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Leveraging Neuroscience and Education to Prevent Youth Aggression and Violence

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In 2014, homicide and suicide were the second and third, respectively, largest killers of youth. Violence among youth appears to be increasing and aggression is prevalent in and out of school settings. This paper first summarizes what we think and we know about adolescent brain development from neuroscience and psychology. Next, we discuss the neural correlates of violence contextualizing information within adolescent brain development. Finally, we explore how mindfulness-based and compassion cultivation curriculum, which includes empathy, may positively influence the dysregulation of some of the known neural correlates of violence. The paper concludes with some recommendations for educators and policy-makers to consider in the development of curriculum that seeks to prevent violence and aggression among youth.

Keywords: mindfulnes, neuroscience, brain development, compassion, aggression, violence prevention

Introduction

The World Health Organization (WHO, 2014) reported an estimated 200,000 homicides that occurred among youth and young adults aged 10-29 in 2014. This placed homicide as the fourth largest cause of death for human beings in this age group and up from being placed in slot No. 5 in 2012 (WHO, 2012).

It is important to note that this number does not include suicides, which were ranked as the third highest cause of death in 2012 and also does not account for those who have survived affliction of physical and emotional violence. Eighty-three percent of the 200,000 young adult deaths were male and most of these deaths occurred in low- and middle- income countries (WHO, 2014).

Yet, the United States of America (USA), considered a high-income country, reported suicide and homicide as the second and third leading causes of death respectively among youth aged 15-19 in 2014 (Centers for Disease Control and Prevention [CDC], 2017).

Popular press reports that violence in youth age is on the rise and has made its way into schools. Preliminary data from the USA shows that there were 48 school associated with homicides and suicides from July 1, 2013 to June 30, 2014 (Institute of Education Sciences & National Center for Education Statistics [IES & NCES], 2017). However, it does not appear to be a large number of human lives lost in comparison to the 200,000 word-wide youth deaths to homicide. It may be important to note that there were approximately 841,100 nonfatal victimizations reported among students aged 12-18 occurring in schools in 2015. In addition, 545,100 nonfatal victimizations away from school were also reported (IES & NCES, 2017). Furthermore, there are total 804 hate crimes (a criminal offense that is motivated by bias toward a

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human's protected identity) reported on college campuses in 2014. Among these, the most common type of hate crime was intimidation (343 incidents), followed by destruction, damage, and vandalism (327 incidents), and assault (61 incidents) (IES & NCES, 2017). As the causes of death, how does homicide and suicide rank in comparison to other causes for all human beings in the world? And what is being done to prevent these causes of death?

In 2017, the WHO reported that the top two global causes of death were heart disease and strokes. In 2005, the Associated Press reported that there had been $95 billion spent on medical research invested in treating, curing, and preventing diseases, such as heart disease and strokes. Meanwhile, data affirm the global concern that physical and emotional violence occurs among youth and is claiming their lives, while also continuing to rise. Investment figures found revealed that the prevention of such violence was related to costs of added security officers and police officials—approximately $1.145 billion were spent on the criminal justice system (Institute of Medicine and National Research Council, 2011) and approximately $13.6 trillion invested in war (World Economic Forum, 2016).

If you could do anything to prevent the rising of death caused by violence among youth, what would you do? How much would you invest and in what ways?

United Nations Educational, Scientific, and Cultural Organization (UNESCO) recently published two useful publications intended to address these escalating concerns. The first entitled *Preventing Violent Extremism Through Education: A Guide for Policy-Makers* (2016a) and the second entitled *A Teacher's Guide on the Prevention of Violent Extremism* (2016b). Both manuals offer helpful tips that could implemented prevention discussions either among youth, educators, and policy-makers, as well as recommending specific prevention modalities, such as creating safer and more supportive school environments, modifying and updating curriculum for youth, and implementing teacher training and support for teachers.

School officials across the globe have devoted time to preventing violence in schools in many of the ways that UNESCO suggests. However, this paper sought to investigate only one UNESCO recommended modality and that is curriculum development for youth. As such, this paper does not summarize the many curriculum-based approaches that many countries are pursuing to prevent youth violence through education, such as offering parenting programs in Burundi and South Africa, strengthening early childhood development in Central Asia, offering pre-school teacher intervention training in Jamaica, bullying prevention programs in Spain and the USA, developing life skills in Columbia and radio-based academic enrichment in Zanzibar, dating violence prevention in the republic of Tanzania and South Africa, and providing after-school activities for youth in Brazil (WHO, 2015). Rather, this paper seeks to explore the aspects and offer specific types of curriculum that may negate violent tendencies among young adults.

Understanding the Brain Development of Youth

It would be irresponsible for us to lead the readers to believe that we could summarize the intricacies of youth brain development in this brief manuscript. However, for purposes of this paper, it is extremely important that we discuss some aspects of adolescent brain development that are widely accepted among neuroscientists and psychologists, but may not have translated directly into youth curriculum design and evaluation. As you read this manuscript, please keep in mind that there are many neurobiological and environmental factors that influence the typically developing brain of adolescents. This paper focuses on only a few brain regions that are relevant to learning and development.

The adolescence is a transitional development period (Spear, 2000; Casey, Tottenham, Liston, & Durston, 2005) where the manner in which youth move into, through, and out of may influence their ability to inhibit the kinds of risky and impulsive behavior associated with a lack of positive goal-directed choices and closer towards inappropriate thoughts and actions that may lead to aggression and violence (Casey et al., 2000; Casey et al., 2002; Casey, Tottenham, Liston, & Durston, 2005; Casey, Jones, & Hare, 2008). Determining the exact age continuum of this transitional brain development period of adolescence is difficult. There are several ways in which researchers define and classify the age range of the developing adolescent brain. For this paper, were viewed studies that cut across age groups ranging between 13 and 22 years old. As such, we will use a definition that most closely approximates this range.

Risky Behavior Choices in Adolescence

While again, adolescence defined differently by researchers, covers an age range of 12-20 (Csikszentmihalyi, 2017) and is known as the period of human development where skills in independence are explored and reinforced. It is also the period where youth are more likely to choose harmful behaviors, even when they cognitively know better, primarily because of imbalances in hormone production and increased sensation seeking, as well as seeking experiences that are different and perhaps unique (Kelley, Schochet, & Landry, 2004; Steinberg, 2004; Casey, Jones, & Hare, 2008). Historically, researchers have posited that youth move through and out of the adolescent period with a growth in pre-frontal brain regions and decreased activity in brain regions that are considered irrelevant to learning (Rubia et al., 2000; Rubia et al., 2006; Tamm, Menon, & Reiss, 2002; Brown et al., 2005; Durston et al., 2006; Monk et al., 2003). If this occurs, then behaviorally, we should see an increase in emotion regulation (ER)[1] and a decrease in behavioral challenges (Casey, Jones, & Hare, 2008). ER is often referred to as the ability of these brain regions (e.g., top region of the brain = rational thinking and bottom region of the brain = emotional and rule-based reactivity) to balance themselves, so that emotion is not overruling rationale thinking and rationale thinking is not suppressing emotion in harmful ways. However, some contest that this is an over-simplified way to view adolescent brain development (Casey, Jones, & Hare, 2008; Spear, 2013). They argued that we first must understand the neurological mechanism for rewarding risk-taking behavior that may lead to harmful decision-making.

The nucleus accumbens is the portion of the brain (e.g., bottom) that plays a primary role in the reward system. It is a part of the ventral striatum within the basal ganglia (e.g., bottom). Youth aged 13-17 show increased activation in the nucleus accumbens prior to choosing risky behavior (Kuhnen & Knutson, 2005; Matthews, Simmons, Lane, & Paulus, 2004; Montague & Berns, 2002). If the choice of the risky behavior is perceived, reward and choice of additional risky behavior will understandably become more likely (Casey, Jones, & Hare, 2008). However, whether the risky behavior is chosen involves a different neural network or not, that of the ventral medial prefrontal cortex (e.g., ventromedial prefrontal cortex [vmPFC]: top region). The vmPFC plays a role in inhibition of emotional reactivity as well as decision-making. Immature development of this region is associated with increased impulsivity (Casey, Tottenham, Liston, & Durston, 2005; Casey, Jones, & Hare, 2008). With regard to curriculum design, this infers that instructors need to become aware of the importance of cultivating students' ability to command their own attention, particularly when impulsivity is high.

[1] ER refers to complex processes that involve initiating, inhibiting, or modulating a state of behavior that may have been stimulated by something perceived to be emotionally disruptive or arousing. The process often involves naming and accepting the emotion, which does not infer acceptance of the cause of the emotion, and then reflecting and re-appraising before a behavioral response is selected.

If curriculum designers took into their planning the intention to train student's awareness of where their attention resides, students might be able to bring attention toward what precedes impulsivity or which conditions feed impulsive acts. Doing so may empower more positive goal-oriented choices. Even so, this does not alone explain why some youth choose to engage in risky behavior, especially when such behaviors appear to be high-reward, such as receiving rewards brought about by increased sense of belonging, money, or other push-pull factors that may be associated with engaging or not engaging in violent behavior (UNESCO, 2016a). Researchers argued that a youth's healthy cognitive development depends on their ability to engage inhibitory brain processes that delay gratification in exchange for optimized goal-directed choices (Brainerd & Reyna, 1993; Dempster, 1993; Casey et al., 2002; Diamond, 1985; Munakata & Yerys, 2001). While cultivating students' attentional control may be useful in heightening inhibitory control, deepening an understanding of that which dysregulates inhibitory brain processes is also beneficial in order to design ER curriculum.

The amygdala that is a part of the limbic system (e.g., bottom) has been identified as a key neural region in emotional and inhibitory brain process dysregulation among adolescents (Casey, Jones, & Hare, 2008, Spear, 2013). The amygdala is often referred to as the center for fight, flight, freeze, and fornicate. Its dysregulation has been associated with anxiety and depression in children and adults (Thomas et al, 2001; Leppanen, 2006; Rauch, Shin, & Wright, 2003). Furthermore, adolescents show greater amygdala activity and reactivity than adults (Casey, Jones, & Hare, 2008). Increased activity in the orbit to frontal cortex (OFC)—a portion of the pre-frontal cortex of the brain associated with the cognitive processing of decision-making correlated with a decrease in emotional reactivity over time (Casey, Jones, & Hare, 2008). In essence, cognitive processing may soothe emotional reactivity in the amygdala (Ernst et al., 2005; Monk et al., 2003; Montague & Berns, 2002; Kuhnen & Knutson, 2005; Matthews, Simmons, Lane, & Paulus, 2004).

Casey, Jones, and Hare (2008) asserted that while the impulse of youth to engage in risky behavior and the subsequent reinforcement of reward for doing so may be regulated by cognitive reasoning. The actual ability to avoid risk-taking behavior, even if youth know it is not the right choice, resides in a separate neural networking process. In other words, while regulating over-reactivity in the amygdala may be key in inhibiting impulses engaged in risk-taking behavior and impulsivity. Casey, Jones, and Hare (2008) argued that the solution may emerge in better understanding how the brain develops and how that development influences the brain's ability to connect important regions to one another in a manner that will optimize positive goal-directed behavior. In order for curriculum designers to leverage this information, we must first understand some basic brain functioning.

