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The Physiology of Social-Emotional Learning: Integrating Biomarkers of Self-Regulation into the Assessment and Implementation of Programs

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Abstract
In the last two decades, formalized social-emotional learning (SEL) programs in schools have proliferated in response to a staggering increase in mental, social, and emotional challenges for youth. SEL programs differ in their theoretical foundations, though there are commonalities among them. Self-regulation (SR) surfaces as an important pillar. Researchers have relied mostly on self-reporting and teacher questionnaires to measure the effectiveness of these programs to improve SR and other aspects of youth well-being, without explicitly considering the physiological effects of these interventions on the biomarkers of youth. By addressing this gap, program researchers, developers, and educators can reach their stated objectives more effectively, thereby better nurturing SR and other social-emotional competencies. This paper explores a new model and rationale for incorporating physiological metrics (biomarkers), such as vagal tone (VT), into current SEL program impact-assessments and recommends incorporating mind-body practices such as exercise, breathing, mindfulness, and yoga into SEL interventions. This model hypothesizes that the integration of physiological measures and the practices that affect these markers will lead to an increase in SR via a bidirectionally-causative upward spiral. Recommendations for school-based interventions to affect VT are discussed, along with considerations for implementation.

Keywords
education, social-emotional learning, social emotional learning, biomarkers, vagal tone, self-regulation, breathing, mindfulness, meditation, mind-body, positive youth development, positive psychology, positive education, program assessment, exercise, physiology, parasympathetic, sympathetic, nervous system, stress, heart rate variability, vagus, school

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University of Pennsylvania

A Capstone Project Submitted

In Partial Fulfillment of the Requirements for the Degree of

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Advisor: Dr. Kathy Hirsh-Pasek

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My mission is to be an instrument of love, protection, and a source of joy and strength for children by helping them to know themselves and live beautiful lives. We are all interconnected. We can only do this together. Thank you, Universe.

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Preface

For an educator, this paper is about saying "I see you," "I acknowledge that to learn, you must feel good," "I validate your inner world of emotions and experiences and feelings and thoughts." This paper responds to decades of the separation of body and mind, to the illusion that body, emotions, and thoughts are not part of learning. The truth is, as we have seen, and as William James (1899/1989) illuminated in his *Talks to Teachers,* we are embodied beings - not just brains. Social-emotional learning (SEL) programs and schools have begun to acknowledge this. When we give kids the tools to manage their own minds, bodies, thoughts, and emotions, we give them the gift of self-regulation, and the capacity to build healthy relationships with others. However, *how* we teach self-regulation (SR) matters as much as doing so. Often attributed to Theodore Roosevelt, people often say in education circles, "people don't care what you know until they know that you care" (Miller, Latham & Cahill, 2016, p. ix). This is why to assess biomarkers: we very literally show that we care. We care about the most foundational aspects of a child, not just his or her behaviors, or scores on exams. We care about the inner, invisible worlds that determine youth behavior, capacities to learn, to love, to connect, and to be happy. This is a shift in the paradigm of what it means to educate: I posit that it means to care about the whole child - biomarkers and all.

I. Introduction

Over the last 20 years, there has been an increase in mental health and social-emotional challenges for youth in the United States (Twenge, Cooper, Joiner, Duffy, & Binau, 2019). Youth experience more depression, anxiety, and other mental health challenges than any other time in history (Blad, 2019). The rates of major depressive episodes increased 52% from 2005-2017 (from 8.7% to 13.2%) among adolescents age 12 to 17 (Twenge et al., 2019). Social-emotional competencies such as empathy are decreasing, and analysis of intergenerational research indicates that the children of baby boomers appear to be more narcissistic (Twenge, 2007). Narcissism is correlated with increased impulsivity, decreased empathy, and increased aggression (Twenge & Campbell, 2009). Compounding the importance of these factors, the fact that the number of school shootings in the United States hit an all-time high in 2018 (97 incidents). Together these incidents may reflect a vacuum of important social-emotional competencies (Center for Homeland Defense and Security, 2019).

Schools play a critical role in nurturing the positive development of children (National Research Council, 2012) and these increases in mental health and social-emotional challenges have motivated schools to implement social-emotional learning (SEL) programs and initiatives. A robust field of research and public resources have been invested in this effort. Today there are thousands of schools in the U.S. and across the world that have adopted SEL programs, with integration-support from state and federal governments (Humphrey, 2013; Weare & Nind, 2011). The U.S. House of Representatives recently approved $260 million for initiatives that reduce and prevent trauma in schools, and support the healthy social and emotional development of students (HR 2740, 2019). In response, many states have made progress in identifying social-emotional competencies and standards (Darling-Churchill & Lippman, 2016). These

policies support, legitimize and sometimes mandate the integration of SEL programs into academic settings.

A review of the landscape of social-emotional metrics, theoretical frameworks, and practices reveals three major take-aways: 1) self-regulation (SR) is a common competency across many SEL programs (Berg, Osher, Same, Nolan, Benson, & Jacobs, 2017; Tolan, Ross, Arkin, Godine, & Clark, 2016); 2) SR, along with other SEL competencies are most often measured through self-reporting, teacher-reporting of behavior, and in some cases, performance tasks (Greenberg, Katz, & Klein, 2015; Duckworth & Yeager, 2015); and 3) SR training in SEL happens in traditional cognitive-behavioral (top-down) practices. **In this paper, I will explore a missing opportunity in the models of change of SEL programs that could augment their impact— the integration of physiological outcome measures and physiological practices that might heighten SR and add a new dimension to the literature.**

This paper makes a case for a stronger connection between the fields of SEL and psychophysiology and neuroscience, in order to strengthen the impact of programs on the social-emotional well-being of youth. It offers 1) an overview of SEL field, common competencies and approaches to measurement; 2) overview of SR as a core competency, and how it is currently developed and measured; 3) a presentation of a physiologically informed model for the development of SR and assessment of SEL programs; 4) an exploration of recommended physiological measures of SR; and 5) a set of empirically validated practices to augment current SEL initiatives and programs.

A. What is Social Emotional Learning (SEL)?

The Collaborative for Academic, Social, and Emotional Learning (CASEL) was established in 1994 “with the goal of establishing high-quality, evidence-based social and emotional learning (SEL) as an essential part of preschool through high school

education" (CASEL, 2019a, para.1). CASEL was established as a clearinghouse for the advancement of the SEL field. Many researchers and programs rely on CASEL's (2013) definition of SEL as "the processes through which children and adults acquire and effectively apply the knowledge, attitudes, and skills necessary to understand and manage emotions, set and achieve positive goals, feel and show empathy for others, establish and maintain positive relationships, and make responsible decisions" (p. 6).

CASEL's (2013) conception of SEL encompasses many different types of approaches to youth wellness programming in school settings; SEL exists as an umbrella. SEL includes recommendations on established practices, as well as a host of disparate programs, but does not provide a one-size-fits-all model or curriculum. Its framework of SEL competencies is derived from existing and evaluated programs (Tolan et al., 2016). The objective of most SEL programs is to help students achieve a level of self-competency, self-concept, social skills and cognitions so they may adapt and behave in ways that promote positive functioning within a variety of social and academic settings (Tolan et al., 2016).

CASEL (2019b) has put forth five SEL competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Self-awareness, refers to the ability to understand one's emotions, goals, values, and strengths as well as limitations and mindsets (CASEL 2019b). It includes having optimism and self-efficacy (belief in one's own abilities). Self-management, which refers to the ability to manage stress, impulses, emotions, reactions, and set and achieve goals effectively. Social awareness, which refers to the ability to empathize with and understand the perspective of others, even those from diverse backgrounds. Relationship skills, which refer to the abilities to communicate, listen actively, cooperate, collaborate, and resolve conflicts. Responsible decision-making, which refers to the ability to make appropriate

choices based on social norms, safety, and ethical standards (CASEL, 2019).

B. Measuring the Impact of SEL Programs

A CASEL(2013) publication entitled *The Missing Piece* highlighted the overwhelming teacher support of SEL among teachers:

> Eight out of ten teachers think SEL will have a major benefit on students' ability to stay on track and graduate and will increase standardized test scores and overall academic performance. Three-quarters believe SEL will improve student academic achievement. Research supports teachers' views in this regard. (Bridgeland, Bruce, & Hariharan, 2013, p. 6)

Evaluations of SEL programs are important for at least two reasons: 1) to make the case to policymakers and funding sources for the inclusion of SEL in schools, and 2) to weed out effective programs from ineffective programs. The former relies on meta-analyses and the latter, on single-program evaluations.

