The Effects of Socioeconomic Status (SES) on the Developing Neural Networks and Plasticity of the Brain

Ven. Kumbukandana Rewatha Thero,
Department of Philosophy,
University of Kelaniya, Kelaniya, Sri Lanka

&

A. R. Kumaranayake,
Department of Philosophy,
University of Kelaniya, Kelaniya, Sri Lanka

Abstract

This review study aims to analyze and synthesize the available finding on effects of socioeconomic status on the development of neural networks and plasticity of the brain. Adopting an approach to discuss the diagnostic and clinical significance of effects of Socioeconomic Status (SES) on the individual's cognitive neuropsychological development, this study begns by understanding the definitions on associated main terms, synthesizing the research in the designated research area as well as emphasizing the preventive value of abnormal developmental aspects of an individual. Finally the paper examines the possibilities of improving suggestions on individuals with disadvantaged socioeconomic status. The analysis and the synthesis of the available studies show that living in a disadvantaged lower Socioeconomic Status, affects the developing brain networks of the children negatively, causing higher level of insufficiencies as well as disparities in number of cognitive functions. Among those cognitive functions which are negatively affected by lower SES, Language, Executive function, Working Memory, Intelligence becomes the highest vulnerable areas. Further, it was identified

in this research that, in line with the concept of neural plasticity, the affected brain areas due to exposure to lower level of SES, can be improved through psychological and developmental interventions. Comparison studies on higher SES and lower SES children groups show that implementing intervention programs will benefit despites the devastating effects of SES as well as disadvantageous genetic makeup. But, addressing them is highly beneficial during the sensitive periods.

Key Words: Socioeconomic status, neural networks, neural structures, brain plasticity, cognitive functions, poverty

Introduction

Large number of studies which are carried out today on the Negative effects on the developmental aspects of the individual seems to focus on Personality, Emotions, Behavioral outcomes, Bullying, Media violence, Physical as well as Social development, Child abuse anxiety, Birth order, Adolescence, as well as Moral development and Child psychopathology. The effects of the socioeconomic status (SES) on above variables have also been investigated in relatively satisfactory amount of scholarly works which are currently available. However, it seems that only a little attention is paid to examine the association between socioeconomic status and the cognitive neuro developmental aspects (Raizada & Kishiyama, 2010). So, the objective of this review paper is to synthesize the available finding on effects of socioeconomic status on the development of neural networks and plasticity of the brain. Further, this research paper aims to emphasize the practical and scientific barriers to carry out vast array of research in the designated research area.

Researching on the effects of socioeconomic status on the developmental neural plasticity and networks is posing number of aspects which can be considered as those with

highest importance. One of them is to understand the diagnostic and clinical significance of such effects on the individual cognitive neuropsychological development. The other is to emphasize the preventive value of abnormal developmental aspects of an individual. Finally the paper further is interested in examining the possibilities of improving suggestions on individuals with disadvantaged socioeconomic status. So, this research review paper will begin with understanding the definitions on associated main terms, synthesizing some of the research in the designated research areas, and discussing their practical and scientific values as well as barriers and finally it will examine those implications discussed above.

Neural Structures and Brain Plasticity

Human brain's neurons are established as organizations of networks. Through the function of localization, different networks in different brain areas have the ability to perform different functions. The functional specificity of these organizations of neural networks depends on strength of synaptic communication; grey matter volume etc. Brain plasticity refers to the brain's ability to change over time by shifting its functions to diferent neural networks. Brain's ability to reorganize its functioning will be done either by forming new neuronal networks throughout the life or strengthening or weakening the available neural networks. As medicine.net defines, "Brain reorganization takes place by mechanisms such as "axonal sprouting" in which undamaged axons grow new nerve endings to reconnect neurons whose links were injured or severed. Undamaged axons can also sprout nerve endings and connect with other undamaged nerve cells, forming new neural pathways to accomplish a needed function." The reorganization of brain neural networks (neural plasticity) will be done by brain in response to the alterations in their environment (Kass, 2001) or to the behavioral demands (Buonomano & Johnson, 2009).