Development of Brain Matter in Adolescents

In general, the gray[2] and white[3] matter sub-components of the typically developed brain continue to mature throughout adolescence even though 90% of the development of brain size is reached by the age of six years (Durston et al., 2001). The regions of the brain involved primarily with motor and sensory systems

[2] Gray matter contains numerous cell bodies and relatively few myelinated axons. Gray matter is distributed at the surface of the cerebral cortex as well as the cerebellum. Also, it is contained in the cerebrum, brainstem, and spinal cord, among other regions of the brain.

[3] White matter (named for the myelination) lies beneath gray matter and is responsible for connecting neurons in different brain regions to functional circuits. It may be useful to conceptualize this to mean that white matter helps expedite or slow the way in which certain parts of the brain connect with each other and then command the body to function in accordance with the quality and speed of those neural communications.

mature earlier, especially when compared to the higher order areas that integrate these motor and sensory processing areas of the brain (Gogtay et al., 2004; Sowell, Thompson, Toga, 2004). This is significant for adolescents, because it means they can sense a lot of stimuli in their environment and have the capability to react to that stimuli, but may not have the full capacity to discern the most rational or kind way to respond, simply because of their natural brain development process. For curriculum design, this means that attention regulation training is not enough, we must incorporate sensory awareness training.

Developmental changes in the pre-frontal region of the brain (e.g., top—primarily for executive functions, such as accessing working memory, inhibitory control, and cognitive flexibility) as well as for changes in the basal ganglia (e.g., bottom—associated with a variety of functions including control of voluntary motor movements, procedural learning, and routine behaviors or habits) are profound during adolescence, particularly among males (Sowell et al., 1999; Caviness et al., 1996; Gieddet al., 1996; Reiss et al., 1996). Some researchers (Sowell, Thompson, & Toga, 2004; Casey et al., 1997; Casey, Jones, & Hare, 2008) argued that while much of education focuses on the development of the pre-frontal cortex regions of the brain, it is important to focus on the development of the basal ganglia region as well, which includes the dorsal striatum (caudate nucleus and putamen), ventral striatum (nucleus accumbens and olfactory tubercle), globus pallidus, ventral pallidum, substantia nigra, and subthalamic nucleus. It is noted that the nucleus accumbens, which was referred to earlier and is a part of the basal ganglia, plays a primary role in the reward system and is also activated prior to youth choosing a risky behavior. What if curriculum designers assumed that this was the case for students' engagement in positive goal oriented learning and development? This means that integrating attention regulation and sensory awareness training in all courses may be important as educators would not be able to take into account all the kinds of varying stimuli of their diverse students in just one course?

We will discuss what this means for curriculum development later, particularly with regard to the importance of training awareness of where one's attention resides as well as awareness of sensations. This training allows students to name sensations, discern, which one is the kind, and promote positive goal-oriented behavior and which one does not. For now, it is important to note that brain development in adolescents includes a mix of brain growth as well as brain regression[4] (Spear, 2013). What is understood is that more brain cells and their synaptic connections are produced during adolescence then will be retained (Oppenheim, 1991; Huttenlocher & Dabholkar, 1997). The over-production and subsequent pruning processes are expected to ensure healthy and optimal connections among brain regions (Rakic et al., 1994), particularly with regard to ensuring speed and efficiency of information across regions.

What is of interest is that during adolescence, white matter production escalates, which means that information across distant brain regions is expedited and heightened in impact (Markham & Greenough, 2004). This can have resounding influences on adolescent behavior when maturation of the PFC and other frontal regions responsible for cognitive control, attention regulation, response inhibition, and other relatively advanced cognitive functions are relatively immature (Casey, Jones, & Hare, 2008) and emotional reactivity is high (Spear, 2013). As mentioned, this can result in behavior challenges for adolescents (increased risk-taking, reward-seeking, and novelty-seeking) and it can also become evident in increased negative peer-directed social interactions and increases in fighting with parents/guardians (Csikszentmihaly, 1977; Primus & Kellogg, 1989;

[4] Brain regression concerns a natural pruning process of neurons during the adolescent process. An understanding of how optimal pruning can be achieved remains unclear at the time of this publication.

Steinberg, 1989). This begins to assert that equipping adolescents with ways to manage not only their attention but also their emotional reactivity may be useful.

While the brain continues to develop significantly within adolescence, there is evidence that certain portions of it can also change once developed. Human brain plasticity or neuroplasticity refers to the capacity of the nervous system to modify the organization of the brain structure and function in response to experience (Jiang, et al., 2015, p. 1). As mentioned, the brain has both gray matter and white matter. The gray matter portion of the brain has historically received more attention when educators discuss neuroplasticity as the discovery of how the posterior hippocampus (the portion of the brain primarily responsible for converting short-term memory to long-term memory and for spatial memory) increased size following a lengthy learning task of London cab drivers (Maguire et al., 2000). Additional studies have shown changes in the right OFC, right thalamus (part of the limbic system relays information to the cortex and regulates awareness and alertness), left interior temporal gyrus (associated with visual processing), as well as the right hippocampus (Luders, Toga, Lepore, & Gaser, 2009) for long-term meditation[5] practitioners. Others have discovered increased density in the lower brain stem region among long-term meditators (Vestergaard-Poulsen et al., 2009). While others have shown increases in a large region of right anterior insula, the inferior occipito-temporal visual cortex, right middle and superior frontal sulci (folds in the front and mid cortex), left superior temporal gyrus, and a small region in the central sulcus (a fold behind the frontal cortex) (Lazar, 2005). To simplify discussion, this research demonstrates that gray matter can also change in structure in brain regions that are important for sensory, cognitive, and emotional processing. The ability to change these brain regions may be key for adolescents' as well as adult's ability to healthfully integrate sensory stimuli into their positive goal-directed choice-making. This is useful for curriculum designers who seek to harness adolescent's desire for sensory stimulation, but to do so in a manner that cultivates positive goal-oriented choices. However, a change in gray matter within brain region may be dependent on changes in white matter (Spear, 2013).

White matter makes up half the brain and is considered to be very important in learning, which involves changes in the strengths of connections in gray matter (Spear, 2013). The attribution of the name white matter is given to the insulated "coating" of the axons (nerve fibers) that serve to communicate with various parts of the brain. That coating is called myelin and it is essential for high-speed transmission of electrical impulses. If myelin becomes damaged (as is often the case in those with autoimmune disorders), it can impair sensory, motor, and cognitive functions essential for learning and development (Fields, 2010). White matter often structurally changes when learning a new skill and the extent of that change may be correlated to number of hours dedicated to learning the task (Fields, 2010) or it may not (Zatorre, Fields, & Johansen-Berg, 2012).

Barnea-Goralyet et al. (2005) demonstrated that white matter changes in the arcuate fasciculus, which is key to connecting various brain regions to the PFC, motor areas of the brain, and in the internal capsule, which carries information beyond the basal ganglia. In addition, their research noted changes in white matter in the PFC. They also observed changes in four brain pathways that may be important for the understanding of how to change brain function during development: the corpus callosum, which joins the two hemispheres of the brain, white matter tracts within the basal ganglia, between the basal ganglia and the thalamus, and in ventral-visual pathways. These brain regions and pathways appear to be important for healthy attention, motor skills, cognitive ability, and memory development.

[5] Meditation here is referring to a sustained and prolonged practice of focusing on the breath sensation in the body.

In order to develop positive goal-directed behaviors, scholars believe that the brain must maintain some degree of functional stability, while still being sufficiently malleable to adapt to new life experiences (Spear, 2013). While plasticity appears to be highest earlier in life, the period of adolescent brain development shows four to five times higher rates of formation of new neurons when compared to adulthood (He & Crews, 2007). Research indicates that the typically developed brain is influenced by life experiences that range from initial sensory experiences to early nutrient exposure/restriction or developmental adversities (Gutman & Nemeroff, 2003; Hensch, 2004; Taylor & Poston, 2007). While sensory issues may be easier to regulate in the home environment for youth who have homes where such regulation can occur, the school environment presents particular challenges that may heighten sensory issues for youth (Howe & Stagg, 2016; Fernández-Andrés, Pastor-Cerezuela, Sanz-Cervera, & Tárraga-Mínguezc, 2015). Here, we remind the reader that violence and aggression among youth is on the rise and it has made its way into schools. And although cultivating a supportive and nurturing school environment are important, this manuscript asserts that curriculum needs to be delivered to students to give them the strategies to regulate their own sensory input.

The influence of sensory experience and its processing to adolescent brain development appears to be key to both white and gray matter growth, pruning, and plasticity (Casey, Jones, & Hare, 2008; Spear, 2013). To clarify, sensory processing refers to how the brain registers, interprets, and uses information from the sensory systems in decision-making. Gohill, Stock, and Beste's (2015) research had shown that sensory integration is important for knowing where to place one's attention, and then, knowing what choice to make. For example, when young adults were presented with more than one stimuli, their ability to integrate their sensory experience to pre-frontal cortex regions of the brain (where executive functions primarily are processed), caused a decision delay. This emphasizes the importance of attention regulation training.

To summarize, according to Casey, Jones, and Hare (2008),

> In emotionally salient situations, the more mature limbic system (emotional system) will win over the prefrontal control system (executive functions). In other words, when a poor decision is made in an emotional context, the adolescent may know better, but the salience of the emotional context biases his/her behavior in opposite direction of the optimal action. The combination of heightened responsiveness to rewards and immaturity in behavioral control areas may bias adolescents to seek immediate rather than long-term gains, perhaps explaining their increase in risky decision-making and emotional reactivity. (p. 124)

While this model appears dismal, there is hope. Research has shown that adolescents show exaggerated responses to reward (observed by elevated nucleus accumbens activity) while also showing less mature recruitment of top-down prefrontal control regions (Casey, Jones, & Hare, 2008). However, the slowing of top-down regulation is heightened by over-activation in the amygdala (Casey, Jones, & Hare, 2008). Over-activation in the amygdala is exasperated by adolescents heightened sensory processing (Spear, 2013). Youth's exposure to multiple sensory stimuli will slow their ability to engage in regulating bottom-up (basal ganglia and amygdala activity) and top-down (pre- and medial- frontal cortex) brain processing in order to make a positive goal-directed choice. As such, we posit that we must intentionally consider the typically developing brain of adolescents in curriculum design and evaluation, particularly with regard to providing attention and ER training practices. We will discuss what that means later. For now, we invite you to note that the typically developing brain process means that adolescents are susceptible to increased sense-seeking, risk-taking, novelty-seeking, and immediate reward gratification. This could naturally lead to their moving away from

positive goal-oriented behavior, but how could this lead to aggression and violence? And how can we intentionally design curriculum to better support them through this challenging developmental time?

