investigated the relationship between socioeconomic status and health using neural imaging techniques. We hypothesized that low-SES individuals would differentially process emotionally-charged information in a manner associated with increased somatic activation, and in turn, increased physiological stress. Overall we saw extensive differences in the processing of highly-valenced images when comparing our low and high-SES samples, differences which implied concurrent somatic activation. Although an initial attempt to elucidate the manner in which poverty "gets under the

skin," these findings set the groundwork for research into the cognition of SES and its relationship to various health outcomes.

The 22 participants enrolled in this study represent an appropriate starting point for this research. As African Americans living in the New York City boroughs of Manhattan and Brooklyn, our participants represented two sides of the urban situation -- low-income individuals (drawn mainly from the east Harlem area) and middle-class individuals. Responses to questionnaires revealed that the high and low-SES samples were basically equivalent in terms of psychosocial standing, with the expected exception of household income and educational attainment. Although a larger sample may have revealed differences on some of the psychosocial and behavioral measures collected, it is clear that large differences were not present in our participants. Given these non-significant results, it was intriguing to observe the vast differences in neural activations between these groups when participants were exposed to the identical provocative imagery.

A few interesting findings did emerge when comparing the psychosocial questionnaire responses. Of note was the lack of relationship between self-reported social standing via the MacArthur Psychosocial Ladder (Goodman et al., 2001; John, 2001a) and objective economic standing as measured via household income, neighborhood in which participants were raised, and educational attainment. This finding may lead to further investigation into how perception of one's social standing can affect neural functioning as well as health outcomes. Further, it may imply a lack of insight on the part of our participants as to how they compare economically with other members of the community, although more subtle internal factors might be influencing this measure such

as self-esteem and feeling of relative importance in the community, factors not directly associated with economic standing.

As for the lack of group differences in both the recognition and reaction time data, again a larger sample may have increased statistical power to reveal significant differences where only small trends were presently observed. Overall, however, our results showed that both groups were cognitively sound and sufficiently able to complete the experimental tasks. Again, this finding increases the value of the neural differences observed, as it suggests that even though both groups were able to function adequately, under the surface enormous differences exist in how they perceive and process emotionally-valenced images. Further, the lack of differences observed for the post-task valence ratings of these images increased the strength of this observation. Although consciously seen as essentially equivalent in both the high and low-SES individuals, these stimuli had vastly different effects at the neural level.

The primary goal of this study was to explore neural activation differences in low versus high-SES individuals as they were exposed to emotionally provocative information. The underlying hypothesis was that low-SES individuals would show increased activation in regions associated with emotional processing when presented with highly-valenced negative images (i.e., limbic regions) (Britton & Taylor, 2006; Canli et al., 2000; Daselaar et al., 2008; G. D. Smith et al., 2004). Further, we expected that activation differences would be seen in areas associated with modulating emotional control (i.e., frontal cortices) and with the transduction of emotional states into physiological changes in the HPA-axis and immune system (i.e., caudate, thalamus, and locus ceruleus) (Bourassa & Deschenes, 1995; Bourassa et al., 1995; Chrousos, 2000;

Devilbiss et al., 2006; Jankovic et al., 1993; Packard & Knowlton, 2002; Sterpenich et al., 2006). In the end, all of these regions showed significant differences when comparing the low-SES participants to a (relatively) high-SES sample, although the pattern of findings was more complex than expected.

As hypothesized, low-SES participants had increased limbic and insula activity when viewing negative versus neutral images, indicating an increased negative emotional response to these stimuli (Britton & Taylor, 2006; Cabeza & Nyberg, 2000; Medford et al., 2005; Mesulam & Mufson, 1982a; Schienle et al., 2006). Further, greater activation was seen in the pons, locus ceruleus, and caudate when low-SES participants were exposed to negative versus neutral imagery, implying a transduction mechanism linking increased emotional response to somatic activation (Bourassa & Deschenes, 1995; Bourassa et al., 1995; Chrousos, 2000; Devilbiss et al., 2006; Jankovic et al., 1993; Packard & Knowlton, 2002; Sterpenich et al., 2006). Although we lack direct evidence that the increased activation seen in these regions had an effect on physiological processes, these areas are known to be involved in the integration of emotion and physical response (Chrousos, 2000; Devilbiss et al., 2006; Graybiel, 2005; Jankovic et al., 1993; Packard & Knowlton, 2002; Sterpenich et al., 2006). This is an area that requires further exploration, and an appropriately designed study may be able to more deeply explore and define this connection.