Socioeconomic Status (SES)

Socioeconomic status is not a purely an individual measure. According to American Psychological Association, it is an individual or a social group's social standing (APA, 2018). When measuring SES, the scientists, preferably, social scientists consider a combination of education, income and occupation (Winkleby, Frank & Fortmann, 1992). An individual or a social group can be compared according to his/her or their standing on socioeconomic status. Being affected by the outcomes of the socioeconomic status, it is possible for the individual or social group to experience inequalities. They are mostly the issues related to power, privileges and control (APA, 2018). Research confirms the idea that SES is positively associated with better health (Baker, 2014). When it considers how it is associated with better health, it involves ability to purchase health promoting materials and treatments, socialization of early health habits as well as how health influences the SES.

Healthier development of neural plasticity of an individual accounts for the better health of an individual. Notably it influences all the aspects of an individual's health. So it is important to understand how a person's SES affects the healthier development of neural plasticity of an individual.

It can be seen that the effects of SES on neural plasticity or at least neural correlates are marginally addressed in brain research. The handful of the studies which are available are also very recent findings. So here, this paper will discuss how neural circuits can be changed by experience.

SES and Development of Brain Plasticity

One of the most influential finding on how environment can change the neural plasticity (i.e. the how SES

alter the brain functioning), is presented by the studies done by Hellen Neville at the University of Oregon. As Merluzzi (2013) presents, Neville's studies based on how brains will shift its functioning of a particular region in case it has either been damaged interfered. She studied people who are born blind or deaf whose occipital cortex is not wired to receive visual signals by default. Conclusions of her studies revealed that their brains are functionally recycled or reorganized to keenly experience other sensory inputs which are tactile or auditory in nature. That is why those individual's such sensory organs are more acute than the other people's. Though this is not directly a study on SES, it indicates that how powerful the environment can model brain functioning differently. One of the most influencing finding of Neville's research is that the argument presented by her as "Disparities in Home environment (being stressful or less stimulating), can account for acute disparities in education, language, as well as intelligence when low SES and high SES children are compared. But Neville challenged the idea that these disparities are genetically imprinted and what she pointed out regarding this is the most important. She said by concluding her research that our brain has the capacity to restructure itself and the condition of those low SES children can be improved by ruling out the disparities (Neville, 2013 as summarized by Merluzzi, 2013).

The processes that takes place under the umbrella term of neuroplasticity includes not only some neurons taking the job of the others (alternations of the functions of neurons) but also formation of new neurons and glial cells (neurogenesis), formation of new connections, and structural alternation of the existing neurons (dendrite remodeling, synaptic formation and elimination and axonal remodeling) (Kays, Hurley, Katherine & Taber, 2012). All of these processes that belongs to neural plasticity accounts for increase or changes in entire brain volume. Though the effects of SES on brain volume has not

widely been studied, Noble, Houston, Kan, & Sowell (2012) examined the neural correlates of socioeconomic status on the developing human brain and their study found that, in a group of 60 socioeconomically diverse children, with respect to the SES, highly significant differences in regional brain volume can be found in the brain regions of amygdala and hippocampus. These two brain regions are considered as critical for the memory and emotional functioning as well as linguistic memories of the humans. So the findings indirectly stand for the idea that SES and learning associated brain stimulation works together in another manner. In other words, we can stand for an argument that "The higher SES accounts for better learning and memory."

Though, the studies on effects of environment on the brain structure and function is not a very old one, the studies which were done approximately two decades ago, were primarily based on animal studies. The recent investigations on humans especially on the topic on Environment on neuroplasticity have been able to pin point to the exact brain region of which the changes takes place due to the effects of environment. In one such study, Lipina and Posner (2012) reviewed the papers on the "Impact of Poverty on the development of brain networks" and their research found that cognitive and imaging studies are indicating which brain region is influenced by poverty. Further, they showed in their review that the neural networks which are hosting for literacy, numeracy and attention are influenced by SES. This also accounts for the idea which this work previously pointed out that the aspects of SES influence how well a child will learn.so it is no need to mention that the neural changes inside accounts for the motor and resulting behavioral changes. in this review, they found that (as Mezzacappa,2004) were able to find, that in a task by which the alerting, orienting attentional networks of

brain show disparities in socioeconomic status even in 6 years old children (Mezzacappa,2004 & Lipina and Posner, 2012).