Defining Violence

In order to understand the neural correlates of violence and their relationship with adolescent brain development, defining violence is important, though not easy. As such, from a practical standpoint, we define violence as "the intentional use of physical force or power, threatened or actual, against another person or a group that results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment, or deprivation" (Krug et al., 2002). Perhaps, the key word in this definition is "intentional." It is clear from the previously cited data that violence among youth is increasing and making its way into schools. How intentional are those acts of violence? How does the typical adolescent brain development process influence aggression tendencies? How aware are youth of their actions and the consequences of those actions? And can the violence be prevented with thoughtfully designed curriculum and caring peers and adults who guide youth through that curriculum? To answer these questions, we need to understand more about the neural correlates of violence. And to do so, we need to examine literature that cuts across adults and also includes studies of rodents.

To begin, Meyer-Lindenberg et al. (2005) attested that poor understanding of the neurobiological factors that contributes to violence exists among human beings. They stated that violent and criminal behaviors are related to complex environmental and social circumstances. However, heritable factors have also been shown to be associated with behaviors, such as disruption of key neurochemicals and deficits in serotonin and dopamine hyperactive functioning (Moffitt, 2005; Lesch & Merschdorf, 2000; Seo, Patrick, & Kennealy, 2008). There are additional key enzymes linked to violent aggression as well as emerging research in gender differences and to discuss this research with any meaning or relevance resides outside the scope of this paper. It is crucial for the reader to know that to only discuss the neural correlates of violence is short-sighted due to the complexity of the: (a) brain; (b) neurology in its entirety; and (c) influence of internal and external factors.

Nonetheless, Meyer-Lindenberg et al.'s (2005) research showed that among heritable neurobiological factors and neurochemical production, increased risk of violent behavior was predicted by hyper-responsive amygdala activity during emotional arousal and diminished reactivity of regulatory prefrontal regions. Davidson, Putnam, and Larson (2000) had posited that dysregulation of emotion may be a prelude to violence. They explained how a complex circuit of many parts of the brain including the PFC, anterior cingulate cortex (ACC), insular cortex, amygdala, and hippocampus among other regions play a large role in regulating emotion. In essence, ER is a process where emotions are either intentionally escalated, weakened, or maintained, influencing choice very quickly or over time. It is noted again that the emphasis is intention.

The amygdala also appears to be crucial for one's ability to associate experiences with primary punishers or rewards (Rolls, 1999; Holland & Gallagher, 1999). For educators, it is important in understanding the role of emotion and how it may regulate cognitive processes to discern whether a reward is positive or negative. For example, the amygdala appears to be more strongly activated by facial expressions associated with fear, as opposed to anger (Davidson et al., 2000), while the OFC and ACC increase in activity when facial images are associated with anger (Blair et al., 1999). This is relevant, particularly for educators, as the OFC plays a role in the cognitive processing of decisions, while the ACC plays a role in regulating blood pressure and heart rate as well as reward anticipation, decision-making, impulse control, and emotion. Davidson, Putnam, and Larson (2000) reported that individuals prone to acts of violence and aggression would have a weakening in the

activation of the OFC and ACC. Cultivating an ability to discern the difference between fear and anger and the ability to turn toward that fear and anger in healthy ways before those emotions are made evident in reactive behavior could prove beneficial to preventing aggression and violence (Koenigs, 2011). And how important might that be, especially when learning something new or challenging can illicit emotions of fear or anger that may be evident on the faces of teachers and students?

In an attempt to appear not to over-simplify the brain regions of concern, we share Horn et al.'s (2003) founding that when studying the behavior of typically developed brains, response inhibition was most prominent in the right lateral OFC. Activity was also recorded in the superior temporal gyrus, medial OFC, cingulate gyrus, and inferior parietal lobe, predominantly on the right side. Subjects who were less able to demonstrate inhibitory control showed greater activation of paralimbic areas (directly connected to the limbic system, particularly the amygdala), while less impulsive individuals activated higher order association areas.

As we relate other research in an attempt to understand the role of the nucleus accumbens and other parts of the striatum (the portions of the brain that have to do with the reward system) may have, it is interesting to note that Pettijean et al. (2014) and Secades-Villa et al. (2013) had shown that cocaine addicts who do not respond to treatment, even after having suffered from cocaine addiction, show impaired self-awareness of cognitive and motivational processing, which implicates the striatum, OFC, and dorsolateral PFC regions of the brain not the nucleus accumbens. Yet, Porges and Decety (2013) found that while one's assessment of violent stimuli is dependent on their social context and individual characteristics, subjects who observe martial arts video clips recorded activation of the anterior insula (AI), brainstem, ventral tegmental area (VTA), striatum, medial, and lateral prefrontal cortex, orbitofrontal cortex, somatosensory cortex, and supramarginal gyrus. However, this pattern of brain activation was not related to participants reported experience of pleasure or displeasure. Pleasurable ratings of marital arts violent videos predicted increased functional connectivity in the nucleus accumbens with the subgenual ACC and anterior insular cortex (AIC), while displeasure ratings of viewing violent martial arts videos were related to increased functional connectivity with the PFC and superior parietal lobe. These data suggest that the way in which parts of the brain connect with each other informs the relationship between feelings of pleasure and pain in brain areas known to respond to both the anticipation of positive and negative rewards. This is important to note when exploring the role the nucleus accumbens may have in rewarding positive or negative goal-directed behavior. To emphasize, however, what can be done from an educational perspective about all of this, we note that Teicher, Andersen, and Hostetter (1995) reported there was evidence of dopamine receptor pruning in the striatum, but not in the nucleus accumbens.

Again, we ask how adolescents are aware of the connectivity they are forming among brain regions and its relationship to rewards and positive goal-directed behavior. Also, how adolescents are aware of their intention for where they place their attention, thus, influencing the development or underdevelopment of specific brain regions important for cultivating positive goal-directed behavior? In other words, how are adolescents aware of the aforementioned connectivity they are forming among brain regions and its relationship to rewards and positive goal-directed behavior as it relates to where they focus their attention? How aware are they of their own sensations and the discernment (or naming) of those sensations as pleasant and unpleasant, or as anger, fear, excitement, and happiness? And how well is curriculum currently cultivating such self-awareness?

Shany-Ur et al. (2014) argued that accurate self-awareness is essential for adapting one's tasks and goals to one's actual abilities. In their research, they noted that inability to do this was associated with degeneration of dorsal frontal regions involved in attention, as well as orbitofrontal and sub-cortical regions likely involved in

assigning a reward value to self-related processing and maintaining accurate self-knowledge. This appears to point back to the importance of these brain regions, which are developing in adolescents, and their role in positive goal-directed choices. For education, this may infer that reflective exercises would be beneficial. However, what about for sensory processing regions? And what about the heightened risk-taking behavior?

As mentioned, Spear (2013) and Ernst et al. (2005) reported that adolescents avoid harm far less than adults. When there is no reward for engaging in harmful behaviors, adolescents' amygdalas appear to be less activated. The PFC was also less active when adolescents were confronted with high-penalties for engaging in harmful behaviors. Overall, adolescents seem to be less sensitive to aversive stimuli, however, they remain very sensitive to perceived high-reward. This means that if an adolescent perceives a reward is high for engaging in harmful behavior, their rational thinking may not be able to deter them. Spear (2013) argued that this social/emotional bias might alter attention to other situational or task features (p. 10). For example, when adolescents are confronted with emotional faces, there is greater amygdala activation and their reaction time on a performance task is diminished (Hare et al., 2008). While adolescents can reach the same level of rational decision-making as adult's midway through their adolescent development, their capacity to engage in adult-level rational decision making is significantly reduced by experiences that are stressful, emotionally charged, and arousing (Steinberg et al., 2009). To summarize, even when adolescents have shown adult-level rationale skills in performance tasks, their risk-taking behavior will still exceed that of adults when in emotionally charged circumstances (Figner, Mackinlay, Wilkening, & Weber, 2009). This suggests that attention and ER may be an important skill that could be incorporated into curriculum design as well as in the training of educators whose very facial expressions can serve to support or hinder students' regulation of emotions.

While the research in understanding violence moves far beyond what has been highlighted in this manuscript, the brain regions implicated in violence that also relate to learning and development within the understanding of the typically developing brain of adolescents are summarized. Perhaps, the best way we can do this is with a diagram. It is assumed that one of the goals of education is to increase positive goal-directed choices among youth, which will in turn decrease the number of homicides and suicides among youth. So, what do we know about the relationship of adolescent brain development and the proclivity toward aggression and violence so far, while also accepting that this picture is incomplete?

We understand that the ability to speedily and effectively connect specific brain regions necessary to mediate risk-taking behavior, discern positive and negative rewards and emotions within a healthy and positive goal-directed manner, and enhance inhibitory control. Even though the adolescent brain has difficulty processing diverse sensory stimuli, rewards for engaging in novelty-seeking or risk-taking are high. It appears that if adolescents are to strengthen neural connectivity, expand and properly prune brain regions that will heighten positive goal-directed behavior, they must also become aware of where their attention resides, discern emotional sensations, as well as inquire into their intention for the kinds of rewards they seek as a result of each choice they make. For example, are they looking for immediate gratification or long-term goal attainment? Interestingly, the very brain regions that are developing during adolescence are also brain regions (among many others) that are implicated in the proclivity towards aggression and violence. The brain regions frequently discussed in violence literature as well as adolescent brain development is outlined in Figure 1. You will see the brain region and its corresponding function in Figure 1. Because enzymes, hormones, and other bio-chemicals are crucial in understanding adolescent brain development as well as aggressive and violent behavior, this

image is indeed over-simplified. Nonetheless, it is important to note that the PFC, OFC, regions associated with sensory processing, and limbic system (particularly the amygdala) have been cited in adolescent brain development research to be at risk of under developing, creating an over-reactive amygdala and an underactive PFC and OFC. While the interaction of these regions is complex, it is complex, because the white matter that connects them is also undergoing development (growth and pruning) during adolescence.

As you examine Figure 1, you will note names of brain regions and their primary corresponding functions. The box in the middle of the diagram demonstrates the importance of the functional connectivity of these regions, so that positive goal-directed behavior is heightened even in the midst of neural growth and pruning processes of brain regions and their neural connectivity. You will also notice the absence of a separate box for the nucleus accumbens in Figure 1. Why? Setlow (1997) argued that the nucleus accumbens is involved in learning and memory processes in a way that is separable from its well-known role in the association of reward and behavior or motivation and behavior. His review of cognitive neuroscience suggests that the nucleus accumbens is a part of a larger striatal system, which serves acquisition and consolidation, but does not relate to long-term storage of different types of learning and memory. This creates confusion for how to address this region of the brain through education. As such, the primary purpose of Figure 1 is to summarize discussion while also emphasizing that what we are positing in this manuscript is the design of curriculum that intentionally cultivates healthier brain connectivity among regions that are developing in adolescents and whose regions have also been implicated in violent and aggressive behaviors. So, how do we intentionally do this?