Many SEL programs have been evaluated in empirical studies, either in randomized control or quasi-experimental studies. From preschool to higher education settings, more than 500 evaluations of programs have been conducted, including universal, school-wide programs, parent trainings, and after-school programs (Conley, 2015; Albright & Weissberg, 2010). Analysis of the four most widely cited meta-analyses of SEL, surveying 356 studies and hundreds of thousands of K-12 students, suggests that SEL benefits youth far beyond simply increasing *SEL skills* such as goal setting, identifying emotions, self-management, decision making, and conflict resolution. In addition to these important skills, SEL programs also help students develop five other domains: attitudes and perceptions, positive social behaviors, conduct problems, emotional distress, and academic performance (Mahoney, Durlak, & Weissberg, 2018). In a meta-study of 213 SEL programs, Durlak and colleagues (2011) showed that

students who participated in SEL programs experienced increased prosocial behavior and academic achievement, improved attitudes about self, others and school, and lower conduct problems and emotional distress. In a meta-analysis of follow-up effects, students who receive SEL programming continued to demonstrate positive outcomes an average of 3.75 years after program participation, some who received programming as early as kindergarten; these effects included increased graduation rates, decreased involvement in crime and lower incidences of mental disorder diagnoses (Taylor, Oberle, Durlak, & Weissberg (2017).

Beyond its role in establishing the legitimacy of SEL, CASEL offers practical applications for administrators of schools as a resource for educators wishing to integrate SEL in their schools and districts. To this end, CASEL (2013) has published a guide of 23 dominant SEL programs which are available for elementary school levels. Educators and administrators rely on CASEL's recommendations and single-program empirical evaluations to make decisions about which programs to implement. CASEL (2013) uses SEL evaluations to formalize their recommendations for schools and districts. To gain CASEL's approval, *SELect* programs must have been shown to positively affect at least one of the following four outcomes (CASEL, 2013, p. 21):

1) Improved academic performance (e.g., tests and grades);
2) Improved positive social behavior (e.g., works well with others, positive peer relations, assertiveness, or conflict resolution);
3) Reduced conduct problems (e.g., aggressive or disruptive behavior); or
4) Reduced emotional distress (e.g., depressive symptoms, anxiety, or social withdrawal).

II. Self-Regulation (SR) Emerges as a Central Pillar

While there are shared objectives among many existing SEL programs, each program may approach implementation theory from a different perspective and a different change model. However, despite these distinct elements, *self-control,* referred to as SR in this paper, surfaces as one of the most pervasive and foundational mechanistic constructs shared across youth development frameworks (Tolan et al., 2016; Berg et al., 2017). Of note, in addition to SR, *positive self-orientation*, *engagement with others, and societal bonding/moral ethical standards, and a focus toward adaptation and flexibility*, prove to be overarching commonalities within youth development programs, whether or not they fall under the SEL umbrella (see Table 1; Tolan et al., 2016). Tolan and colleagues (2016) identify four dominant theoretical frameworks for youth development: SEL, Social Competence, Positive Psychology, Positive Youth Development. The first of these relates to the scope of this paper; the latter three of these four are described in Appendices A, B, and C.

Table 1

Common Construct Threads and Potential Alignment Across the Four Frameworks

Overarching constructs	*Social competence*	*Social-emotional learning*	*Positive youth development*	*Positive psychology*
Self-control	*Self-control*	*Self-management*	*Character Competence*	*Accomplishment/ Achievement*
Positive self-orientation	*Positive sense of self*	*Self-awareness*	*Confidence*	*Positive emotions / Optimism*
Engagement with others	*Prosocial connectedness*	*Relationship skills*	*Connection*	*Engagement & positive relationships*
Societal bonding / Moral ethical standards	*Moral system of belief & decision-making skills*	*Responsible decision making*	*Caring/ Compassion*	*Meaning*

Table 1. Adapted from "Toward an Integrated Approach to Positive Development: Implications for Intervention," by P. Tolan, K. Ross, N. Arkin, N. Godine, & E. Clark, 2016, *Applied Developmental Science, 20*(3), 214-236.

A. What is Self-Regulation (SR)?

Although there is much overlap in terminology and conceptualizations across various fields and programs, this paper focuses specifically on self-regulation (SR) as it relates to SEL. This is due to SR's relatively foundational position in the hierarchy of development of social-emotional competencies (Eisenberg, Spinrad, & Eggum, 2010; Greenberg, 2006). SR is both a reciprocal and prospective predictor of other social-emotional competencies and is central to many determinants of well-being (Moffit et al., 2011).

SR is generally conceived as the ability to manage one's thoughts, behaviors, and emotions in the service of goals (Duckworth & Carlson, 2013). It exists in three domains: cognitive, behavioral, and social-emotional, all processes which are related to each other (Blair & Razza, 2007). Cognitive SR processes refer to abilities to plan, reflect, and direct one's behavior toward a goal. Social-emotional SR relates to the abilities to inhibit emotional and social reactions to stimuli and to delay gratification in pursuit of a goal or in the service of creating healthy relationships with others (Bandy & Moore, 2010). And behavioral SR entails the ability to place distancing between instincts and behaviors (e.g., as opposed to impulsivity or rashness). Blair and Ursache (2011) add two more underlying and foundational dimensions of SR in their Architecture of Self-regulation model: genetic dispositions for SR and physiological (e.g., autonomic nervous system) mechanisms for SR (see Figure 1). Blair (2002) and Blair and Raver (2015) describe SR as a set of skills that are connected to biobehavioral systems and that enable the healthy regulation of emotions and attention in the service of reaching goals. Blair and Ursache (2011) describe SR as a top-down (executive control of emotions and attention), bottom-up (effects of stress and arousal) process which has bidirectional influence — as the balance between suppressing negative emotions (inhibitory control), and promoting positive emotions.

This paper focuses specifically on the physiological mechanisms that underlie emotional SR, the second and third component from the bottom of Blaire and Ursache's (2011) model.

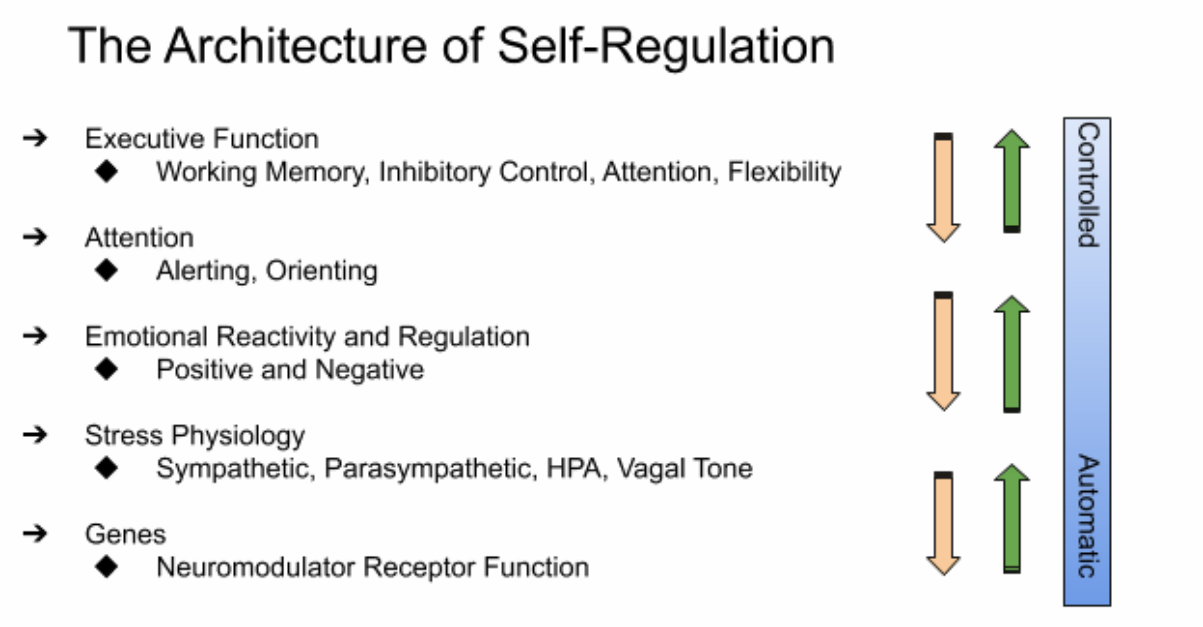

Figure 1. Architecture of self-regulation. From "The Neuroscience of SEL," by C. Blair, & C. C. Raver, In J. A. Durlak, C. E. Domitrovich, R. P. Weissberg & T. P. Gullotta (Eds.), *Handbook of Social and Emotional Learning: Research and Practice* (p. 67), 2015, New York, NY: Guilford.