Usually, the default neural structure of any organism is mainly due to inherited genotype and phenotype. Then we can assume that any of the alterations are partly due to the environment (epigenetics) as well as gene and environment interactions. When the interventions that the professionals employed fall into the category of environment, the effects of interventions can be interesting to understand. In one review study titled "Neuroplasticity of Selective attention-Research foundations and preliminary evidence for a gene by intervention interaction", Isbell et.al (2017), found that exposure to family based training can modify one of the given genotype in their study and neural mechanisms of selective attention when administered on the child from lower socioeconomic status. Up to now, we could understand that not only the SES can have an effect on neural plasticity of developing brain but also such effects can be reversed or altered using intervention methods.

When we examine the studies on effect of socioeconomic status on number of other psychological variables, clear evidences can be found the role of SES as a causal variable. But when it comes to the effect of SES on brain development and its plasticity we have some questions to answer. One of them is how SES does SES relate to brain development and what are the associated mechanisms. To study this, raising the same research questions, Hackman & Farah (2009) summarized number of previous studies which fall under the general category of effects of SES on neurological functioning. In their review, they examined how SES is associated with brain functioning. When analyzed the functioning of brain regions such as left perisylvian, prefrontal, medial temporal, parietal, occipital-temporal which are correspondingly host for language, executive function,

memory, spatial cognition as well as visual cognition, and the researchers found that for each of the variable psychological functioning, disparities are present related to each brain region and their neural networks (Hackman & Farah (2009).

One of the most striking finding in the related literature for my research concern is that the effect of environment, or specially SES, affect not only on a single variable, It affects many other functions and skills of an individual in a continuum , basically by altering the neural circuity for the functions of such a continuum. Knudsen, Heckman, Cameron and Shonkoff (2006), quoted the study by "Institute of Medicine and the National Research Council" who says that every aspect of human development and their neural circuity is affected by environment (experiences). Knudsen, Heckman, Cameron and Shonkoff (2006) summarizing the findings of two intervention programs; Perry Preschool Program and the Abecedarian Program" noted the sample group of participants who were coming from SES wise disadvantaged backgrounds, showed improvements in IQ. As scholars in psychology, it can be said that any increase in a cognitive function is not a simple behavioral demonstration. There should be an underlying neurochemical functioning of a neuronal network. So these findings demonstrate that not only SES affect the neural plasticity of the brain but also the interventions can reverse such negative effects as I have already noted.

As the brain volume is made up of billions of neuron circuits, the larger the brain volume is associated with large number of neuronal circuity plus other intracranial contents. Smaller the brain volume associated with lesser amount of brain circuity and intracranial contents. In a study, which was titled, "The influence of Socioeconomic status on children's brain structure", Jednoróg et.al (2012), described that children's cognitive abilities, language are associated with low SES. Furthermore, they showed in their result that brain

volumes in the certain brain areas are associated with low SES. For example, smaller Grey matter volumes are associated with bilateral hippocampi, middle temporal gyri, left fusiform and inferior occipito-temporal gyri. They concluded that disadvantaged SES have been associated with these kind of negative brain development. Further, explaining the findings, the researchers said that cognitive functions like language, memory and executive functioning are highly influenced by SES. Based on these information what we can say is the underlying neurological structure have the ability to readapt, or be influenced negatively and positively by SES.