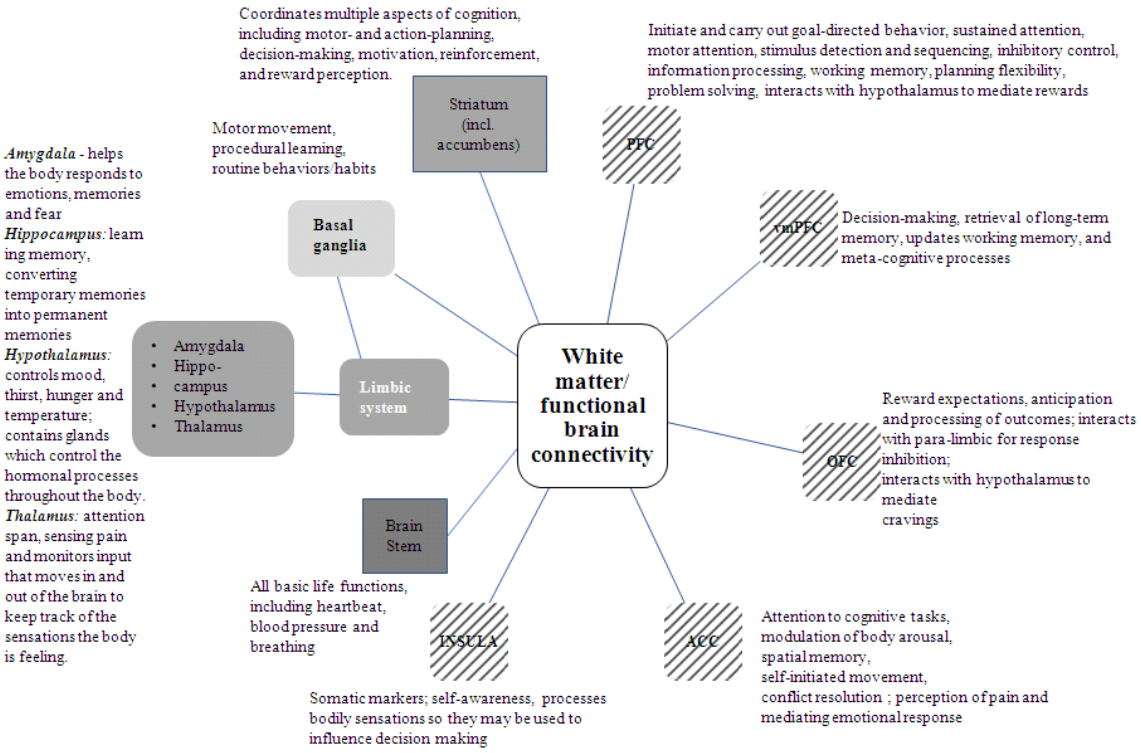

Figure 1. Summary of brain regions discussed.

What We Know About Education in Relationship to Specific Brain Development

As we have discussed, to pull apart the brain into specific regions without underscoring the importance of all

the internal and environmental variables that influence the connectivity of these brain regions conveys an incomplete understanding of how adolescent brains typically develop, and subsequently, how they learn. Nonetheless, in this section, we summarize recent research that helps us understand how intentional curriculum design cultivates functional activity in the key brain regions, particularly of the OFC, ACC, Insula, PFC, and amygdala, along with other brain regions and their role in sensory processing. Similar to earlier cautions, we note the challenge of summarizing volumes of research in this short paper. As such, we seek to discuss relevant research to the topic at hand, that of preventing youth violence and aggression through education.

Prior to diving into summaries of research about which types of curriculum appear to change and/or develop specific brain regions and the connectivity between them. It is important for us to discuss a bit more about the interaction of brain regions, particularly with regard to the interaction of emotion and reasoning. Earlier in this paper, we referred to the importance of adolescents developing the ability to regulate top-down and bottom-up processes. In Figure 2, you can see a generalized diagram of the top-down and bottom-up regulation of brain regions. The brain areas in Figure 2 are designed to mirror the areas discussed in Figure 1. When we state that the intention of education is to optimize positive goal-directed behavior, what we are seeking to improve is this top-down and bottom-up regulation processing. Now, what do we mean by that and what do we know is possible within that?

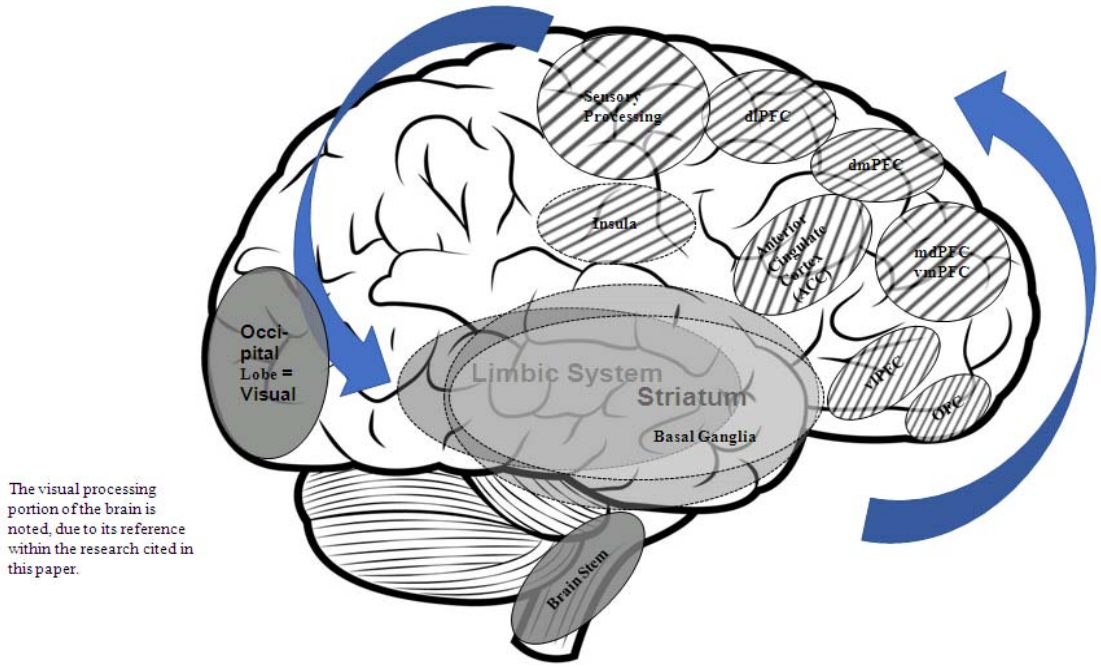

Figure 2. Top-down and bottom-up regulation.

Bresciani Ludvik (2017) characterized the summary of Zelazo, Blair, and Willoughby's (2016) work that explains curriculum influences on the development of executive functions. Executive functions (e.g., top part of the brain processing) encompass many of the kinds of learning outcomes educators hope to see among youth, such as analytical reasoning and positive goal-directed decision-making. The diagram that synthesizes some initial key points of Zelazo, Blair, and Willoughby's (2016) research is represented in Figure 3. In Figure 3, you will note the acknowledgment of research declaring that neural processes are influenced by environmental

factors and internal factors, such as genetics and initial perception of experience (Gluckman, Hanson, Spencer, & Bateson, 2005; National Research Council [NRC], 2015; Shonkoff & Phillips, 2000; Hertzman, 2012). This is a point that we cannot underestimate in curriculum design intended to influence the brain. As such, Figure 3 represents an underlying evidence-based acceptance that no one curriculum can accommodate the very diverse internal and external choices that influence the expression of genes (epigenetics) and other neurobiology and chemical biology that influences brain development, both structurally and functionally.

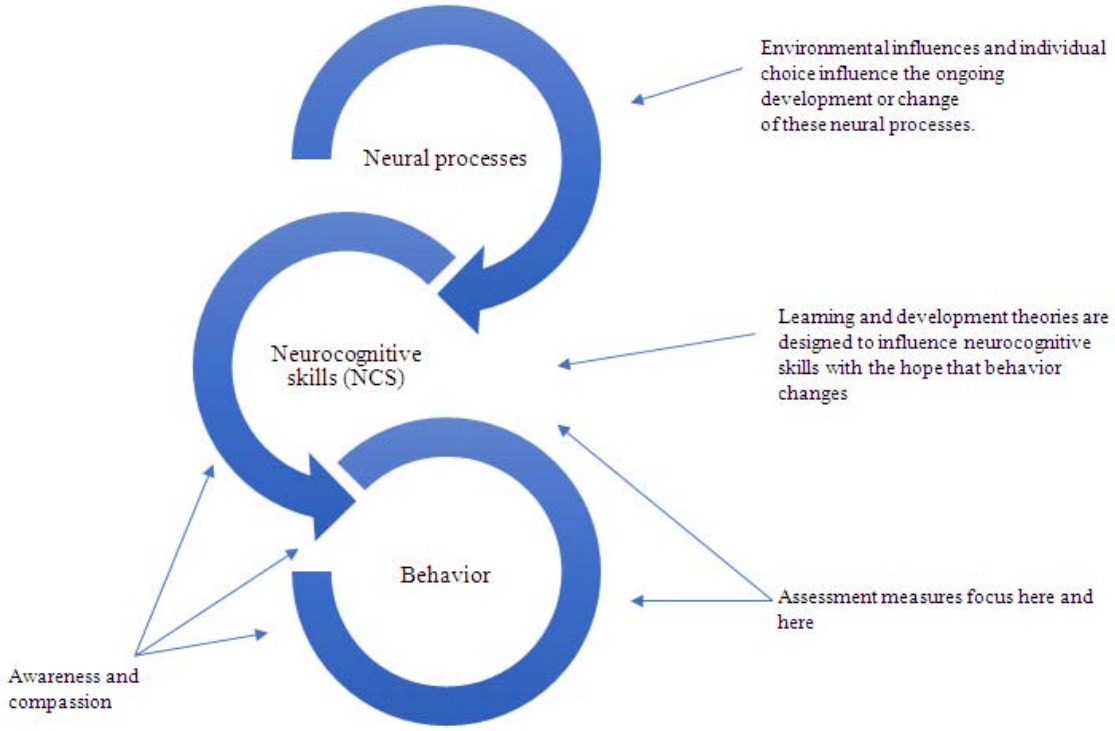

Figure 3. Theoretical characterization (Source: Bresciani Ludvik, 2017).

Having made that point, as educators and policy-makers, we still set the intention to systematically design curriculum that seeks to systematically improve NCS that include reflection, formulation of rules and rules systems into working memory, cognitive flexibility, working memory, and inhibitory control. The behavior we intend to create, as a result, is optimization of positive goal-directed behavior. Furthermore, we seek to systematically evaluate that curriculum, so we can systematically improve the learning experience and demonstrate accountability for having done so. Historically in education, we have privileged the top-down regulation process—the rationale thinking over emotional response (Bresciani Ludvik, 2016). However, what educational psychology and neuroscience tell us is that this is counter to how decision-making occurs, particularly among adolescents, as we have discussed. Our intent is not to swing the pendulum in order to now privilege bottom-up processing (emotion and instinctual behavior over rationale behavior). Instead, our intent is to integrate an understanding that this top-down and bottom-up processing is essential to motivating adolescents to engage in positive goal-directed behaviors. If we ask youth to suppress or deny their feelings, they will likely be less motivated to engage in the learning that has been designed for them (Csikszentmihalyi, 2017).