B. Reasons behind the Centrality of SR

Strong empirical evidence supports the importance of developing SR in youth and adolescents. Early predictors of SR, defined by aspects of temperament, such as effortful control or emotionality, also predict many other indicators of well-being (Moffit et al., 2011). This has broad implications for young people's executive function, language skills, academic performance and engagement, physical health, income, avoiding illicit drug use and violence, and gaining a higher salary level, among other factors (Moffit et al., 2011; Shoda, Mischel, & Peake, 1990; Caruso, Salovey, Brackett, & Mayer, 2015; Greenberg, 2006). SR is strongly correlated with grit, a determinant of skill-mastery, and general achievement across domains (Duckworth and Gross, 2014). SR predicts achievement above and beyond IQ (Duckworth & Seligman, 2005). In young adults and

adults, low SR has been associated with many maladaptive psychosocial tendencies (Smallbone & Dadds, 2000; Howells, Day, & Wright, 2004).

The four common constructs which Tolan and colleagues (2016) identify as common to all youth development frameworks (self-control, positive self-concept, interacting with others in authentic ways, or conforming to societal norms, standards, and expectations) do not operate independently of each other. Bandura (1994) and Eisenberg & Fabes (1992) explore the influence of SR on these constructs. SR arguably underlies the other three. This may be because SR is a basic competency that is fundamental to developing other SEL skills (Eisenberg, Valiente, & Eggum, 2010; Sameroff, 2010; Shonkoff & Phillips, 2000; Ponitz, McClelland, Matthews, & Morrison, 2009; Greenberg, Katz, and Klein, 2015). Blair and Raver (2015) posit that "effective self-regulation in many ways underlies and facilitates the thoughts, feelings, emotional states, and behaviors that are characteristic of SEL and enables individuals to engage in and learn from beneficial interactions with others" (p. 65). Indeed, SR is the foundation upon which numerous other developmental competencies can be built.

C. Can SR Be Developed?

In an overview of the history and impact of SR research, theory, and its integration into education and SEL, Duckworth and Carlson (2013) present strong empirical proof that "a child's temperament, while strongly influenced by genetic factors, is nevertheless amenable to environmental influence. Self-regulation can be cultivated." (p. 223). Many parents and teachers might attest to this, through personal experience.

Strength models of SR posit that self-regulatory resources, like muscles, can be exhausted in the short-term and strengthened and developed with practice (Baumeister, Gailliot, DeWall, & Oaten, 2006; Heatherton & Wagner, 2011). Furthermore, SR is domain-general, meaning that developing it in one domain (e.g., dieting), increases the

reserves for the self-regulatory capacity in other domains (e.g., managing anger). Indeed, the development of SR stamina through deliberate practice of SR is effective in a variety of behavioral and cognitive practices, including monitoring and regulating eating, regulating mood, and improving posture (Muraven, Baumeister, & Tice, 1999).

III. How SR Shows Up in SEL Programs

Many SEL programs center SR at the core of their frameworks. This foundation influences their content and practical interventions. The following section explores the way three programs are currently developing SR in order to identify gaps and opportunities to enhance this vital social-emotional competency. SEL programs that support SR development generally concentrate on behavioral and emotional regulation, self-control, self-awareness, emotion identification and labeling, healthy communication, and conflict resolution (Greenberg, Katz, & Klein, 2015). The following three program examples: Second Step (Committee for Children, 2019), RULER (Rivers, Brackett, Reyes, Elbertson, & Salovey, 2013) and PATHS (Greenberg & Kusché, 2006) utilize behavioral and emotional regulation strategies that are aligned with strength-models and grow-and-strengthen conceptualizations of SR.

1. Second Step

Second Step (Committee for Children, 2019) is offered in K-8 levels and has been used internationally by over 20,000 schools. It has an important focus on developing SR skills (Committee for Children, 2015). Depending on the grade, this curriculum offers 22 to 28 lesson themes, with five subthemes per week, threading SR skills into lessons on learning, empathy, emotion management, friendship, and problem-solving. It is designed as an explicit-skills instructional program, aligned with the field's focus on skills and competencies, rather than on individual strengths and dispositions. Randomized-control trials and quasi-experiments have shown that students who have participated in the

Second Step program experienced increased prosocial behaviors, SEL skills, reduced negative behavior, and emotional distress (Holsen, Smith, & Frey, 2008; Holsen, Iversen, & Smith, 2009; Low, Cook, Smolkowski, & Buntain-Ricklefs, 2015).

The majority of the lessons have a primarily strong interpersonal and intrapersonal cognitive component; most lesson objectives of the program *encompass identifying*, *demonstrating*, *naming*, and *communicating* feelings and behaviors (Committee for Children, 2017).

2. RULER

Based on an emotional-intelligence framework created by Marc Brackett at Yale University, the RULER approach culminates in teaching students to exercise tools for emotional SR. The acronym RULER represents five skills: recognizing emotions, understanding emotions, labeling emotions, expressing emotions, and regulating emotions. RULER is not conceived as a curriculum or program, but as an approach to teaching and relating in schools (Niehoff, 2019). RULER has been effective in improving emotional intelligence and emotion recognition in youth (Nathanson, Rivers, Flynn, & Brackett, 2016). In addition, likely because SR is highly related to other important youth outcomes relevant in schools, RULER has also been effective in improving youth school climate, decreasing bullying, and decreasing depression and anxiety (Rivers et al., 2013; Brackett & Rivers, 2014; Hagelskamp, Brackett, Rivers, & Salovey, 2013). Caruso and colleagues (2015) would support RULER's approach to consider regulating emotion as a culminating skill. Caruso and colleagues' (2015) present a four-branch model of emotional intelligence that places *managing emotions* as its culminating branch (the first three branches are perceiving emotions, using emotions to facilitate thought, and understanding emotions). Someone skilled at managing emotions can improve negative moods and maintain positive moods when appropriate, which allows one to engage

actively with stress, not shy away from challenges (Caruso et al., 2015). The ability to manage emotions, as well as the behaviors that might flow from those emotions, is an integral aspect of SR.

3. PATHS

Promoting Alternative Thinking Strategies uses top-down instruction (e.g., cognitive reappraisal) to teach self-control (Greenberg & Kusché, 2006). Its lessons include making posters, writing stories, discussing with others, and creating a *feelings dictionary.* Entire lessons are devoted to exploring feelings, one at a time (e.g., mad/angry, calm/relaxed, shy/lonely). In addition to curriculum, the PATHS program, like RULER, also provides tools for educators to create environments that help children develop social-emotional competencies they wish to teach.

PATHS curriculum is shown to support the development of SR in youth through training in emotion identification and regulation, inhibitory control, and social problem solving (Bierman et al., 2010). PATHS has demonstrated an impact on improving and predicting social-emotional competence and academic performance while decreasing aggression in young (K-5) students, and has been used in thousands of schools (e.g., Crean, & Johnson, 2013; Domitrovich, Cortes, & Greenberg, 2006; Fishbein et al., 2016). Riggs and colleagues (2006) found PATHS to be successful in improving inhibitory control for students who participated in the program for one year when compared with control groups who did not.

IV. What's Missing: Physiological Indicators/Biomarkers and Practices

Most studies that have examined the impact of SEL programs for youth development skills, including SR, rely primarily on self-reporting and observational assessments such as teacher report questionnaires (e.g., Durlak et al., 2011; CASEL, 2013; Mahoney et al., 2018). In some cases, studies of SR in youth use performance task

tests, such as the Stroop test (Golden, 1981), as used in Riggs and colleagues' (2006) assessment of PATHS impact on self-regulatory capacity in youth. While these types of assessments are useful, they do not have the rigorous clarity and reliability that more objective measures, such as biomarkers provide.

Strimbu and Tavel (2010) define the term *biomarker* as:

> A broad subcategory of medical signs — that is, *objective indications* [emphasis added] of medical state observed from outside the patient — which can be measured accurately and reproducibly. Medical signs stand in contrast to medical symptoms, which are limited to those indications of health or illness perceived by patients themselves. (p. 463)

Although Strimbu and Tavel define biomarkers in a medical context, the term can also refer to objective indications of social-emotional competencies like SR (Porges, 2007; Rottenberg, Salomon, Gross, & Gotlib, 2005).