The layers of the brain's cortex are made up grey matter while the inner layer is made up of white matter. The content of the grey matter is neurons and glia cells (cell bodies) while the content of the white matter is nerve fibers. In a study to understand the effects of socioeconomic status on the Reading ability in response to intervention, Romeo et.al (2017) assessed reading ability and cortical thickness of the children (65) aged 6-9 years. Their findings revealed that higher SES is associated with greater cortical thickness and greater vocabulary in the bilateral perisylvian area as well as supramarginal regions. Lower SES was associated with improved reading ability as well as greater cortical thickness but only after intervention. So this study stands for the idea that neural plasticity is negatively affected by the lower SES as well as the interventions for positive results in neural plasticity. The negative effects of low SES as well as the SES disparities in brain circuity have been noted even in the studies done by Johnson, Riis & Noble (2016) too.

According to neuroscientists, one of the brain areas in which stress hormone receptors are located is the hippocampus (Stallen, 2017). These receptors are found to mediate between the stimulation and influences made by SES during child's brain development, by affecting a child's short term as well as

long term memory, especially in response to parent's caregiving styles. Scientists have found that having nurturing parents who stimulate the child lessen the impacts of poverty. So these experiences pose a higher influence on the neural circuits of the developing child.

It not a recent finding that an individual's cognitive and affective systems, are based on corresponding neural network's functioning in the brain as SES represent household income, material resources, education and occupation, neighborhood, as well as associated family characteristics (Hackman, Farah & Meaney, 2010); it has been found that SES affects the above mentioned neurocognitive systems more than the other physiological components (Hackman, Farah & Meaney, 2010). According to Hackman et.al, out of those influences, the largest effect is on language functioning while the moderate effect is there on executive functioning and working memory. The role of SES on neural plasticity of executive function has even been documented in the other studies too (Bull et.al, 2011 as referenced by Karbach, 2015).

One of the key ideas associated with the concept of neural plasticity and neural networks is that the remarkable changes that occur due to the influences place on neural plasticity causes notable behavioral changes in later life. According to Kolb, Harker & Gibb (2017), the review paper on neural plasticity and developing brain, they identify four special features associated with concept of developmental plasticity. As they mentioned, the first feature is cells in the sub ventricular zone of the lateral ventricles and dentate gyrus both of which the cells are active throughout life as well as the cells in those areas capable of remodifying , migrating, reforming and establishing new connections throughout life. The second feature that those researchers identified is the three types of plasticity (experience - independent, experience- expectant and experience -dependent). The first type of these types of

plasticity refers to the original nature of established neural connections generated by genome. The second one refers to the condition where the inherited functioning of neural connections are ready to be either strengthened or weakened depending on experiences are received or not. The third type refers to the idea that if connections are strengthened by experiences, will be continued to later life while the other connections will be weakened. This is the point where SES intervenes with the plasticity of developing brain. The third special feature according to the researchers is the idea that dendrites of the neurons can modify their structures either by forming or deleting synapses in response to the experiences. The fourth special feature according to Kolb, Harker & Gibb (2017) is the presence of critical period for these structural changes. In this sense the summery findings identified by Kolb, Harker & Gibb are with a special significance to the literature on neural plasticity. Based on these evidences, we can clearly and scientifically place the previously discussed finding on effects of SES on neural plasticity of the developing brain. Throughout the discussion in their research article, Kolb, Harker & Gibb (2017), discussed the effects of environmental factors (specially SES) like sensory and motor experiences, language and executive functioning, prenatal and post-natal stress, parent child as well as peer relationships, poverty on neural functioning and networks.

The contribution of environment for the neural plasticity and neural networks, especially to the intelligence is also studied. Thomas (2016), reviewed the literature on whether the presented ideas on how more intelligent brains retain heightened plasticity fore longer in development and summarized, different and contrasting viewpoints on the subject area. In the summery of several literature works, Thomas arrived in some of the conclusions. Among them the idea which is directly in line with the present research is “the

individual differences on ability are largely genetically constrained, but correlations between inheritance and environment can be seen". This is supportive of the present work because the plasticity is largely affected by environment (SES) as we have already discussed.