When considering the results of the poverty versus neutral contrast condition, findings again revealed increased limbic activation, accompanied by fusiform and thalamic increases. Here increased hippocampal activation relates to enhanced emotional memory for low-SES participants (LaBar & Cabeza, 2006), while thalamic activations

may act to coordinate the physical state with this increased level of arousal (Bourassa & Deschenes, 1995; Bourassa et al., 1995; Britton & Taylor, 2006; Daselaar et al., 2008; Medford et al., 2005). The remaining results from this condition were unexpected and warrant further exploration. Low-SES participants showed relative deactivation of both the amygdalae and frontal cortices. Although not hypothesized, this finding may correspond to levels of exposure to poverty-related stimuli, with high-SES participants showing increased emotional intensity compared to low-SES individuals who have habituated to poverty images because they are present in their daily environment. Evidence for this association is currently lacking, but future studies can be designed to explore this possibility.

What is certain when viewing the results from these contrast conditions is that poverty images are not simply a subset of negative imagery to low-SES individuals. We compared neural activations seen in the poverty and negative stimuli conditions, and again found unexpected results. Low-SES participants had significant deactivations in limbic and frontal regions compared with high-SES subjects when viewing poverty versus negative images. Again this supports the idea that low-SES individuals are less disturbed by the poverty imagery than general negative images (at least when compared to the high-SES group). This finding requires further exploration, and future studies can be designed to elucidate this phenomenon.

The final contrast condition was positive versus neutral images. Although we expected to observe decreased activity in low-SES individuals when viewing positive imagery, the vast levels of attained differences were beyond what we hypothesized. Interestingly, low-SES participants showed increased insula activity when viewing

positive images, which could be interpreted as "disgust" (Mataix-Cols et al., 2008; Stark et al., 2007). Although we expected a frame-shift in emotional perception for low-SES individuals where all information would be seen in a more negative light, the intense reaction against positive stimuli was unexpected. The low-SES individuals appear to have been disturbed by seeing picturesque scenes and images of happiness. Further, large deactivations were seen across the frontal and temporal cortices, as well as in the fusiform gyri and ACC. Such large distributed differences have been associated with psychopathology such as depression (Nikolaus, Larisch, Beu, Vosberg, & Müller-Gärtner, 2000), and imply a lack of ability in low-SES individuals to perceive positive information appropriately. This may represent an important finding, and further exploration is warranted.

Overall, this study accomplished a portion of its goal, which was to elucidate the relationship between SES and health by mapping the neural differences in the perception of emotionally-valenced and neutral stimuli in low-SES individuals. As research has yet to explain the robust link between SES and health (Lantz et al., 2001), it may be reasonable to postulate that the observed neural processing and the hypothesized related somatic changes are a primary cause. To our knowledge, this was the first study to explore the relationship between SES and health using an fMRI approach. Our findings revealed significant and potentially meaningful differences in the manner in which low-SES individuals perceived and processed emotionally-charged information as compared to high-SES individuals. Although we were unable to link these differences directly with physiological changes and altered health outcomes, we have taken an important first step toward mapping this relationship. These findings have significant implications, as

impoverished environments represent a greater threat to health than any other single factor in the first world (more than diet, access to healthcare, and smoking). Therefore, understanding the manner in which impoverished environments impact morbidity and life-expectancy is of critical importance.

Limitations

When interpreting the study results, several limitations must be acknowledged, particularly with regard to the sample selected for this pilot study. First, the limited size of the sample calls into question the robustness of our findings. Further, all of the participants were of African-American descent and drawn from urban populations, limiting the generalizability of these findings to other ethnic groups and rural populations. Recent research has shown differences in relative brain volumes and white matter hyperintensity burden in African American versus Caucasian populations (Brickman et al., 2008). Also, we did not screen for several factors that can potentially impact neural activations (e.g., ADHD and asthma) (Rosenkranz et al., 2005; Ströhle et al., 2008).