Duckworth and Yeager (2015) explore the shortcomings of various ways of assessing noncognitive abilities to measure success. In their study, they "compare self-report questionnaires, teacher-report questionnaires, and performance tasks, using self-control as an illustrative case study to make the general point that each approach is imperfect in its own way" (Duckworth & Yeager, 2015, p. 237). In their critical analysis, Duckworth and Yeager do not recommend using universal between-school measures to compare competencies in one setting vs. another, citing subjectivity of measures and definitions, the ease in which self-reporting can be faked, the impact of bias in influencing subjects to respond in certain ways, the limitations of performance tasks such as the artificiality of testing situations. See Appendix D for a full list of the synthesis of the limitations Duckworth and Yager (2015) propose for the three assessment types.

Teacher reports, self-report questionnaires, and performance tasks may always

present challenges. The persistence of questionnaire and performance task limitations might exist due to an element of subjectivity on both ends of the study: both the subject being assessed and the researcher who is interpreting the data. Biomarkers mitigate subjectivity on both ends. I contend that indicators such as cortisol levels and heart rate may not be as easily altered by *practice effects* nor misinterpreted as easily by researchers. This lessened subjectivity is one incentive for using biomarkers as indicators of SR in SEL programming. In essence, these measures are not be prone to the same types of limitations that Duckworth and Yeager (2015) have explored in their analysis.

A. Biomarkers in Educational Policy: Objectivity Takes the Cake

The inclusion of biomarkers in SEL increases its legitimacy as an important component in education. The challenge of schools, districts, and states to rely on common measures of social-emotional competencies, such as the ones explored by Duckworth and Yeager (2015), has implications for educational policy and access to SEL-related funding. The Every Student Succeeds Act (ESSA) of 2015, a replacement of the No Child Left Behind Act of 2001, still places its highest priority on academics. However, ESSA also acknowledges the importance of including nonacademic measures in determining the quality of a school (Batel, 2017). States are required to collect data about one nonacademic measure, commonly known as a fifth indicator (Batel, 2017). Only eight states have established their fifth indicator as relatively related to social-emotional competencies (e.g., school climate; Swaak, 2018). Berg and colleagues (2017) posit that states' hesitation to include measures of social-emotional competencies as their fifth indicator may stem from skepticism about the reliance of self-reporting and that there is currently a dearth of reliable measures (Zernike, 2016).

For this reason, states would rather include more objectively measurable items, such as chronic absenteeism (the most common) or physical fitness (Swaak, 2018). The

objectivity of biomarkers may facilitate the integration of SEL into federal school ratings under ESSA. Schools and states can report physiological measures more readily, which can reflect the presence of social-emotional competencies objectively, much as they might report on the level of physical fitness of students based on biomarkers using body mass index. Measuring biomarkers can put social-emotional competencies *on the map* of valid school-quality fifth indicators by legitimizing the integration of SEL (e.g., SR measures) in describing the quality of education in a school, district, or state in ESSA. This in turn can provide funding incentives for schools that show improvements in these measures.

B. Biomarkers as Indicators of SEL Program Impact on Self-regulation

Fields outside of SEL (e.g., neurophysiology, psychophysiology, clinical neurology, psychiatry) have identified biomarkers shown to have correlations to SR (Bornstein & Suess, 2000; Geisler, Kubiak, Siewert, & Weber, 2013; Porges, 2012; Beauchaine, 2015a; Beauchaine, 2015b, Shaffer & Ginsberg, 2017). However, almost none of the common types of studies in the SEL and youth development literature include physiological indicators of SR. There is an absence of biomarkers as integral measures of SEL program impact.

Identifying this gap is not about fixing a broken SEL field - it is about *improving* the impact and study of the field; augmenting the quality of SEL programming and the level of impact on SR capacities. The integration of biomarkers into SEL is supported by theorists who point to the relationships between SEL programming, SR, and biomarkers, based on neurobiological and physiological models or SR and argue for the integration of neuroscientific and biological elements into intervention SEL program design and study. To this end, Greenberg and colleagues (2015) “argue that current SEL models would be substantially enriched by acknowledging the potential effects of interventions on

biomarkers and other physical health outcomes" (p. 90). To improve the field requires improved tools for measuring the impact of interventions, as well as interventions which affect these measures. While SEL programs have been successful in affecting SR capacities, the measured increases, although significant, are not strong consistently. Not all studies of SEL have shown favorable results in the development of social-emotional competencies (Ruby & Doolittle, 2010). It is possible that the discrepancies lie in the measurement tools, rather than in the programs. Also, by attempting to impact a new set of measures (biomarkers) programs set themselves up to even more strongly increase already positive outcomes.

Biomarkers can help researchers more dynamically conceptualize SR. By failing to address some of the mechanistic psychophysiological underpinnings of SR (and other social-emotional competencies), many researchers are limited to analyzing observable behavioral data and fail to assess SR in a way that is aligned with neurobiological models of SR (Blair & Raver, 2015). The objectivity of biomarkers and as indexes of SR gives researchers and program developers a more useful data to be able to make stronger claims about the impact of programs.

Biomarkers can improve interventions (Greenberg et al., 2015; Blair & Raver, 2015). Educators can examine biodata to inform future programming. For example, because biomarkers can predict self-regulatory capacity as well as tendencies for dysregulation (Bornstein & Suess, 2000; Geisler et al., 2013; Porges, 2012; Beauchaine, 2015a; Beauchaine, 2015b, Shaffer & Ginsberg, 2017), baseline biodata can allow practitioners and designers to customize SEL interventions that might be most appropriate for given individuals on a long-term basis. This might include spending more or less time discussing or practicing SR tools or changing the types of interventions that are being used to match the needs of students.

Biomarkers can encourage the integration of mind-body practices in SEL programs. Program developers can strengthen the training of SR skills for youth by addressing *deeper* aspects of SR capacity and incorporating practices that affect these underlying biomarkers.

The integration of biomarkers as integral measures of SR is supported by somatic models which posit an inextricable connection between body and mind, such as Damasio's (2010) conception of emotions as deep subcortical processes which are beyond our conscious awareness until they manifest as what he differentiates as feelings. He states:

> A discussion of emotions entails an investigation of the extremely varied devices of life regulation available in brains but inspired by principles and goals that anteceded brains and that, by and large, operate automatically and somewhat blindly, until they begin to be known to conscious minds in the form of feelings. Emotions are the dutiful executors and servants of the value principle, the most intelligent offspring yet of biological value. (Damasio, 2010, p. 108)

Greenberg (2006) emphasizes the benefit of including physiological biomarkers in the assessment and implementation of SEL. He writes:

> Effective preventive models that have more fully articulated logic models of action should begin to ask 'deeper' questions about the neuroscientific underpinnings of either change processes or obstacles to intervention impact. That is, how might measures of the biological substrate serve as mediators, moderators, and outcomes? (Greenberg, 2006, p. 147)

Blair and Ursache's (2011) bidirectional psychobiological Architecture of Self-Regulation model, described above, would support the integration of physiological measures into SR research within SEL programs. It presents genes, stress-physiology,

emotional reactivity and regulation, attention, and executive functions as layers of SR. Their model defines SR as a complex system of emotional, physiological, cognitive, and behavioral responses to stimulation, which is "hierarchically organized and reciprocally integrated" (Blair & Raver, 2015, p. 66). It supports the conceptualization of SR as a competency with physiological underpinnings that must be observed to assess an individual's self-regulatory capacity (see Figure 1 above).

C. Why Biomarkers May Be Missing

The current lack of physiological indicators/biomarkers in SEL program evaluation may be a product of various factors. The first of these includes the public's hesitancy in sharing biological data (Greenberg et al., 2015). Schools and policies often prioritize of measuring behavioral outcomes that are captured easily in school settings (S. Rimm Kaufman, personal communication, July 9, 2019). With a reliance on medical equipment, biomarkers may be deemed burdensome and expensive.

The second reason that biomarkers may not be currently top-of-mind for SEL researchers and practitioners is that educators and school stakeholders may see psychophysiology as external to the scope of the field of K-12 education (M. Greenberg, personal communication, July 25, 2019). Most major youth development program frameworks fall under *school-based competency development*, which has an underlying focus on developing learning-based behaviors and skills in K-12 schooling, such as SR and goal-setting, and making recommendations to teachers about cultivating social-emotional competencies in the classroom (Berg et al., 2017). The context of this field might not make it immediately apparent why integrating biomarkers into program impact assessment or interventional design may be relevant for researchers or practitioners. Finally, there tends to be a lack of mind-body integration in SEL logic models of change (M. Greenberg, personal communication, July 28, 2019). Educators more concerned with

behavioral outcomes might ask, "As long as the car works, why should I care about the parts of the engine?; As long as youth are improving SR behaviors, why should I care about the physiological substrates underlying these improvements?; Isn't SEL already impactful enough and aren't current SEL impact measures sufficiently useful?" This line of thinking fails to recognize the benefits of assessing and addressing underlying physiological mechanisms in SEL, explored below.