Poverty is one of the prominent criteria which are used as indicative of lower level of SES (Scandrett, 2018). In 2015, in an article titled "Family income, Parental education and Brain structure in children and adolescents" published in Nature Neuroscience, team lead Elizabeth R. Sowell (who has previously also conducted similar studies) have found that higher levels of parental education and family income were associated with increases in the surface area of numerous brain regions (especially those responsible for language and executive functions). According to them Family income level appeared to have a stronger correlation with brain surface area than parental education (Psychology Today, 2015).

When the whole time span of childhood is considered, the crucial and the most sensitive periods for establishing or forming new neuronal connections are said to take place during adolescence where the child is in middle school. Quoting Dr. Jacquelyn Gamino, Psychology Today (2015) says, during this period, bringing up the child in a poor or lower SES can place negative effects on the neural plasticity of the developing brain.

In many of the pieces of relevant literatures, SES falls in the category of natural causes of deprivation that happen to brain structure. In line with this kind of conceptualization, some of the researchers examined the roles of enriched rearing environments on the brain plasticity mostly of animals in the studies. Through these practices, where the researchers adapted training programs or laboratory based interventions, they have developed the conceptual framework and the practice of neuro rehabilitation (Bryck & Fisher, 2012). Neuro rehabilitation is

ideally counter functioning against the devastating or the negative effects placed by lower SES.

Neural oscillations, or in lay persons language, Brain waves are the rhythmic and repetitive patterns of neural activity of the brain. This can be as a result of single neurons or interaction of neural networks (Wikipedia, 2018). To understand the associations between brain waves and the SES, Polish neuroscientist Przemyslaw Tomalski and colleagues (as Noble, 2014 quotes), have studied SES differences in students' brain functions. Using EEG method, the researchers found that parent's occupation and income were associated with higher-power brain waves (in frontal brain regions) of the infants. As Noble (2014) notes, critically, higher-power brain waves in these regions have been associated with better language development at later ages. Higher the wave activity predict the positive aspects of neural plasticity. This study indicates two important aspects. One is the idea that the adverse effects of growing in low SES can be identified even in early ages. The other is if we tally the ideas with previously discussed implications, it connotes with the intervention possibilities even from early years.

When we consider the influence of SES on neural networks and plasticity, how SES affects executive function was discussed in a previous study summery too. Similar information from available literature has been reviewed in other studies too. The brain region which hosts the executive function is mainly the prefrontal cortex of the frontal lobe of human brain which is subjected to crucial development during post-natal period (Hook et.al, 2013). As we have already become familiar that executive functioning related neural networks are affected by SES, this implies training possibilities as well as how SES influences other associated cognitive functions and their neural networks too. It indicates that the childhood experiences of these sensitive periods must be

carefully intervened in a positive way to assure healthier brain development. When we consider these adverse effects on the developing brain, it poses an urgent need to address the intervention needs. But intervention needs must be carefully monitored (Blair & Raver, 2016).

Though, many of the studies on neural plasticity and how it is affected by lower SES are mainly concerned on the prime brain regions which are vulnerable (i.e. The areas corresponding to language (Romeo et.al, 2011), executive function and working memory), the other available research indicates that other brain regions are also affected by lower SES. For example, Skoe, Krizman & Kraus (2013), investigated how the impoverished brain (due to not being exposed to cognitively stimulating environments, exposure to stress and noise as well as toxins) affect the auditory cortex areas of the brain. In their study, adolescents whose mother had lower level of education, showed abnormal responses for the auditory stimuli compared to the other group. But generally many of the studies show that interventions are capable of bringing positive impacts in the process of education. In Nobel, Tottenham, Casey (2005), the authors explained that children's brains remain plastic and capable of growth and development. Targeted educational interventions thus have the promise of improving both brain function and behavior.So the idea that due to the plasticity of neural pathways, some of the effects of poverty on the brain may be reversible is not strange (Azma, 2013).