In addition, it is highly probable that the differences in neural activations seen in this experiment were the result of long-term exposure to adverse environmental conditions. This implies that these differences have a developmental time course that cannot be detected in a cross-sectional experimental design, and are variable due to several factors including length and intensity of exposure to conditions of poverty and age of study participants. Further, this study lacked direct measures of somatic response to aversive stimuli. This is a major limitation as we were trying to draw a parallel

between differential neural activations and (theoretically associated) health outcomes, but lack the means to directly observe any connection.

Further, our sample consisted of both males and females in unequal proportions. Previous research has shown that males and females have different neural responses to stress (Kajantie & Phillips, 2006; Kudielka & Kirschbaum, 2005), although results vary according to the type of stress-inducing task employed (Stroud, Salovey, & Epel, 2002). For example, in an fMRI study of 32 male and female subjects in which stress was induced using a mental arithmetic task, increased activation was seen in the limbic system including the insula and cingulate cortex in female compared to male subjects (Wang et al., 2007). In addition, hormonal cycles including the female menstrual cycle have been shown to influence HPA activity and arousal circuitry (Bradley, Cogispoti, Sabatinelli, & Lang, 2001; Fernandez et al., 2003; Roca et al., 2003). In a recent fMRI study of 12 premenopausal women scanned at two points in their menstrual cycle (early follicular menstrual cycle phase and late follicular/midcycle period), cycle-phase dependent activation differences were seen in the amygdala, hippocampus, orbitofrontal cortex, and cingulate gyrus when subjects were exposed to negative IAPS images (J. M. Goldstein et al., 2005).

We originally deigned this study to include only women to eliminate potential confounding effects of gender-related differences in neural responses to stress and emotionally charged stimuli. Unfortunately, the IRB committee at Mount Sinai deemed it unethical to exclude low-SES males; therefore, we recruited both males and females for the study. Due to our limited sample size we were unable to segregate our sample to see

if our findings were gender-specific, but future studies with more subjects should permit such analyses.

In addition, we employed a block-design task as our imaging paradigm. Several investigators consider an event-related design to be more sensitive when comparing emotionally-valenced stimuli, as block designs allow for expectation of a specific condition to occur within each block. We employed a block design as it seemed appropriate, especially considering the need to maximize detection power when examining a previously unexplored hypothesis. Future studies may be developed using an event-related or mixed study design to remove the possibility of expectation tainting the results.

Finally, it is possible that the stimuli used for this study were insufficient to evoke an intense enough response to observe neural activation differences actually present in the daily lives of low-SES versus high-SES individuals. No set of images can replicate the daily experiences faced by low-income African American in New York City nor the response to such circumstances in non-impoverished individuals. Future studies should validate stimuli in the specific population being studied to ensure that they are appropriately emotionally provocative to induce the ideas being explored.

Future Research

As this is a pilot study in a yet-unexplored research area, there is extensive room for future research. Areas that require further exploration include a closer examination of potential transduction mechanisms linking neural activations to somatic effects, an examination of these effects in other populations, and documentation of the developmental time course of the observed differences. Specifically, this line of research

would benefit greatly from relating somatic factors such as heart rate variability, galvanic skin response, cortisol levels, and other physiologic measures to functional differences in the neural system to clarify the mode of transduction of negative emotions into somatic changes. Further, exploring a wider range of individuals, including other ethnic groups, age groups, and non-urban populations, would greatly enhance the generalizability of these findings.

In addition, future research could explore the differences seen in low-SES individuals exposed to poverty-specific versus generally negative stimuli. To truly get a handle on the issues involved in the link between SES and health, a longitudinal study is required that tracks a large and diverse sample of children as they grow into adulthood. Obviously, such a study would be difficult and expensive to execute and would have many confounding factors that would need to be measured and controlled for. Such a study could consider many of the factors not included in this pilot study, such as the effect of self-perception of social status on neural activations and health outcomes or the effect of shifting fortunes throughout the course of an individual's life.