V. Integrating Biomarkers

A. Which Biomarkers Should Researchers Examine for Assessing SR?

What would make a biomarker a valid indicator of a desired outcome? There are a multitude of biomarkers that clinicians and researchers use to evaluate an individual's health: e.g., heart rate, body mass index, and pulse. Some biomarkers can be used as *surrogate endpoints*, defined as being meaningfully associated with clinical measures. To be surrogate endpoints, Strimbu and Travel (2010) explain:

> There must be solid scientific evidence (e.g., epidemiological, therapeutic, and/or pathophysiological) that a biomarker predicts a clinical outcome consistently and accurately, either a benefit or harm … a surrogate endpoint is a biomarker that can be trusted to serve as a stand-in for, but not as a replacement of, a clinical endpoint. (p. 3)

There are a variety of indicators which theorists have hypothesized to be affected by SEL interventions (e.g., cortisol, salivary alpha-amylase, C-reactive protein, and blood pressure; Greenberg et al., 2015). As this paper has established the centrality of SR training and outcomes throughout a wide range of SEL interventions and studies, I will focus on biomarkers which have identified to have established link between SR behaviors, tendencies, and capacities.

B. Vagal Tone (VT)

Vagal tone (VT) stands out in medical, neuroscience, and social sciences literature as a noninvasive, reliable surrogate endpoint correlated with self-regulatory capacity in youth, and indexes the degree of control of the vagus nerve over the heart. It has been connected to a variety of illness and well-being outcomes in both humans and animals (Porges, 2007).

VT provides researchers with an affordable, ecologically valid measurement tool to examine the physiological substrates of SR. VT is easier to administer in children than other measures of SR, such as neuroimaging of the central nervous system (CNS), which has also served as a biomarker of emotional dysregulation (Beauchaine, 2015b).

The vagus nerve is the longest of all cranial nerves and extends from the brain, through the face, to the heart and other vital organs and systems, including those involved in social and emotional responses to stimuli such as the pharynx, larynx, and soft palate (Porges, 2007). Theoretical models of the vagus nerve reveal its importance for individuals' flexibility and adaptability to their environment (Porges, 2007; Rottenberg et al., 2005).

Heart rate variability (HRV) is an indicator of vagal tone. HRV refers to the naturally-occurring variability between heartbeats. HRV is analyzed and interpreted as a metric of autonomic health — the degree to which the autonomic nervous system (ANS) is balanced. When variability between heart beats is low (like a metronome), there is little variation between heartbeats, suggesting that sympathetic nervous system has higher control over the innervation of the heart, moving toward fight-or-flight response. When HRV is optimal, this means that the parasympathetic system is in control, enabling a state of rest and digest and more enabling executive function and SR. As a person experiences high amounts of stress and continually activates the SNS, this decreases VT, measured by

HRV. Optimal HRV can be used as a biomarker for self-regulatory capacity of youth in the face of internal or external stress (See Figure 2).

Figure 2. Illustration of heart rate variability in normal subject. From "Heart Rate Variability (HRV) as a Tool for Diagnostic and Monitoring Performance in Sport and Physical Activities, by B. Makivić, M. Nikić Djordjević, & M. S. Willis, M. S., 2013, *Journal of Exercise Physiology Online*, *16*(3), 106.

A more in-depth review of basic mechanisms and measures of VT are presented in Appendix E.

The connection between VT and a variety of clinical indicators of illness, including psychiatric pathologies, such as neuroses was first drawn by physicians Eppinger and Hess (1915). Their work forms the foundation of current VT research and the allopathic understanding of the mind-body connection (Porges, 2007). Since then, VT has been found to be correlated with a host of processes which indicate well-being, including exercise, positive emotions, attention and cognitive performance, respiration, sleep and decreased symptoms of depression (Dixon, Kamath, McCartney, & Fallen, 1992; Hansen, Johnsen, & Thayer, 2003; Rottenberg et al., 2007; Vanoli, Adamson, Pinna, Lazzara, & Orr, 1995). When compared to other biomarkers, heart rate variability (HRV; a measure of VT) was shown to be most strongly correlated with a single-item positive health measure in 3,942 adults (Jarczok et al., 2015).

VT has also been identified to have a moderating role on anxiety caused in

Adverse Childhood Experiences, which have been shown to inhibit a host of well-being measures, including learning, attentional control, anxiety, and SR. In a study of 75 children ages 8 -12, El-Sheikh, Harger, and Whitson (2001) found that children with increased VT were less adversely affected by marital conflict of their parents than children with low VT. In this study, VT served as a buffer from anxiety derived by marital conflict (Figure 3).

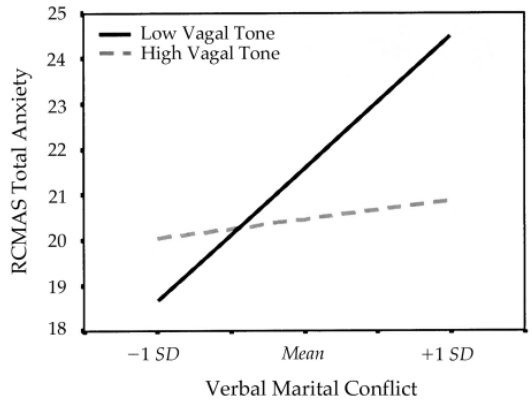

Figure 3. Representative example of interactions between verbal marital conflict and vagal regulation predicting child outcomes. RCMAS Revised Children's Manifest Anxiety Scale. From "Exposure to Interparental Conflict and Children's Adjustment and Physical Health: The Moderating Role of Vagal Tone," by M. El-Sheikh, J. Harger, & S. M. Whitson, 2001, *Child Development*, *72*(6), 1625.

C. Vagal Tone and Self-Regulation

VT is a reliable biomarker for SEL researchers wishing to understand the psychophysiological impacts of programs on social-emotional competencies. Indeed, there is a bilateral causal relationship between the competencies that SEL programs aim to teach (e.g., SR) and the underlying physiological substrates involved in the experience of such competencies (VT). Researchers have often used VT as an index for the capacity of higher-order cortical brain structures to regulate subcortical structures associated with impulsivity and reactivity to stimulus (Beauchaine, 2001). VT improves the capacity of higher-order executive functioning to *check* lower-order aggressive social tendencies or

stress responses thereby improving SR (Porges, 2012).

In addition to other health VT has been hypothesized to be a reliable indicator of and correlate to SR, among other well-being metrics because of its ability to provide a *vagal brake* to SNS-activation (Porges, 1992; Porges, Doussard-Roosevelt, & Maiti, 1994), confirmed in a variety of studies (Bornstein & Suess, 2000; Geisler et al., 2013; Porges, 2012; Beauchaine, 2015a; Shaffer & Ginsberg, 2017).

VT serves as a predictive mechanism of an individual's capacity to successfully create interpersonal relationships by influencing self-regulatory capacity (Porges, 1992). VT is a central component of Kok and Fredrickson's (2010) Upward Spirals of the Heart theory, which holds that positive emotions influence and are influenced by physical health via an upward spiral of social connectedness, positive emotions, and physical health, as indexed by VT. The skill to connect with others requires a degree of SR and other executive function skills, like threat-response inhibition and understanding social norms and moral values (Forbes & Grafman, 2010).

Mammals are the only animals endowed with the capacity to switch between three behaviorally linked phylogenetic states: social communication (e.g., facial expression, vocalization, listening, attentional and emotional regulation, mobilization (e.g., fight-or-flight behaviors), and freezing (e.g., feigning death, system shutdown; Porges, 2007). Increased VT allows for the strength of mammals to remain in parasympathetically dominant states, even under stress, and for this reason, allows for improved SR, and subsequent social connectedness and ability to relate with others (Porges, 2009).