As mentioned, Zelazo, Blair, and Willoughby (2016) suggested that the NCS we are intending to influence can be divided into five areas: (a) reflection; (b) rule use; (c) cognitive flexibility; (d) working memory; and (e)

inhibitory control. While they go onto explain that there is debate in how these NCS could be categorized and organized, there is growing consensus that goal-directed behavior is either facilitated or undercut by emotion and stress (p. 7). The research remains compelling that one of the single most effective ways we may be able to heighten positive goal-directed behavior and potentially prevent violence and aggression is to provide youth with the strategies to regulate their attention and emotions and to provide those who facilitate their learning and development with the same strategies to do so themselves (e.g., educators). But what does that really mean and how is that best achieved? Bresciani Ludvik (2016) along with many psychologists and neuroscientists (Davidson et al., 2012; Sanger & Dorjee, 2015) asserted, as noted in Figure 3, that curriculum designed to cultivate youth's awareness of their experience, as well as compassion[5] for themselves and others as they become aware of their experience in this moment may empower youth to "choose again" in the next moment. However, at this time, the choice is informed by awareness, rather than simply reacting to an experience. This is particularly relevant to youth because, as was mentioned, the typical adolescent developing brain tends to choose the opposite of what youth know would be a more positive goal-directed choice. As such, training awareness into the present moment (often referred to as mindfulness[6]) with compassion may also improve resilience among youth, so you can simply endure the challenges (internal and external) they experience as their brains continue to develop (Davidson et al., 2012).

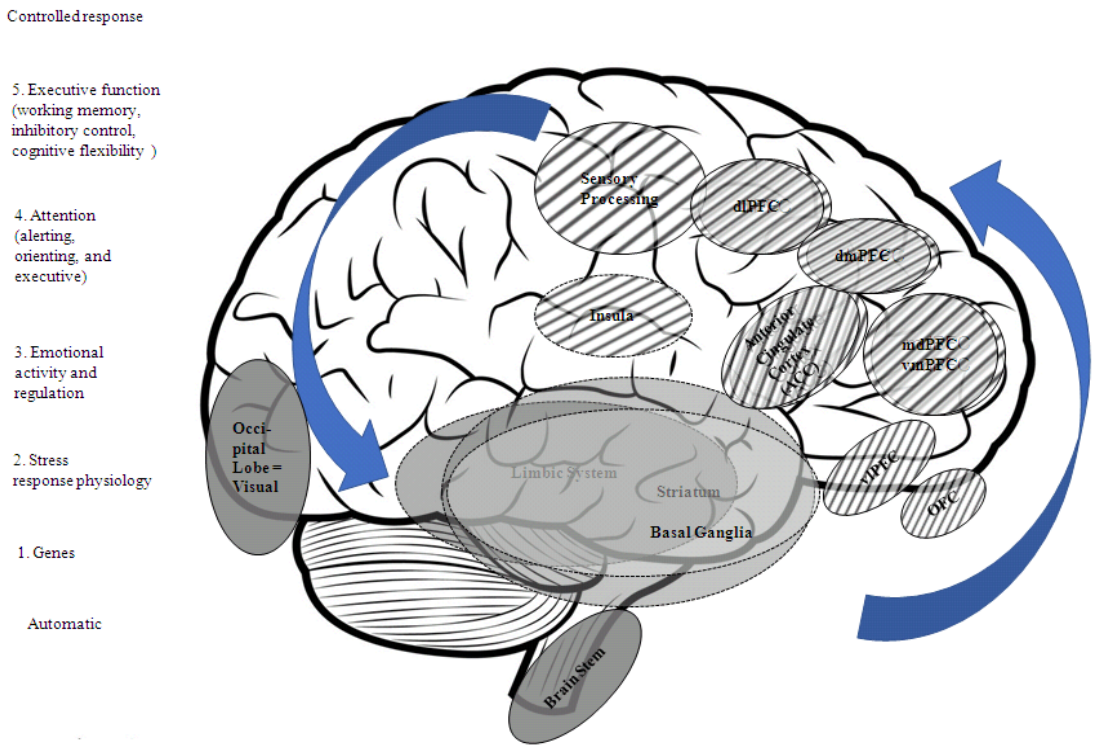

Figure 4. Characterization of top-down and bottom-up regulation (Source: Zelazo, Blair, & Willoughby, 2016).

[5] Compassion is defined as a complex multi-dimensional construct that is comprised of four key components: (a) an awareness of suffering (cognitive component); (b) a sympathetic concern related to being emotionally moved by suffering (affective component or often referred to as empathy); (c) a wish to see the relief of that suffering (intentional component); and (d) a responsiveness or readiness to help relieve that suffering (action component) (Jazaieri et al., 2013; Jazaieri et al., 2014).

[6] Mindfulness is the awareness that arises from paying attention in a particular way, non-judgmentally to the present moment (Kabat-Zinn, 2013).

In order to understand how a mindful compassion curriculum (or any curriculum for that matter) might be designed, Zelazo, Blair, and Willoughby (2016) recommended that we first dissect the top-down and bottom-up process for regulating emotion that fosters enhanced executive functioning (see Figure 4). As discussed, they assert that genetics and stress response physiology (influenced by external and internal characteristics) form the basis for automatic reactivity. If we overlay this onto the brain regions discussed in Figures 1 and 2, the bottom-up portion would involve the brain stem, basal ganglia, striatum, and limbic systems. However, it is actually more complex than this. These portions of the brain are also involved in Zelazo, Blair, and Willoughby's (2016) next layer of moving from automatic behavior to controlled behavior, called the emotional reactivity and regulation layer. Recall earlier that parts of the brain represented in ovals filled with stripes in Figures 1 and 2 are also implicated in emotional regulation and begin to bring in the attentional aspects (alerting, orienting, and executive control) of determining whether stimuli are associated with positive or negative awards. Additionally, the same brain regions are implicated in the highest level of behavioral control (e.g., top-down), which Zelazo, Blair, and Willoughby (2016) called executive functions (e.g., reflection, rule use, working memory, inhibitory control, and cognitive flexibility).

Working With the Stress Response Physiology

As we mentioned, discussing genetics and epigenetics resides outside the scope of this paper. As such, we begin with Zelazo, Blair, and Willoughby's (2016) Layer 2, working with the stress response physiology. As educators, we affirm that we cannot ignore the unique lived experience of each human being who walks into our classroom, albeit virtually or online. Each student's individual and external lived experience has shaped who they are and how they are arriving in the classroom. Environmental factors and subsequent internal processing (or not) of those factors significantly influence stress response physiology (Zeman, Cassano, Perry-Parrish, & Stegall, 2006). What do we mean by stress response physiology?

When a person experiences a stressful event (albeit an internal thought about a deadline that has passed or an external experience of conflict with another person), the amygdala immediately sends a signal to the hypothalamus (see Figures 1 and 4). The hypothalamus is often referred to as a command center for the body. When the amygdala sends the immediate signal as a response to the stressful event to the hypothalamus, the hypothalamus communicates to the body through the rest of the nervous system (recalling that neural pathways are the ones communicating between and among brain regions and body parts). The hypothalamus prepares the body's physiology to either fight, flee, or freeze. This communication process is typically classified into two systems. The sympathetic nervous system, which tells the body to run or fight, and the para-sympathetic system and tells the body to calm and move back into a resting state once the stressful event has ended.

The communication process between the amygdala and the hypothalamus happens so quickly, the glands, neurochemicals, and other corresponding parts of the brain send the body into fight, flight, or freeze via the sympathetic system before the brain's visual centers have time to even process what is happening. All of this often occurs without awareness to the human being experiencing this stress response physiologically. This stress response will remain activated until the stress event passes and then the para-sympathetic system will activate to soothe the body's physiology with the intent to return the physiology back to a resting state. For some humans, that soothing process happens automatically. For others, their unintentional or intentional recalling of the stressful event (either worrying that it will happen again, wondering what to do about it in the

future, or re-living it to see how it could have been avoided) may need an intentional activation of cognitive processes that could then intentionally activate the para-sympathetic system.

For educational purposes, it is important to know that stress response physiology is, in essence, programmed into human beings. This means that we cannot stop the stress response physiology from activating and it is there for survival purposes. The challenge is that not all stressful events require us to act on the stress response with behavior that looks like fight, flight, or freeze reaction. Since the body is prepared for fight, flight, and freeze without one's awareness, a person must train oneself to become aware of the stimulus of the stressful event (e.g., the source of the stressor) and begin an inquiry process into it in order to determine what action in this moment is most appropriate for the situation and is also a kind choice that will move one toward a positive goal.

So, how does one intentionally activate awareness? This is not an easy answer from a neurological perspective. Parts of the brain implicated in awareness of self as self, emotions, body, environment, and others includes a dynamic interweaving of activity between the brain stem, limbic system, and wide spread areas of the cerebral cortex (Schapira, 2007; Benarroch, Daube, Flemming, & Westmoreland, 2008; Jacobson & Marcus, 2008; Shewmon, Holmes, & Byrne, 1999; Merker, 2007; Philippi et al., 2012). Given that research is still emerging and some of that research is contradictory, it may be helpful to inquire into what brain regions are activated during self-referential reflection, particularly if that is the kind of reflection that can be taught and is also needed to select a positive goal-directed choice when stress response physiology has been activated.

Herwig et al. (2012) argued that self-reflection is necessary for positive goal-directed choices. They found that when participants were engaged in self-reflection, there was more prominent activation in the dorso-medial and lateral PFC, insula, ACC, and posterior cingulate, particularly when compared with reflection of other. At this point, we should keep in mind that these are portions of the brain needed for top-down regulation of emotional reactivity. Therefore, intentionally activating them within educational environments may prove beneficial to adolescent development and optimal goal-directed behavior.

Indeed, Espinet, Anderson, and Zelazo (2013) found that when youth were provided with reflection training, and then, given opportunities to "pause" and "reflect" before responding to task-relevant stress activities (often experienced when learning something new), they showed greater improvements in cognitive flexibility and perspective taking. Zelazo, Blair, and Willoughby (2016) argued that the associated brain changes that correlated with these improved executive functions reflected use-dependent myelination, dendritic thickening, and synaptic pruning—all white matter related changes important to influence during adolescence brain development.

The reflection training used in the referenced study involved youth being guided to pause 15 minutes before responding. During that pause, youth were invited to reflect on how they might approach the task—thinking of the hierarchical steps needed to resolve the learning task and to formulate other ways they might approach the task. In this situation, the trigger for the physiological stress response was learning a new task. In this scenario, the initial phase of soothing the physiological stress response was to train the students to "pause." Often, inherent in the "pause" is that the student breathes. The pause and breathe process acts as a brake on the sympathetic nervous system, allowing the parasympathetic nervous system to soothe the fight, flight, and freeze reactivity that is inherent within stress response physiology. Once, the reactivity is calmed and the student returns to a resting state, reflection can be activated.