Volunteers Needed for an MRI Study

African-American individuals are needed for an MRI research project at the Mount Sinai School of Medicine. To participate, **you must be 20 to 25 years old, right handed, earn less than $10,000 per year, and without serious medical conditions or substance/alcohol abuse.** The research will take approximately 4 hours and will involve interviews and brain imaging. There are no medications, radiation or invasive procedures involved in this study.

Participants will be reimbursed for their inconvenience.

In addition, free confidential psychological evaluation and treatment referral are available.

For more information, please call Pam Burke at (212) 305-1376.

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Volunteers Needed for an MRI Study

African-American individuals are needed for an MRI research project at the Mount Sinai School of Medicine. To participate, **you must be 20 to 25 years old, right handed, earn more than $40,000 per year, and without serious medical conditions or substance/alcohol abuse.** The research will take approximately 4 hours and will involve interviews and brain imaging. There are no medications, radiation or invasive procedures involved in this study.

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Normal Control Screening Sheet – Pre-scanning Information

This study examines the long-term effects of a low-income environment on health. We plan to show our participants pictures of wealth and poverty in an attempt to see how the brain thinks about ideas relating to wealth and income, and how these thoughts affect the body.

Those who agree to participate will be asked to come to a laboratory in Lower East Harlem. There, participants will first be asked to fill out a questionnaire. This should only take about 15 minutes. Then participants will then be asked to enter a machine that takes pictures of the brain with a magnet. While in the machine we will show the pictures and ask you to do a simple task. This portion of the study should take no more than 45 minutes. The machine is completely safe as long as the participant has no metal in his or her body. Overall, you should plan on being in the laboratory for 2 hours. You will be paid $150 for participating. In addition, we will notify you if any medical conditions are found. If a condition is found, you will be referred to receive medical care.

The study will be conducted in 3 parts. This part of the study will examine only African-American subjects who are born in the United States. Other phases of the study will examine members of other ethnic groups and races. We use only one race at a time because we believe that racial discrimination interferes with the way that the brain thinks about wealth and poverty. Using only one race at any given time allows us to reduce interference produced by racial discrimination.

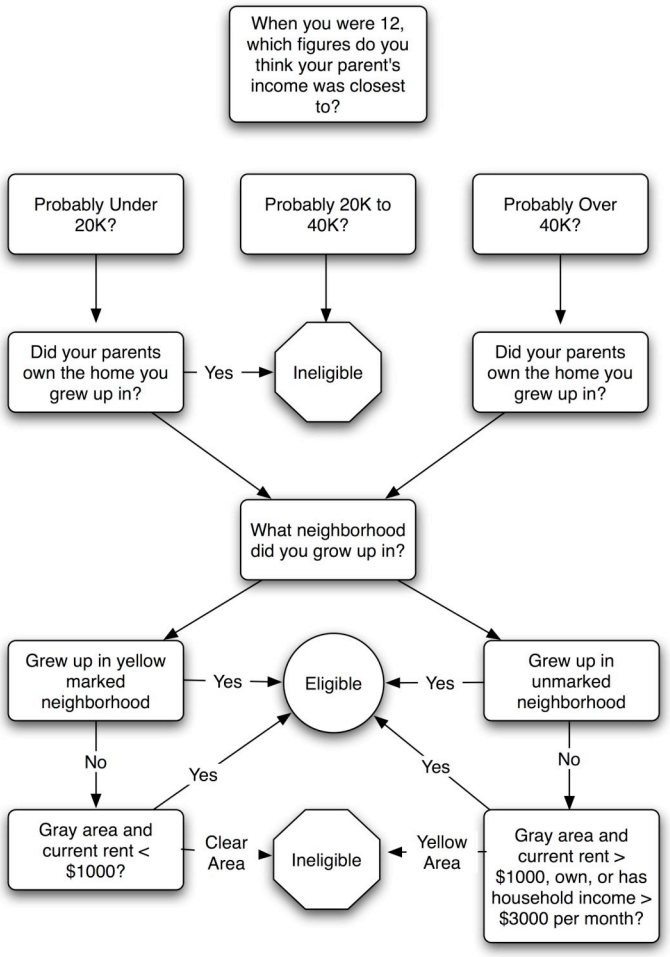
If interested, we need to ask some questions over the phone to make sure you are eligible. Of course, all of this information will be held confidential.