The validity of VT in measuring SR has been established by a multitude of studies. In some studies, researchers examine the reverse tendency: emotion dysregulation. In a meta-analysis of these studies, Beauchaine (2015a) explores the power of respiratory sinus arrhythmia (RSA), a widely used measure of VT in predicting

individuals' capacity for SR. He writes, "RSA is a non-invasive proxy for poor executive control over behavior, which characterizes most forms of psychopathology" because either low or high RSA reactivity "index poor ER because they are downstream peripheral markers of prefrontal cortex (PFC) dysfunction" (Beauchaine, 2015a, p. 43). In this sense, vagal tone is a lever for self-regulation: VT strengthens the capacity for individuals to think twice before acting and to put things into perspective in objectively non-threatening situations where a fight-or-flight response might not be warranted.

A landmark longitudinal study showed significant positive correlation between measures of vagal tone and self-reported SR as measured by the Difficulty in Emotion Regulation Scale (Gratz & Roemer, 2004; Vasilev et al., 2009). Vasilev and colleagues (2009) showed a strong correlation of baseline vagal tone of youth of ages 8 to 12 to subsequent self-reported measures of SR using the one- and two-year post-baselines. Interestingly, this study showed that "youth reporting strong emotion regulation demonstrated increasing respiratory sinus arrhythmia reactivity over time [a measure of VT], whereas youth reporting weak emotion regulations skills maintained constant respiratory sinus arrhythmia reactivity over time" (Vasilev et al., 2009, p. 1363). This suggests the promise of developing VT as an indicator of future SR-related difficulties and strengths. This landmark study demonstrates both the correlation between a VT biomarker and SR, and the predictive power of the former over the latter. This offers an advantage for SEL programs who wish to customize the curriculum, delivery method, and setting for a given population (e.g., students with an increased likelihood of having difficulties in SR).

By including physiological components of self-regulation such as vagal tone as part of program impact assessment, the field of SEL is acknowledging the inextricable

link between body and mind insofar as it relates to the development of SR and other important well-being outcomes.

D. Proposed Upward-Spiral Model for the Integration of Biomarkers and Mind-Body Practices in Social-Emotional Learning Programs and Evaluations

There are two main ways to incorporate the use of biomarkers into SEL programs: A) by examining the physiological effects of youth SEL participation on the biological substrates of the competencies which are being targeted (e.g., SR) and B) by integrating mind-body practices to build the physiological resources and affect the biomarkers for a given competency, e.g., self-regulation. Each of these two topics will be addressed in turn.

This paper proposes the following model. The Upward-Spiral Model for the Integration of Biomarkers and Mind-Body Practices in Social-Emotional Learning Programs and Evaluations illustrates the hypothesis that the benefits of incorporating physiological practices and measures into programming and assessment are greater than those achieved by either alone. It assumes a bilateral causative relationship between the impact of SEL programs on physiological measures (Greenberget al., 2015), and the impact of physiological practices (e.g., breathing, mindfulness, and exercise) on the effectiveness of SEL programs, as shown by empirically validated physiological interventions on SEL objectives (Ghahremani et al., 2013). The bilateral causation between biomarkers and SEL training reflects the benefit of incorporating biomarkers as predictors of future SR measures (Vasilev et al., 2009) to tailor SEL interventions.

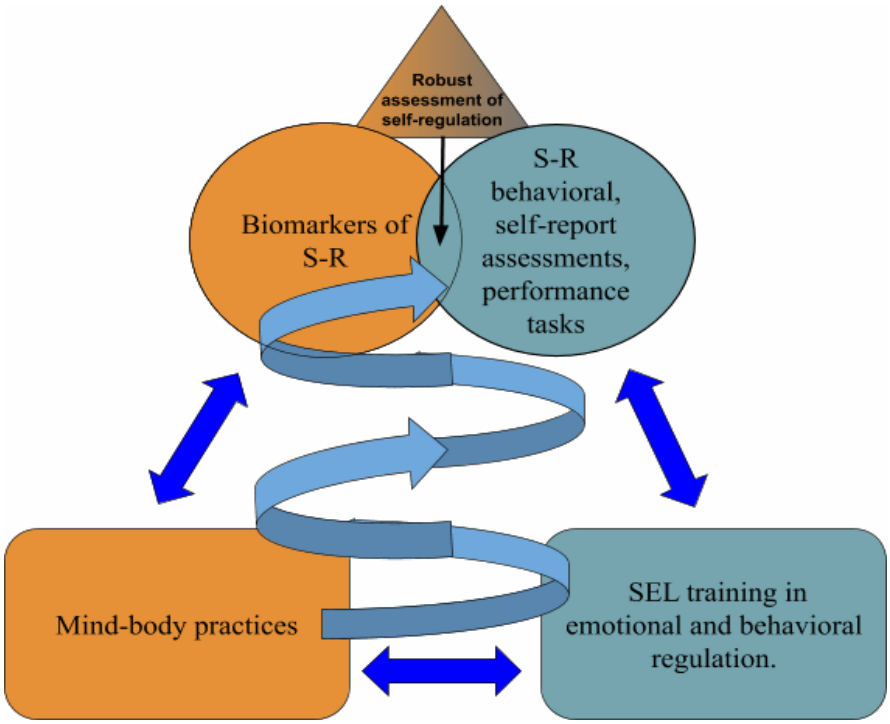

Figure 4. The Upward-Spiral Model for the Integration of Biomarkers and Mind-Body Practices in Social-Emotional Learning Programs and Evaluations Using Self-Regulation as Exemplar Competency.

This model aligns with Gard, Noggle, Park, Vago, & Wilson's (2014) comprehensive bottom-up (physiology to behavior) theoretical model of SR. Pointing to the bidirectional nature of physiological-cognitive causality, Gard et al. (2014) explore the power of mind-body practices like yoga and meditation to develop SR via "bidirectional feedback and integration between high — and low-level brain networks" (p. 1), and suggest that with regular practice, "the processes that subserve self-regulation become more automatized and efficient over time and practice, requiring less effort to initiate when necessary and terminate more rapidly when no longer needed" (p. 1). This increased efficiency from practice with simultaneously less effort over time is the essence of bidirectionality and upward spiral mechanism of this model.

This model illustrates the way that physiological indicators of SR and well-being can be leveraged to assess the impact of and strengthen the quality of SEL interventions on student SR capacities. The model represents the hypothesized mechanism by which

the integration of physiological measures of SR capacity (VT) and the integration of practices that affect these measures can respectively add an empirically validated dimension to the way that SEL programs are evaluated and strengthen the impact of such programs on physiological indicators of well-being tied to SR.

The model presented here is built on three premises and one hypothesis.

1. Premise: SR can be developed through practice in behavioral and cognitive practices (Baumeister et al., 2006); these types of practices make up the majority of SEL training interventions (Greenberg et al., 2015).
2. Premise: VT can be developed through physiologically integrated practices and through more traditional SEL practices (e.g., cognitive behavioral).
3. Premise: SR is correlated with VT. Exercising self-regulation can strengthen vagal tone.
4. Hypothesis: Engaging in both physiological *and* behavioral/cognitive practices creates an upward spiral in which both VT measures and SR capacity increase more than they would if targeted on their own.

To review, biomarkers a) enable a more objective SR data-set, which allows for the credibility of impact and customization of SEL intervention. In addition, physiologically integrated practices influence physiological substrates (measured with biomarkers), which themselves affect the observable behavioral manifestations of SR competencies. Finally, physiologically integrated practices enhance other ways that programs target SR (behaviorally and emotionally).

E. Adding Bottom-Up Measures & Practices to SEL Interventions

Most SEL program interventions use established traditional top-down interventions (e.g., cognitive appraisal) and top-down measures (e.g., self-reporting).

Essentially, this model adds bottom-up SR measures and components to current SEL studies and interventions. Although this model acknowledges and leverages current top-down (cortical to subcortical) measures and interventions, it offers a bottom-up (subcortical to cortical) mechanism in SEL programs' study and development of SR.

In studies of the change-mechanisms of mindfulness, for example, there is a discrepancy in which conceptualization is most correct, bottom-up or top-down (Gard et al., 2014). Understanding whether physiologically-integrated practices have top-down or bottom-up mechanisms can offer valuable insight for SEL educators working with groups that might not be able to employ typical psychotherapeutic interventions for the regulation of emotion (e.g., cognitive reappraisal; Chiesa, Serretti, & Jakobsen, 2013).By employing a mindfulness-based interventions or other parasympathetic practices with these groups, SEL programs can be more effective in achieving SR and other SEL outcomes. Even for groups without difficulties in practicing traditional interventions, establishing that there is a strong bottom-up component complements current interventions and could strengthen the impact on SR and other measures, and therefore justify their inclusion in every program, not just mindfulness-based interventions.