Some of the neurotransmitters that stimulate activity in PFC, "such as dopamine and nor-epinephrine, originate in areas of the brain, such as the limbic system and brainstem. These areas influence attention,

emotional responses to stimulation, and the physiological response to stress" (p. 13). Experiences in the classroom (again, regardless of whether it is online or face-to-face) rapidly activate neural activity in the limbic system and brainstem, releasing those chemicals. If the learning experience is stimulating but not over stimulating, there can be optimal release of chemicals to maintain positive award association but not over power the PFC, allowing it to continue to function optimally (Arnsten, 2009).

Nonetheless, under conditions of stress, adolescents experience events with high emotional arousal, which interferes with top-down regulation. Such interference may also interrupt the adolescent's adaptive coping methods and result in maladaptive coping efforts that could eventually lead to psycho-pathology (Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Referencing earlier research on adolescent brain development, as well as dysregulation that can lead to interfering with positive goal-directed behavior (including acting with aggression and violence), inviting students to become aware of their own levels of stimulation through pausing and breathing, as well as providing them with healthy options to cope and manage over-stimulation could prove beneficial not only to optimal classroom management but also to empower adolescents to become aware of and manage their own stress response physiology. This leads us to discuss the next level of regulation in Figure 4.

Working With Emotional Activity and Regulation

Emotions are defined as an "affective state of consciousness in which joy, sorrow, fear, hate, or the like, is experienced, as distinguished from cognitive and volitional states of consciousness" (Retrieved from http://www.dictionary.com/browse/emotion). Emotions have historically and often been considered destructive to adolescents' learning and development (Zeman, Cassano, Perry-Parrish, & Stegall, 2006). In the past two decades, researchers have shifted their perspective and now focus on increasing their understanding of how emotions are identified and regulated and how that regulation influences positive goal-directed choices (Zeman, Cassano, Perry-Parrish, & Stegall, 2006). ER as defined by Grolnick, Bridges, and Connell (1996) was the processes of harnessing awareness of where attention resides, and then, initiate, maintain, and modulate an emotional response. ER is not suppressing, denying or avoiding emotions, rather Thompson (1994) argued that ER "is rather a broad conceptual rubric encompassing a range of loosely related processes" (p. 30). To emphasize this point, Kassam and Mendes (2013) explained that simply understanding emotional activity in order to regulate it involves "complex processes involving multiple response channels, including physiological systems, facial and vocal expressive tendencies, and cognition" (p. 1). Furthermore, when a human experiences an emotional event, the event activates a series of neural activities which can change neural and bio-chemical systems (Northoff et al., 2000), the very systems that are developing during adolescence (see Figure 1).

Zelazo, Blair, and Willoughby (2016) pointed out that the interaction between the brain regions recruited for executive functions (the ovals filled with stripes in Figure 4) and the limbic system and brain stem (also depicted in Figure 4) are distinctly different in the presence of high-level emotions as opposed to neutral ones. It is not that the brain regions involved differ when adolescents are experiencing high-level of emotion as compared to neutral emotions, rather it is the way in which these brain regions interact that differs (Zelazo & Carlson, 2012). Researchers have suggested that emotions are needed for motivation and discerning whether rewards are positive or negative, thus, optimizing goal-directed behavior (Zelazo & Cunningham, 2007). However, we should recall that adolescents, during development, show enhanced sensitivity to strong rewards (Spear, 2013). Adolescents may not be able to discern among these emotions. High-reward seeking (particularly during a time when increased risk-taking is also high) often leads to negative addictive behaviors that dampen

sensing abilities and deter adolescents away from positive goal-directed choices (Spear, 2013). As such, Spear (2013) argued that given adolescents' heightened sensitivity, it may be possible to construct educational experiences where youth discern for themselves among the types of "exciting and emotionally arousing circumstances that increase activity in subcortical regions modulating reactivity to socio-emotional and rewarding stimuli, but also attenuate activity in regions of the frontal cortical critical for logical thinking and cognitive control" (p. 13). Zelazo, Blair, and Willoughby (2016) believed that much more research is needed on the distinct differences that exist in connectivity to be able to discern how to specifically train adolescents to self-discern. Nonetheless, there are clues from ER research that may prove beneficial to educators.

Mindfulness training, "involves intentionally paying sustained attention to ongoing sensory, cognitive, and emotional experience, without elaborating upon or judging any part of that experience" (Kabat-Zinn, 1994, p. 7). Mindfulness methodology involves a range of exercises, often referred to as practices, as well as a number of psychological processes involving reflective practices (Germer, 2005), such as self-regulation (Brown & Ryan, 2003), meta-cognition (Bishop et al., 2004), and acceptance (Linehan, 1994). The intent of mindfulness practices integrated into existing curriculum is to train attention as well as ER. It is unclear to psychologists whether mindfulness is a distinct construct that could become a part of an educational learning domain or a quality of consciousness that could be embedded into any lesson (Chamber, Gullune, & Allen, 2009). Others have proposed multi-faceted models that link to other neurocognitive skills, reflecting various activities involved in mindfulness training, such as non-judgment, acceptance, present awareness, attention, and intention (Dimidjian & Linehan, 2003; Ivanovski & Malhi, 2007). What remains consistent in the types of practices used within mindfulness methodology is presenting the participant with an "invitation" to first set an "intention" to improve personal well-being or to increase the ability to pay "attention" to what is happening in this experience right now. Then, when the mindfulness-training participant "notices" something that is unwelcomed or feels unhealthy, such as anger or stress, they are invited to stop/pause and invite a gentle attention to the "sensation of the breath in the body." The next step is to "reflect and notice" what is happening within the "self" and in relationship to the "other" person who may be the source of the stress stimulus.

Within the ER training process, skilled professionals invite youth to reflect upon what they are sensing, their emotions, and thoughts (include their beliefs, values, and ideas). Youth are also invited to engage in cognitive activities where they name the emotions as either pleasant or unpleasant, or discern among them as anger, fear, excitement, happiness, etc.. This differs from the Espinet, Anderson, and Zelazo (2013) exercised where youth were only invited to reflect on possible solutions to the problem-solving task that was intended to create a physiological stress response. The purpose of inviting youth to reflect on bodily sensations, emotions, and thoughts is so that youth can learn how to be with discomfort (whether that be an uncomfortable bodily sensation, emotion, or thought), without judgment, noticing also the different qualities and degree to which these unwelcomed bodily sensations, emotions, and thoughts shift over time. This can be guided in relationship to how youth associate these sensations with thoughts and/or how youth associate these sensations with how their attention shifts from one moment to the next. This practice is expected to cultivate healthy top-down regulation processes within youth as well as cultivate a more accurate sense of self (e.g., self-awareness) (Davidson et al., 2012; Sanger & Dorjee, 2015).

As youth practice the variety of mindfulness exercises offered to cultivate attention and ER from professionally trained facilitators, youth are also encouraged to offer themselves and others kindness as they practice. The practice of offering kindness stems from a much larger body of work on compassion cultivation

training. Compassion training has been shown to activate the neural network of the medial OFC, putamen (located in the striatum), pallidum (a part of the basal ganglia), pregenual ACC (regulates blood pressure and heart rate), and ventral tegmental area (implicated in the reward system of the brain) (Klimecki, Leiberg, Lamm, & Singer, 2013; Klimecki, Leiberg, Ricard, & Singer, 2014). These are all brain regions that have been previously associated with positive affect (Kringelbach & Berridge, 2009), affiliation (Strathearn, Fonagy, Amico, & Montague, 2009), and reward (Haber & Knutson, 2010). Intentionally offering kindness to self and other seeks to train connectivity among the brain regions that are developing in adolescents that may otherwise turn students away from positive goal-directed behavior, in a manner where students are able to discern whether rewards are indeed positive and kind, thus, turning them back towards positive goal-directed behavior.

Furthermore, a part of the compassion cultivation training within curriculum is to access empathy for other, which activates neural circuitry that can enhance social connectivity (Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008). To discuss the empathy portion of the curriculum in more detail resides out of the scope of this paper, however, more can be found in compilation of works (Bresciani Ludvik, 2016). What is relevant for this conversation is that compassion cultivation training, which includes empathy training, has been known to increase altruistic and pro-social behavior (Leiberg, Klimecki, & Singer, 2011) as well as deepen relationships and social connection (Frederickson et al., 2008; Hein et al., 2010; Hutcherson, Seppala, & Gross, 2008; Klimecki, Leiberg, Lamm, & Singer, 2013; Leiberg, Klimecki, & Singer, 2011). Compassion cultivation training has also been known to reduce implicit bias (Kang, Gray, & Dovidio, 2014; Lueke & Gibson, 2014), stereotype threat (Weger, Hooper, Meier, & Hopthrow, 2012), and reduce racial bias (Stell & Farsides, 2016). However, the specific neurological processes related to these findings are yet unclear.

Returning to the discussion at hand, when youth offer kindness to self and others, it allows youth to access the non-judgmental and acceptance part of their experience and help them discern that what they are experiencing is a part of being human, as opposed to an interpretation they might have about their experience. This can be a key ingredient in the ER process as it allows adolescents to access executive functions (e.g., PFC) that are needed to down regulate over-reactive limbic systems (Davidson et al., 2012; Sanger & Dorjee, 2015). Accepting the present experience, in contrast to reacting within a habitual risk-taking or avoidant pattern can lead to more positive goal-directed behavior (Brown & Ryan, 2004; Hayes, 1994; Roemer & Orsillo, 2002; Teasdale, Segal, & Williams, 1995). Acceptance of the present experience (not to infer that this means an acceptance of the underlying cause of the experience, such as bullying or harassment) has been associated with general decreases in arousal (Kabat-Zinn, 2013). This is particularly beneficial to adolescents who are experiencing increased sense-seeking, risk-taking, novelty, and immediate gratification from their risk-taking behavior. Mindfulness training has been implicated in down-regulation (e.g., top-down processing, see Figure 4) of defensive action and reactivity, which correlate with increased adaptive behavior (R. A. Lanius, U. F. Lanius, Fisher, & Ogden, 2006). Within the context of interpersonal relationships, particularly when coupled with compassion exercises, mindfulness may increase secure attachment (Shaver, Lavy, Saron, & Mikulincer, 2007), which may improve motivation and positive sense of self.

While the practice of mindfulness—where participants are invited by trained professionals to turn toward their experiences and reflect on what they are sensing, feeling, and thinking—may result in increased exposure to unpleasant emotional states, such as anxiety. Anxiety would otherwise engender cognitive and behavioral defenses and reactivity, the practice of non-judgmental, accepting awareness provides the participant with an opportunity to examine their thoughts, beliefs, and values related to these sensations, emotions, and other

thoughts in a kind and supportive environment (Baer, 2003; Borkovec, 2002; Kabat-Zinn, 1982; Kabat-Zinn et al., 1992). Putting all these practices together may allow for a decrease in experiential avoidance (Hayes & Wilson, 1994; Kumar, Feldman, & Hayes, 2008), which can occur when one is unwilling to remain in contact with elements of one's experience that are unpleasant, such as the stress associated with learning a new task, subsequently and potentially moving toward more immediate high reward risk-taking behavior away from positive goal-directed behavior (Chambers, Gullone, & Allen, 2009).