Conclusions

Almost all the studies which have been reviewed above implicate that examining the indicators on how SES affect brain neural networks and plasticity is having the highest clinical and diagnostic significance. The individual differences due to the disparities of SES have been clearly documented that

the brain regions have been affected due to living in a lower SES background. As the concept of neural plasticity itself stand for the idea that brain is capable of remodifying, generating and regenerating neural networks, it supports the proposition that intervention programs are possible with affected individual with vulnerable genetic makeup, as well as living in disadvantaged SES. But the concerns should be addressed during the sensitive periods. If not, more research is needed in the relevant area. When it comes to the practical as well as scientific implications and the limitations of the research area, it can be seen that some of the research strategies are not possible with the human subjects, where more animal studies are needed. But when humans are studied, neuropsychological test instruments provide the highest value for generating results.

References

American Psychological Association (2018). Socioeconomic Status, Retrieved from www.apa.org

Azma, S. (2013). Poverty and the Developing Brain: Insights from Neuroimaging. *Synesis:A Journal of Science,Technology, Ethics, and Policy,* G40-G46

Baker, E.H.(2014). Socioeconomic Status, Definition. *The Wiley Blackwell Encyclopedia of Health, Illness, Behavior,andSociety*,Retrievedfrom https://doi.org/10.1002/9781118410868.wbehibs395

Blair, C. & Raver, C.C. (2016). Poverty, Stress, and Brain Development: New Directions for Prevention andIntervention.*Academicpediatrics,16*(3).S30s36.D OI: https://doi.org/10.1016/j.acap.2016.01.0*0*

Buonomano, D. V., & Johnson, H.A. (2009). Cortical Plasticity and Learning: Mechanisms and Models.Encyclopedia of Neuroscience, 183-188. ***https://doi.org/10.1016/B978-008045046-*** 9.00790-7

Hook, C.J., Lawson, G.M. & Farah, M.J. (2013). Executive Functions: Socioeconomic Status and the Development of Executive Function. *Encyclopedia on Early Childhood Development*. Retrieved from http://www.child- encyclopedia.com/sites/default/files/textes-experts/en/646/socioeconomic-status-and the-development-of-executive-function.pdf

Hackman, D.A. & Farah, M.J. (2009). Socioeconomioc status and the developing brain. *Trends in Cognitive Science*, *13*(2), 65-72.doi:10.1016/j.tics.2008.11.003

Hackman,D.A., Farah, F.J., & Meaney, M.J. (2010). Socioeconomic status and the brain:Mechanistic insights from human and animal research. *NATURE REVIEWSNeuroscience,* 651-659.

Isbell, E., Stevens, C., Pakulak, E., Wray, A.H., Bell, T.A. &Neville, H.J. (2017). Neuro-- Plasticity of Selective Attention: Research Foundations and preliminary Evidence for a gene by intervention interaction. *Proceedings of the National Academy of Sciences of the United States of America, 114* (35), 92479254.https://doi.org/10.1073/pnas.170241114

Johnson, S.B., Riss, J.L. & Noble, K.G. (2016). State of the Art Review: Poverty and the Developing Brain. *Pediatrics, 137*(4). Retrieved from pediatrics.aappublications.org

Jednorog, K., Altarelli, L., Monzalvo, K., Fluss, J., Dubois, J. et.al. (2012). Correction: The influence of Socioeconomic Status on Children's Brain Structure.*PLOS ONE, 7*(10).

Kaas, J.S. (2001). Neural Plasticity. *International Encyclopedia of the Social and Behavioral Sciences*, 10542-10546.https://doi.org/10.1016/B0-08-043076-7/03619-6

Karbach, J. (2015). Plasticity of executive functions in childhood and adolescence: Effects of cognitive training interventions. *Revista Argentina de Cienciasdel Comportamiento (*Argentine Magazine of Behavioral Sciences), 7(1), Retrieved from scielo.org.ar