Inclusion/Exclusion Questions:	**Yes**	**No**
Have you been diagnosed with depression or other mental illness?		
Do you have seizures?		
Have you ever suffered a head injury where you have become unconscious for more than 30 seconds?		
Do you have any metal in your body?		
Do you smoke more than 5 cigarettes a day?		
Will you be able to refrain from using cocaine, marijuana, and other drugs for 10 days prior to the day of the experiment?		
Do you have hair extensions or metal in your hair you would not be willing to remove?		
Do you have a tattoo?		
Do you have non-removable jewelry?		
Do you have any loose dental fillings?		
Are you currently pregnant?		
Have you had unprotected sex since your last period?		
Would you describe yourself as African-American?		
Is English your native language?		
Would you be willing to give urine for pregnancy and drugs?		
Are you between 20-30 years old?		
Are you right-handed?		

Females only: please explain that we only need this information because we are not yet sure if the magnet used in an MRI is safe for a fetus.

Note: if any questions fall within of grey boxes above, subject is ineligible. If all answers fell within unshaded boxes, please proceed to the flowchart on the next page.

Hunts Point - Mott Haven	
High-Bridge - Morrisania	
Crotona - Tremont	
East Harlem	
Williamsburg - Bushwick	
Central Harlem - Morningside Heights	Yellow
East New York	
Fordham - Bronx Park	
Bedford Stuyvesant - Crown Heights	
Greenpoint	
Washington Heights - Inwood	
Sunset Park	
Coney Island - Sheepshead Bay	
Borough Park	
Pelham - Throgs Neck	
East Flatbush - Flatbush	
Rockaway	
Long Island City - Astoria	
West Queens	
NE Bronx	
Bensonhurst - Bay Ridge	
Union Square - Lower East Side	Gray
Jamaica	
Ridgewood - Forest Hills	
Port Richmond	
Canarsie - Flatlands	
SW Queens	
Flushing - Clearview	
Stapleton - St. George	
Kingsbridge - Riverdale	
Downtown Hts - Slope	
Fresh Meadows	
Chelsea - Clinton	
SE Queens	
Bayside - Little Neck	
Greenwich Village Soho	
Willowbrook	
South Beach - Tottenville	Clear
Upper West Side	
Lower Manhattan	
Gramercy Park - Murray Hill	
Upper East Side	
Yellow = poor	
Gray = base on other factors	
Unmarked = wealthy	



Availability: _____

SUBJECT INSTRUCTIONS

-- if have contacts, bring them along with wetting solution
-- bring contacts, if no contacts bring glasses
-- confirm appointment and get number where they can be reached the day before admission
-- please do not use any drugs for 10 days before coming in for the test, and do not smoke or drink large amounts of coffee on the day of the test.

Note to Pam: this is the end of the telephone screen. Please call the lab (Lena 212-241-9369, use GCO# 05-1811) and email Michael Silverman (michael.silverman@mssm.edu) to schedule a screen (any day but Friday, any time but Tuesday after 2:00). Michael can also be reached at 917.579.5667. Once the time and date is set up, please contact the subject to let him or her know. Also, a reminder call a day in advance would be great.

General Information
For day of scan

General Information/Demographics

Name: _____ Date of Birth: ____/____/____
Address: _____ Age: _____
_____ Gender M F

Phone Numbers (*preferred contact number):

work _____ can we leave a message Y N

home _____ can we leave a message Y N

cell _____

Highest Level of Education
____ 1. <high school
____ 2. high school graduate/GED
____ 3. some college/community college/business training
____ 4. college degree
____ 5. Graduate and/or professional training (law, medicine/dentistry) _____

How many people sleep in your household on a regular basis?_____

What would you estimate the total income of everyone in your household to be?_____

Discrimination by Income

Do you feel that people discriminate against you because of your income? Y/N
Do you ever think that others see themselves as “better than you” because they earn more than you? Y/N

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month.** In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

0- Never 1- Almost Never 2-Sometimes 3-Fairly Often 4-Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and “stressed”?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Perceived Neighborhood Scale

Next, we will ask some questions about your neighborhood.