Consistent mindfulness practice creates a shift from focusing on present experiences, explored non-judgmentally and with kind reflection, rather than using past experiences to predict and avoid possible future events (Kabat-Zinn et al., 1992; Ogden, Minton, & Pain, 2006). This may promote increased awareness of perceptual inaccuracies resulting from unexamined thoughts, feelings, and sensations that may drive maladaptive behavior (Krasner, 2004). Mindfulness, thus, ultimately, aims to alter the relationship individuals have toward their mental processes, questioning how past experiences could be applied to present moment experiences (Siegel, 2007). The potential of these practices to alter current trends in aggression and violence are compelling. Still, the challenge may be how do educators provide opportunities for students to soothe emotional reactivity within their already overloaded curriculum that is focused on getting students to pass exams? Perhaps, it is important to know that, as educators, we may be cutting off access to learning if we do not provide students with these skills.

Brain regions implicated in ER processes that also include stress response physiology suggests that ER may involve specific pathways between the PFC and the limbic system, particularly the amygdala (Banks et al., 2007; Ghashghaei, Hilgetag, & Barbas, 2007; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner & Gross, 2004). Strengthening the connectivity among these brain regions in positive ways may predict any decreases in negative emotion that could affect cognitive educational strategies (Banks et al., 2007). As a reminder,

> Clinical research implicates prefrontal–limbic dysfunction in ER as observed in behaviors, such as depression, anxiety, aggression, and personality disorders. Strengthening the neural pathways linking the amygdala and areas of the PFC has been shown to predict successful ER in terms of decreased self-reported negative affect. (Chambers et al., 2009, p. 566)

It is also noted that the OFC appears to play an especially crucial role in ER (Quirk & Beer, 2006). The OFC is also implicated in compassion cultivation practices and other parts of the brain (striatum, basal ganglia, insula, ACC, and other portions of the brain connected to the reward system).

The mindfulness training process, as discussed in this section and summarized in Figure 5, may be at least one way to positively approach assisting adolescents through their typically developing brain processes, while also improving positive goal-directed behaviors, which lead them away from aggression and violence. As we move to discuss the next two levels of Zelazo, Blair, and Willoughby's (2016) work, you will notice that what was discussed in this and the previous section appear to be tightly intertwined with the other two levels. We point this out because it is not clear (given the complexity of the brain and the complexity of adolescent brain development, along with the limited imaging available of the adolescent brain during mindful compassion practices). How much mindfulness training is needed, when, and for how long in order to be able to confidently strengthen healthy top-down regulation processes that are typically dysregulated during adolescence. Nonetheless, the brain regions implicated in these processes call us to pay more immediate attention to how we are intentionally cultivating Zelazo, Blair, and Willoughby's (2016) synthesis of top-down and bottom-up regulatory process in school curriculum.

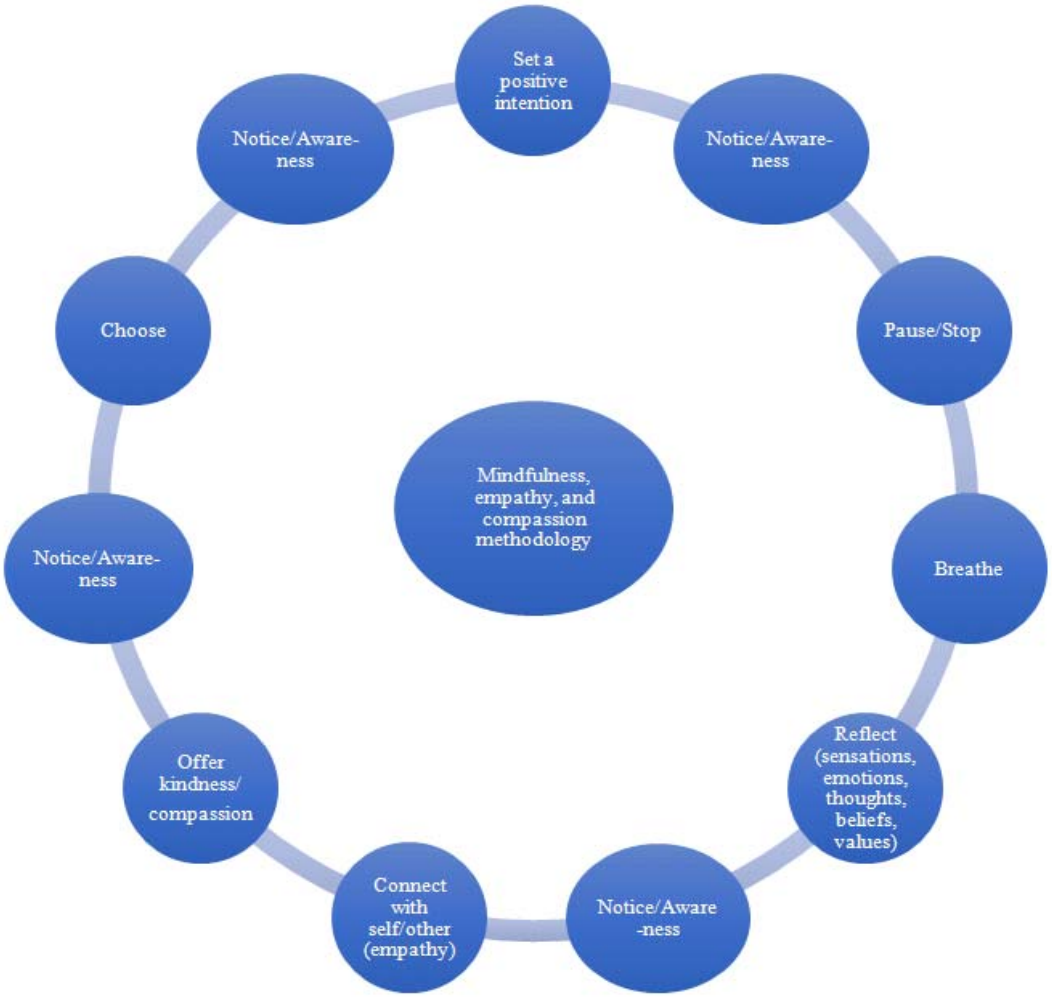

Figure 5. Top-down and bottom-up brain training process methodology.

Working With Attentional Control

The importance of attentional control to the ability of adolescents cultivating healthy top-down and bottom-up regulation processes has been a consistent theme throughout this paper thus far. Since 1998, Coull had argued that attention and arousal have tightly intertwined neurobiological processes. Coull (1998) posited that in order to control arousal, awareness must be brought to the object of attention as well as to the corresponding physiological expression/sensations of where attention rests. Only then, can there be a discernment of where to place one's attention in order to optimize positive goal-directed behavior. Treue's (2001) work affirmed Coull's position and also posited that attentional control and the correlating neural connectivity will be influenced by one's visual world and the behavioral relevance of that information, rather than a seeking to reflect and discern the accuracy of what is observed. If you consider that adolescents in the USA consume nine hours of media a day on average and they often do multi-tasking (note this excludes media assignments during school and media-assigned homework) (Common Sense Media, 2015), the challenge of re-wiring attentional control networks toward reflecting and discerning is further challenged. Would it be possible for educators to harness adolescents' desire to engage in media to advance attentional regulation? If so, in using media, could educators invite students to become aware of where their attention rests and reflect on sensations to heighten awareness?

For now, it is unclear. Currently, researchers are increasingly investigating the attentional and neurocognitive processes that underlie psychological and physiological states that cause dysregulation and exploring how mindfulness training may mitigate that. Thus, researchers have noted that mindfulness can improve attentional control and other executive cognitive functions in adults (Baer, 2003) as well as improve sustained attention and working memory in adults (Chambers, Lo, & Allen, 2008; Valentine & Sweet, 1999). Furthermore, mindfulness can improve attention switching and inhibitory control (Bishop et al., 2004), reduce reactivity toward unexpected stress inducing incidents, and increase visual perceptual sensitivity and acuity (Ivanovski & Malhi, 2007). Furthermore, sustained and prolonged mindfulness practices can increase visual discrimination (Brown, Forte, & Dysart, 1984) and reduce attentional blink[7] (Slagter, Lutz, & Greischar, 2007).

Attentional control research is quite complex in and of itself. To differentiate the neural correlates of varying types of attention resides outside the scope of this paper. What is important to note is that the links between attentional control (what we refer to as attention regulation) and ER have significant consequences for the adolescent population (as previously referenced), because adolescents tend toward more impulsive and their behaviors are risk-taking (Sanger & Dorjee, 2015). Ernst, Pine, and Hardin's (2006) and Van Leijenhorst et al.'s (2010) research emphasized how the adolescent reward-driven system implicated by activity in the ventral striatum and ACC can exert more control over adolescents' behavior than the amygdala, especially while the regulatory control portion of the brain (PFC) is still developing. This can lead to riskier decision-making. As such, training adolescents' attention toward the object of their attention as well as the sensations, emotions, and thoughts they are experiencing when they notice where their attention rests may prove extremely beneficial for increasing positive goal-directed behavior.

Recall in the earlier section, how offering kindness can also activate the ACC, striatum, and the ventral tegmental area (implicated in the reward system of the brain). Researchers (Dywan et al., 2008) had shown how integral the connection between attention control and ER through the ACC is. This is where mindfulness methodology allegedly can influence ER strategies, as mindfulness practices have been associated with greater cortical thickness (Tang et al., 2010) that might lead to enhanced white matter integrity in the ACC (Tang et al., 2012; Grant et al., 2010). Yamasaki, LaBar, and McCarthy (2002) asserted that attentional and emotional functions are segregated into parallel top-down and bottom-up connectivity processes originating in the visual cortex (see Figures 2 and 4) that extend into the PFC. They also asserted that these processes are integrated in the ACC. Their findings may help educators better understand the complex dynamics underlying emotional dysregulation and its influence on attentional tasks. It is plausible that mindfulness practice, which enhances attention and ER could encourage connections among the relevant prefrontal structures in adolescents, stabilize arousal and reduce harmful risk-taking (Atkins, Bunting, Bolger, & Dougherty, 2012; Davidson et al., 2012; Sanger & Dorjee, 2015).