Using neuroimaging studies of mindfulness practitioners, Chiesa and colleagues (2013) propose a solution to the discrepancy between bottom-up and top-down theories of mindfulness mechanisms. They suggest that for short-term practitioners, mindfulness is more likely to function through top-down mechanisms (as cognitive appraisal would). And for experienced meditators, the mechanism is more likely to be bottom-up; however, other variables can affect the types of mechanisms, such as the type of instruction received and the type of practice (Chiesa et al., 2013). This finding might suggest that as practitioners continue to practice, biomarkers associated with SR become more developed (e.g., VT is strengthened). Like exercise, the benefits of automation come with

repetition - and SR may become easier and easier with this practice. This increase in benefit over time is reflected in the model presented in this paper.

VI. Implementation

Biomarkers of SR encourage the design and development of mind-body practices that affect these markers, thereby augmenting SR interventions. Measuring biomarkers related to SR, may inspire program designers to prioritize these measures and begin to acknowledge the relationship between the physiological underpinnings of SR and the capacity to exhibit self-regulatory behaviors. Mind-body practices can help to strengthen the impact of SEL programs in developing youth SR.

The embodied approach to self-regulating is not new. William James (1899/1989), in his *Talks to Teachers on Psychology: And to Students on Some of Life's Ideals*, wrote of the link of action and feeling, and proposed a bottom-up (action to felt emotions) approach to managing emotions. “Action seems to follow feeling, but really action and feeling go together; and by regulating the action which is under the more direct control of the will, we can indirectly regulate the feeling, which is not” (p. 118). More recent studies of *facial feedback* or *power posing*, where researchers investigated the effects of physical action on feeling states validates James’s theory (Ekman, 1993; Matsumoto, 1987; Carney, Cuddy, & Yap, 2010).

Some programs outside of SEL (e.g., athletics, arts, meditation, and psychotherapy) and even some within the field (e.g., mindfulness) have shown promise in developing SR by leveraging the mind-body connection (Behncke, 2002). Within SEL, these physiologically integrated practices have been traditionally practiced in mindfulness, yoga or physical education programs. Programs can enhance the development of these skills and dispositions by incorporating techniques for improving parasympathetic tone (Gillespie, Mitchell, Fisher, & Beech, 2012).

Integrating Practices that Influence Vagal Tone

Youth development programs that train students in skills that increase VT and, therefore, retain first-order neural skills under stress more readily, are laying the foundation for SR skill acquisition and social-emotional wellness. VT is theorized to operate bidirectionally (Kok & Fredrickson, 2010; Porges, 2009). This means that while VT increases levels of well-being, it is also the case that well-being increases VT. Given this two-way street, interventions designed to increase the social-emotional competence of youth in the interest of thriving in school and life (the supposed goals of education, positive psychology, and SEL), may benefit from integrating interventions that increase VT.

A discussion follows of a few interventions that have been shown to increase VT, along with considerations for best practices and implementation. While there are many ways which have been empirically shown to affect VT and HRV positively, the interventions presented here have been selected due to their ease of implementation within a school environment and their subsequent potential impact on student well-being measures.

This section will explore how VT can be affected through a variety of physiologically integrated interventions: a) exercise, b) breathing techniques, c) mindfulness, and d) yoga.

a. Exercise and well-being. Engagement in physical activity predicts health outcomes, social cognitive skills and self-efficacy, time management, executive function and academic performance, and protects against depression (Janssen & LeBlanc, 2010; Strong et al., 2005; Penedo & Dahn, 2005; McPhie & Rawana, 2015; Hortz & Petosa, 2008; Ratey, 2008). Sedentary behaviors are associated with decreased mental health, well-being, and increased incidence of obesity and metabolic risk (Mitchell, Rodriguez,

Schmitz, & Audrain-McGovern, 2013).

Unfortunately, physical activity declines 7% per year during each year of adolescence (Dumith, Gigante, Domingues, & Kohl, 2011). The decrease has been observed especially in early adolescence, with a decline between the ages of 11 to 12 and 15 to 16, with the declines disproportionately affecting students of lower socioeconomic status, and girls over boys. (Ekelund, Tomkinson, & Armstrong, 2011; Brodersen, Steptoe, Boniface, & Wardle, 2007).

Ratey (2008) explores the effects of fitness-based physical education programs on student neurological function. In *Spark: The Revolutionary New Science of Exercise and the Brain*, Ratey (2008) celebrates the effects of a fitness-based physical education program on academic and physical measures of well-being for 19,000 students in grades 5-12 in the Naperville, Illinois District 203. By focusing on fitness rather than sports, this program was able to drive up test scores of the district, mediated by brain-derived neurotrophic factor, helping the brain grow connections and perform better on cognitive tasks (Ratey, 2008). While Ratey does not specifically discuss an association between exercise and VT, his example draws attention to the power of fitness-based programs for improving the cognitive capacity of youth, and the potential for measuring such improvements with biomarkers.

As far as the effect of exercise on vagal tone, intensity matters. The more intense the exercise, the higher the impact on vagal tone ((Buchheit, Platat, Oujaa, & Simon, 2007). Buchheit et al.'s (2017) study tracked the physical activity of adolescents using objective and subjective measures for a week and found benefits for VT. Controlling for body weight and fat, they found that while moderate-intensity activity could improve physical fitness (measured by cardiopulmonary recovery, heart rate recovery, and muscular fitness). However, only higher intensity activity predicted improved cardiac

parasympathetic control (VT).

Some examples for offering high-intensity exercise to children and youth include competitive dance squads, recreational modern dance and gymnastics, intramural basketball, rugby, and lacrosse, as well as fun runs, boxing, martial arts, wrestling, bicycle trips and races, and skateboard lessons and competitions.

Most importantly, however, programs should utilize a fitness-based, rather than performance-based approach in order to encourage exercise which stimulates biomarkers (Ratey, 2008). The school district in Naperville, Illinois has implemented this type of dynamic program (Ratey, 2008). Rather than grading students on their performance in comparison to others, the district has implemented biomarker tracking to grade students in relation to their performance in the past. Students are challenged to run a mile within a given heart rate range, rather than under a given a universal time benchmark. The physical education classes in Naperville have personalized the experience for students, taught the value of fitness, decreased social comparison, engaged students in technology, added an integral component for data, and achieved increased fitness goals. Ratey (2008) attributes impressive academic accolades achieved by Naperville district to improved fitness thanks to this strategy. Given the impact of fitness on VT and the central importance of VT in SR and other social-emotional competencies, including HRV as an additional metric associated with the Naperville program could also shed light on the role of this type of fitness intervention on SEL-related outcomes.

b. Breathing techniques. Breathing is a pseudo-rhythmic phenomenon. This means that while it is often rhythmically stable, it can change in frequency or change in nature easily in response to a host of different stimuli. Located in the brainstem, pacemaker cells manage respiratory rhythm and depth, which is controlled primarily by central and peripheral chemoreflexes. However, various factors can affect the frequency

and depth of respiration, including temperature, exercise, stress, and voluntary control, and (as described above), the PNS and SNS (Kitney & Rompelman, 1987; Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001). Long-time practitioners of yoga show improvements in the ability to perform, even with insufficient oxygen, because they have learned to manage their breath (Spicuzza, Gabutti, Porta, Montano, & Bernardi, 2000).

Since respiratory sinus arrhythmia (RSA; the change in heart rate due to exhalation and inhalation) is a measure of VT, it is not surprising that "respiration is a powerful modulator of heart rate variability" (Bernardi et al., 2001, p. 55). Shaffer and Ginsberg (2017) describe the effect of slow breathing on SR as mediated by HRV. They write that "teaching clients to breathe slowly when they experience high levels of SNS activity can engage both branches and increase RSA" (Bernardi et al., 2001, p. 3).

Importantly, there is an observed interaction between HRV and respiratory frequency (Bernardi et al., 2001). When respiration rate drops to six cycles per minute (0.1 Hz), HRV is at its maximum state (see figure 6; Bernardi et al., 2001). It is likely for this reason that a variety of yoga, meditation, and mindful breathing practices (e.g., Complete Yoga Breathing; Hewitt, 2012) adopt this rate of breathing.