Knudsen, E.I., Heckman, J. J., Cameron, J.L., Shonkoff, J.P. (2006). Economic, neurobiological, and behavioral perspectives on building America's future workforce. *Proceedings of the National Academy of Sciences of the United States of America, 103*(27), 10155-10162. doi: 10.1073/pnas.0600888103

Kolb, B., Harker, A. & Gibb, R. (2017). Principles of plasticity in the developing brain. Developmental Medicine and Child Neurology, https://doi.org/10.1111/dmcn.13546

Lipina, S.J. & Posner, M.I. (2012). The impact of Poverty on the Development of Brain Networks. *Frontiers in Human Neuroscience*, Retrieved from https://doi.org/10.3389/fnhum.2012.00238

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: developmental properties and socio- demographic correlates in an epidemiological sample of young, urban children. *Child Development,75*(5),1373-86.doi:10.1111/j.1467- 8624.2004.00746.x

Merluzzi, a. (2013, Spetember 30). Brain Development and Neuroplasticity. *Association for Psychological Science*. Retrieved from ***http://www.psychological*** science.org

Noble, K. G., Houston, S., Kan, E. & Sowell, E. R. (2012). Neural correlates of socioeconomic status in the developing human brain. Developmental Science, *15*(4), 516-27. doi: 10.1111/j.1467-7687.2012.01147.x

Noble, K. G. (2014). Rich man, Poor Man: Socioeconomic Adversity and Brain Development. *CEReBRUM*. Retrieved from http://dana.org

Noble, K.G., Houston, S. M., Kan, E. &Sowel, E.R. (2012).Neural correlates of socioeconomic status in the developing human brain. *Developmental Science*. 1-12. DOI: 10.1111/j.1467- 7687.2012.01147

Noble,K. G., Tottenham, N. &CaseyB.J. (2005). Neuroscience Perspectives on Disparities in School Readiness and Cognitive Achievement. *THE FUTURE OF CHILDREN*, *15*(1). 83-84.

Raizada, R.D.S. & Kishiyama, M.M. (2010). Effects of Socioeconomic Status on Brain Development, and How Cognitive Neuroscience May Contribute to Levelling the Playing Field. *Frontiers in Human Neuroscience, 4*(3), doi**:** 10.3389/neuro.09.003.2010

Romeo, R.R., Christodoulou, J.A., Halverson, K.K., Murtagh, J., Cyr, A.B., Schimmel, C., Chang, P., Hook, P.E. & Gabrieli, J.D.E. (2018). Socioeconomic Status and Reading Disability:Neuroanatomy and Plasticity in Response to Intervention. *Oxford Academic:* **Cerebral Cortex***, 28*(7), 2297–2312. ***https://doi.org/10.1093/cercor/bhx131***

Romeo,R.R., Segaran J., , Leonard,J.A., Robinson, ST., West,M.R., Mackey,A.P., Yendiki, A., Rowe,

M.L., & Gabrieli., J.D.E. (2018).***Conversation Strengthens a Child's Brain***. *Developmental Biology-Brain*. Retrieved from www. visembryo.com

Scandrett, L. (2018). Childhood Poverty and Its Effects on the Brain: Physiological and Functional Implications. *Undergraduate Honors Theses. Honors Theses AY 17/18. University of Wyoming. Wyoming Scholars Repository*

Skoe, E., Krizman, J. & Kraus, N. (2013). The Impoverished Brain: Disparities in Maternal Education Affect the Neural Response to Sound. 33 (44), 17221-17231. DOI: https://doi.org/10.1523/JNEUROSCI.2102-13.2013\

Stallen, M. (2017). Poverty and the Developing Brain. *BehavioralScientist*,Retrieved behavioralscientist.org

Thomas, M.S.C (2016). Do more intelligent brains retain heightened plasticity for longer in development? A computational investigation. *Developmental Cognitive neuroscience, 19*, 258-269.***https://doi.org/10.1016/j.dcn.2016.04.002***

Winkleby, M. A., Jatulis, D.E., Frank E. & Fortmann, S.P. (1992). Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. *American Journal of Public Health, 82*(6), 816-820.