Thinking of your neighborhood, please circle how true each statement is for you.

1- not at all true 2-not very true 3-sort of true 4- very true

1. Overall, I like living in my neighborhood very much.	1	2	3	4
2. I feel like I fit in with the people in my neighborhood.	1	2	3	4
3. The relationships I have with my neighbors means a lot to me.	1	2	3	4
4. If I had the chance, I would like to move out of my neighborhood.	1	2	3	4
5. I believe my neighbors would help me in an emergency.	1	2	3	4
6. Most people who live in my neighborhood would be able to tell if someone was a stranger to the neighborhood.	1	2	3	4
7. My neighborhood is a better place to live than other nearby neighborhoods.	1	2	3	4
8. In the past two years, things in my neighborhood have gotten worse.	1	2	3	4
9. In general, people in my neighborhood do not watch out for each other.	1	2	3	4
10. There are people in my neighborhood that sell drugs	1	2	3	4
11. There are places in my neighborhood where you can buy or sell stolen property.	1	2	3	4
12. There is a lot of violence in my neighborhood.	1	2	3	4
13. There are gangs in my neighborhood.	1	2	3	4

Rosenberg Self-Esteem Scale

Circle the appropriate response (1-5) for whether or not you agree with each statement below.

1- Strongly agree 2- Somewhat agree 3-Agree 4-Somewhat disagree 5-Strongly disagree

1. On the whole, I am satisfied with myself.	1	2	3	4	5
2. At times, I think I am no good at all.	1	2	3	4	5
3. I feel that I have a number of good qualities.	1	2	3	4	5
4. I am able to do things as well as most other people.	1	2	3	4	5
5. I feel I do not have much to be proud of.	1	2	3	4	5
6. I certainly feel useless at times.	1	2	3	4	5
7. I feel that I'm a person of worth, at least on an equal plane with others.	1	2	3	4	5
8. I wish I could have more respect for myself.	1	2	3	4	5
9. All in all, I am inclined to feel that I am a failure.	1	2	3	4	5
10. I take a positive attitude toward myself.	1	2	3	4	5

COMQOL 5: Comprehensive Quality of Life Inventory

This scale has three sections. The first will ask you factual information and the other two will ask how you feel about various aspects of your life.

Section 1:
Please place a check next to answer that most accurately describes your situation.

1.

a. Where do you live?
____a house
____an apartment
____a room

b. How many personal possessions do you own compared with other people?
____more than almost anyone
____more than most people
____about average
____less than most people
____less than almost anyone

2.

a. How many times have you been to the doctor over the past 3 months?
____None
____1-2 times
____3-4 times (about once a month)
____5-7 times (about every two weeks)
____8 or more times (about once a week or more)

b. Do you have any disabilities or medical conditions? (e.g. visual, hearing, physical, etc.)
____Yes
____No

3.

a. How many hours paid work do you do <u>each week</u> (Average over past three months)?
____0 hours
____1-10 hours
____11-20 hours
____21-30 hours
____31-40+ hours

b. How many hours do you spend on formal education each week?
____0 hours
____1-10 hours
____11-20 hours
____21-30 hours
____31-40+ hours

c. How many hours do you spend on unpaid child care each week?
____0 hours
____1-10 hours
____11-20 hours
____21-30 hours
____31-40+ hours

d. In your spare time, how often do you have nothing much to do?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

d. On average, how many hours of TV do you watch each day?
____None
____1-2
____3-5
____6-9
____10 or more

4.

a. How often do you talk with a close friend?
____Daily
____Several times a week
____Once a week
____Once a month
____Less than once a month

b. If you are feeling sad or depressed, how often does someone show they care for you?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

c. If you want to do something, how often does someone else want to do it with you?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

5.

a. How often do you sleep well?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

b. Are you safe at home?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

c. How often do you feel worried or anxious during the day?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

6a. Below is a list of activities. Indicate how often in an average month you do each one.