Summary and Conclusion

Enhancing executive function has been a focal point of many educational outcomes. As such, this paper will not discuss that portion of Zelazo, Blair, and Willoughby's (2016) diagram. Instead, this paper will summarize the importance of adding attention and ER training as well as compassion cultivation into

[7]Attentional blink describes the phenomenon where one can miss important information that is given in quick succession.

curriculum. By doing so, it may positively address how dysregulation in the typically developing adolescent brain can lead to poor executive functioning, as well as a lack of positive goal-directed behavior (Zelazo, Blair, & Willoughby, 2016). These assertions are well understood among psychologists, neuroscientists, and educators. What is less well known is how education can specifically prevent such dysregulation, particularly among adolescents. When coupled with the concern of increasing violence in schools, and homicide and suicide remaining the second and third reasons for death among youth, the need for educators to take into account the research synthesized in this manuscript (while also accessing additional research that expands and contradicts this summary), is imperative.

In overlaying the neural correlates of adolescent brain development and violence, the intent of Figure 1 was to illustrate the importance of exploring the connectivity among various regions inferred in the study of violence. Many of the regions of the brain implicated in violence are also regions of the brain that are undergoing significant change during adolescence. In order to reduce what appears to be natural aggression tendencies among adolescents, the interaction of these portions of the brain (see Figure 2) require a sophisticated top-down and bottom-up regulation practice that is not always readily accessible to the developing adolescent brain. Furthermore, portions of the brain implicated in motivation, self-awareness, and reward discernment are also developing, complicating adolescent's positive goal-directed choices even further.

Theorists have simplified (perhaps over-simplified) representations of how executive functions are typically cultivated or could be cultivated within educational systems (see Figure 3). When such processes are overlaid onto the top-down and bottom-up regulatory systems of the brain (see Figure 4), educators may begin to realize the complexity and importance of emotion to the learning process. In presenting mindful compassion practices (which include attention and ER, empathy, offering kindness to self and other, and inviting students into compassionate action) as a possible educational methodology to cultivate healthier top-down and bottom-up regulatory processes, while also leveraging what is known about cultivating accurate self-assessment and rewards discernment (see Figure 5), empowering adolescents to discover how to access their own attention and ER strategies when needed may be possible. Figure 6 illustrates an example of an 8-week online mindful compassion curriculum (Retrieved from http://www.integrativeinquiry.org), where weekly content is introduced and participants are invited to engage in daily practices and reflection exercises. This online model is embedded into existing curriculum. This curriculum also includes a pre- and post- assessment packet with valid and reliable assessment instruments, however, a longitudinal study would be required to determine its influence on participants' ability to avoid aggression and violence and continue to choose positive goal-oriented behavior. Preliminary findings of a small pilot study for this curriculum administered to young adult college students is very promising. Qualitative findings from journal analysis are providing specific examples of participants' ability to regulate attention and emotion across contexts, as well as providing examples of compassion in action.

There have been many mindfulness-based curricula developed for adolescents. Some of these curricula include Mindful Schools (Mindful Schools Non-Profit Organisation, 2010), Mind Up (The Hawn Foundation, 2011), the Mindfulness in Schools Project (MiSP) (Kuyken et al., 2013), Learning to Breathe (L2B) (Broderick, 2013), Still Quiet Place (Saltzman & Goldin, 2008), Mindfulness-Based Stress Reduction for Teens (MBSR-T) Biegel, 2009), and Mindfulness for Adolescents (Dewulf, 2009). While the research on the effectiveness of some of these curricula have shown low to midium effect sizes in areas of self-reported improvements in attention and ER, neuroimaging results have yet to report consistencies in findings (Meiklejohn et al., 2012). Sanger and

Dorjee (2015) contended that these low to medium effect sizes might be due to the intentional reduction in course length, as well as reductions in practice frequency and duration. These reductions were intentional so as to coincide with what is understood about the developing adolescent brain as well as an attempt to work with educators who are already overloaded with curriculum demands and testing requirements. Nonetheless, it seems that perhaps these practices may be exactly what the typically developing adolescent brain requires. However, we simply do not know yet, as there has not been enough research conducted.

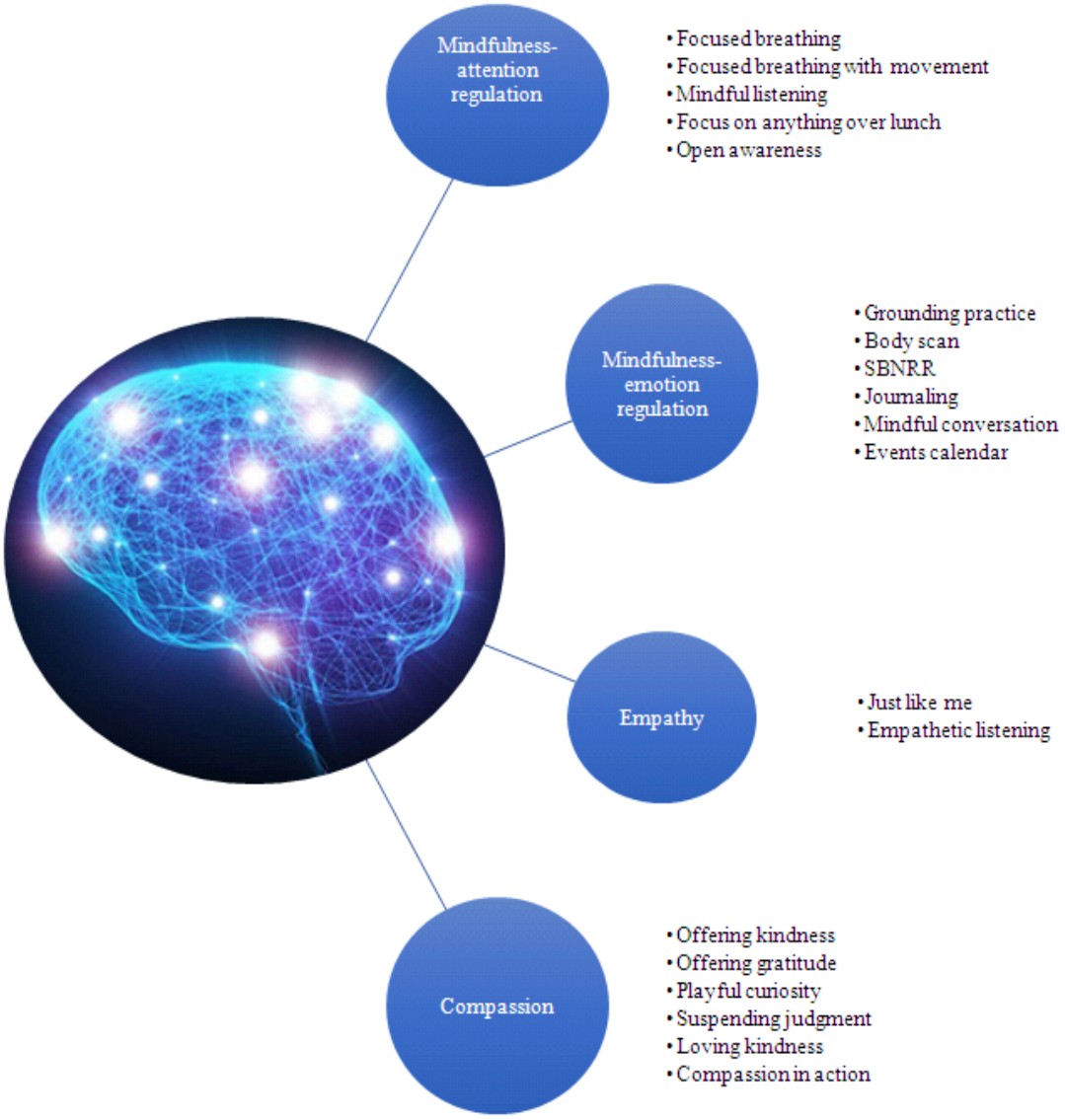

Figure 6. Mindful compassion curriculum content and practices.

Given the growing epidemic of aggression and violence among youth, as well as compelling evidence that mindful compassion practices have medium to large effect sizes among adults in advancing attention and ER and overall well-being among other related outcomes (Grossman, Niemann, Schmidt, & Walach, 2004; Hofmann, Sawyer, Witt, & Oh, 2010; Hölzel et al., 2011; Kabat-Zinn, 2013; Van Dam et al., 2017), it seems unwise for us to ignore the integration of these practices into curriculum wherever it is possible.

Indeed, we could adopt a model where a separate mindful, empathy, and compassion curriculum could be administered to students. However, the question of when to provide that curriculum becomes a challenge. Some school leaders have provided curriculum in after-school programs or early start programs, while others have integrated mindfulness lessons into existing curriculum. Still others are exploring offering these programs in a summer term before students' transition into upper level coursework. For us, we have integrated the mindful compassion curriculum into existing classes and also offer it as a stand-alone course. We began with small pilots and it is expanding because family members, community members, other teachers, peers, and students themselves are seeing shifts in how they can regulate their attention, emotion, and cognition as well as practice compassion even for difficult people. To summarize what students report with a recently gathered quote,

> It is like now, I can climb into the control tower of my mind, watch what is bugging me, and choose what to do about it instead of like, and just punching the dude … Why did not anyone ever tell me I could do this before now?

Given the compelling known of adolescent brain development and the growing incidents of violence and aggression among youth, we wonder why we are not doing as much as possible to integrate these practices into existing curriculum and measuring the results.

As such, we conclude with some recommendations for policy-makers and educators. For policy-makers, we invite you to consider the following questions:

1. What is keeping current accreditation or quality assurance processes from expecting educational systems to include such practices and measurement of the effectiveness of curriculum that could prevent violence and aggression?

2. If you are looking for more evidence that a specific approach of integrating mindful and compassion cultivation practices work effectively, how can you promote and support pilot projects to be implemented within your educational system? And how will you use data that emerge from those studies in your decision-making?

3. How will you provide training to educators, so that they can adopt and adapt existing curriculum for adolescents and evaluate its effectiveness?

4. How will you support educators' time to collect meaningful and longitudinal data that will responsibly measure the success of the curriculum?

5. While youth aggression and violence is on the rise, what exactly are you waiting for? What do you need to know in order to take action to potentially prevent it? And have you communicated whatever that is to someone who can actually provide that information (or assurance) to you?

For educators, we invite you to consider the following questions:

1. If student's stress and adolescent brain development processes are keeping them from optimal learning, why so much emphasis on getting them to pass exams, when could you be focusing on curriculum that may help you to achieve positive goal-oriented behavior, such as potentially passing exams?

2. How do you want to train yourself in this curriculum, so that you can adopt and adapt it in order to best serve your students, as well as your own well-being?

3. Who do you need to get permission from to pilot some curriculum in your classroom and measure its effectiveness?

4. What specifically do you need to support that pilot and evaluation process and who can provide that to you?

5. While youth aggression and violence is on the rise, what exactly are you waiting for? What do you need to know in order to take action to integrate a curriculum that potentially prevents it? And have you communicated whatever that is to someone who can provide that information, assurance, or curriculum to you?

We close with a firm recommendation that policy-makers and educators invest, with immediacy, in exploring how mindful compassion practices and other curriculum could prevent youth aggression and violence in your schools. The most meaningful and relevant data are which you gather in your own classroom from your own students to convince you whether this works. So, what are you waiting for?

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