Activity:	**Number of times per month:**
1. Go to a club/group/society	
2. Hotel/Bar	
3. Watch live sporting events (not on TV)	
4. Church	
5. Chatting with neighbors	
6. Restaurant	
7. Movies	
8. Other:	

b. Do you hold an unpaid position of responsibility in relation to any club, group, or society?
____no (If "no" go to question c)
____yes:
____committee member
____committee chairperson/convener
____secretary/treasurer
____group president, chairperson, or convener

c. How often do people outside your home ask for your help or advice?
____Almost every day
____Quite often
____Sometimes
____Not often
____Almost never

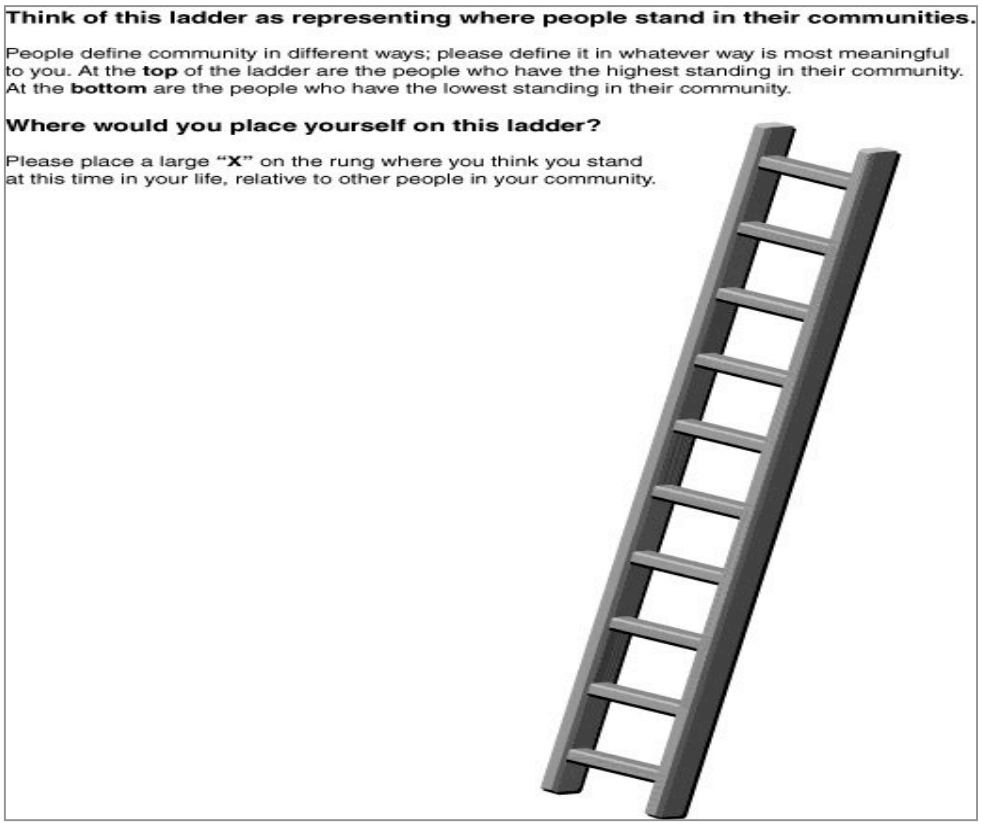
7.

a. How often can you do the things you really want to do?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

b. When you wake up in the morning, how often do you wish you could stay in bed all day?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

c. How often do you have wishes that cannot come true?
____Almost always
____Usually
____Sometimes
____Not usually
____Almost never

MacArthur Psychosocial Ladder



In your community, do you see yourself as rich, middle class, or poor? _____

Social Support

1. Please fill in the total number of people in your life (friends/family) that you feel like you could rely upon to talk to you if you were having a difficult time? ___
2. If you needed $100, how many people close to you (friends/family) do you think would lend you the cash? ___

Negative Life Events

1. In the past 2 years, have you experienced:
    a. The loss of a romantic partner? Y/N
    b. The loss of a job you wanted to keep? Y/N
    c. A move to a neighborhood you didn't want to move to? Y/N

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