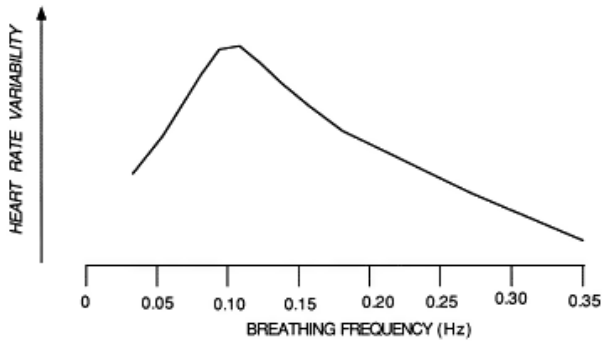

Figure 5. Breathing frequency and heart rate variability. From "Modulatory Effects of Respiration," by L. Bernardi, C. Porta, A, Gabutti, L. Spicuzza, & P. Sleight, 2001, *Autonomic Neuroscience*, *90*(1-2), 49.

There is a bidirectional relationship between respiration and cardiovascular response to a stimulus. The cardiovascular system reacts to external transient stimuli by

changing the interaction of PNS and SNS interaction (Kitney & Rompelman, 1987). Stimuli which increase the stress levels in the system and engage the SNS may increase or decrease the frequency and depth of breathing. It has been proposed that yoga and breathing techniques train the autonomic nervous system to be more adaptive to internal and external stressors (Gard et al., 2014). This type of effect may be analogous to the function of strength-training on muscles. Baumeister and colleagues (2006) strength-model of SR might support this. In practicing retention breathing and meditation, for example, "the mind/brain becomes better at doing things outside of meditation that it practices in an extended way during mediation" (Travis & Shear, 2010, p. 9).

Breathing techniques are often practiced in conjunction with postures (asanas), or on their own. Pranayama, the harnessing of life-force energy (prana) through breathing, is often considered preparation for meditation. Pranayama decreases arousal intensity and turns attention inward (Sovik, 2000).

i. The link between emotions and breathing patterns. Mastering the breath has been used as an ancient tool for mastering the mind. Eastern religions and martial arts have understood the intimate connection between breathing, mental function, experience of the world, and physical health (Brown & Gerbarg, 2005).

Empirical research has confirmed the power of the breath in regulating and influencing mental states by showing breathing rhythms are bidirectionally causally related to feeling-states. Philippot and colleagues (2002) studied breathing patterns associated with four emotions (i.e., joy, anger, fear, and sadness) established by a group of research subjects (see Table 2). A second group was then asked to mimic the breathing patterns without further information or instruction and reported feeling the emotion associated with each pattern, to varying but significant degrees. The amount of variance for breathing patterns associated with emotions was 40%. Notably, this is greater than the

amount of variance reported by Matsumoto (1987) for facial feedback (13%) studies shown to affect emotions associated with certain facial expressions.

Table 2

Breathing Patterns for Four Emotions (Joy, Anger, Fear, Sadness)

Emotion	**Associated Breathing Pattern**
Joy	"Regular, moderately deep and slow breathing through the nose and with minimal thoracic tension, tremors and sighs...tends to be diaphragmatic or both thoracic and diaphragmatic" (p. 615)
Anger	"fast, irregular, and deep nasal breathing with marked thoracic tension, minimal sighs, and some tremors. The expiration was diaphragmatic" (p. 616).
Fear	"fast, irregular, rather shallow breathing, with much thoracic tension, some tremors, and minimal sighs. More thoracic breathing was reported for fear than for any other emotions" (p. 616)
Sadness	"nasal breathing with average amplitude and frequency, marked with sighs and tremors as well as some thoracic tension and irregularity" (p. 616)

Note. Adapted from "Respiratory Feedback in the Generation of Emotion," by P. Philippot, G. Chapelle, & S. Blairy, 2002, *Cognition & Emotion*, *16*(5), 605-627.

Philippot, Chapelle, and Blairy (2002) illustrated the bidirectional relationship between breathing and emotions, as mediated by differentiated autonomic nervous system response-types. For example, stronger SNS-activation during the experience of a stressful stimulus signals the need for increased ventilation and predicts the breathing pattern, as well as other physiological changes (e.g., HRV or digestive slowdown) associated with the given state. This influence on other physiological changes (e.g., HRV, heart rate, and sweating) may be the mechanism by which breathing influences subjective feeling states themselves (Philippot et al., 2002). See figure 6 below for an illustration of this mechanism.

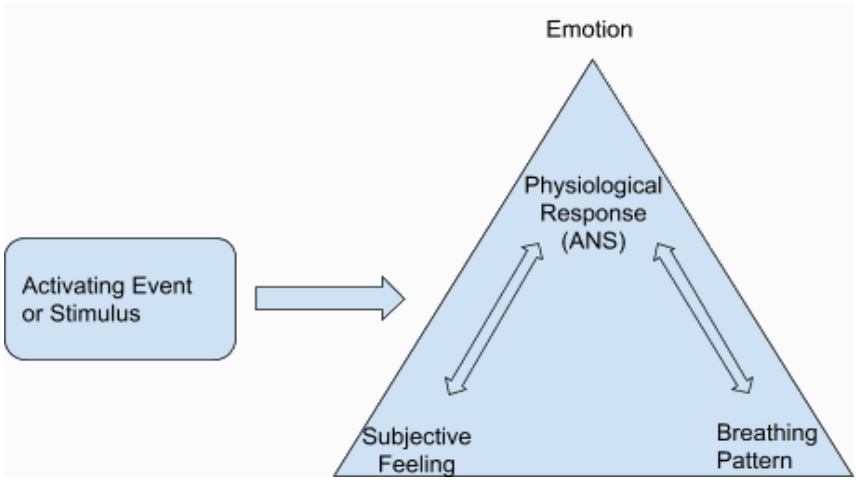

Figure 6. Activating Event – Emotion (Feeling - Physiology - Breathing Pattern)

Regulated and targeted breathing patterns are tools for the development of SR capacity in youth. These strategies allow individuals to change from an anger to a calm state, or from fear to peacefulness, an integral component of SR. My model proposes that for maximal impact, SEL programs can utilize breathing techniques in conjunction with emotion-identification, and emotion-regulation lessons.

ii. Examples of outcomes associated with breathing interventions. Breathing techniques have been found to improve SR. This relationship has been explored in a study of the effect of mindful breathing techniques on emotional volatility in response to aversive pictures when compared to control groups in undergraduate healthy populations (Arch & Craske, 2006). For example, the Youth Empowerment Seminar, a breathing-based program for teens, showed a significant decrease in impulsive behavior in teens who had participated in the program for 20 hours over four weeks (Ghahremani et al., 2013). The Learning to BREATHE program has shown promise in helping students decrease negative affect and increase of calm and emotional SR (Broderick & Metz, 2009).

Cheng, Croarkin, and Lee (2019) found that, when compared to control groups, participants who practiced a five-minute deep breathing exercise (guided by a video

animation for inhaling and exhaling at six breaths per minute) experienced an increase in HRV and decrease in depression scores.

Ma et al. (2017) showed that, for adults, teaching slow abdominal breathing increased attention span, decreased negative affect and lowered cortisol levels. The breathing exercises were taught over a period of eight weeks to the test group. These adults were given a real-time feedback device and instructed to achieve a mean breathing rate of only four breaths per minute. The test group showed an increase in attention-span, a decrease in both negative affect and cortisol levels. Each result was found to correlate with the training received in slow abdominal breathing (Ma et al., 2017). Sustained attention achieved through taking deep breaths breathing techniques has been shown to significantly improve a timed math test performance for children in Grade 5. The effect was more pronounced in boys than in girls. Researchers found that the deep-breathing technique was simple and learned easily (Khng, 2017).

Kajander and Peper (1998) taught diaphragmatic breathing to children. They noted that newborn babies breathe naturally using the diaphragm, but that, by age 10, most children adopted shallow thoracic breathing, unless they were lying down. The researchers also found that 10-year-old children were breathing at 20 beats-per-minute (bpm) and since adults who practiced diaphragmatic breathing could slow their breath to 5 to 8 bpm, the researchers taught slow diaphragmatic breathing to children through the nose. They reported the following physiological effects of the activity and posited a vagal mechanism. As Kajander & Peper (1998) describe:

> Breathing in through the nose stimulates the vagus nerve endings resulting in lowering of the sympathetic response and inhibiting the fight/flight response...Slow breathing results in mild increases in CO2, which causes slowing of the heart rate, dilation of peripheral vessels, stimulation of gastric secretions,

> depressed cortical activity, and mild somnolence, all characteristics associated with relaxation. (p. 15)

Slow breathing techniques have been used in Eastern spiritual paths and martial arts for millennia. Tanden, a slow abdominal breathing technique used by Zen practitioners, has been shown to impact cardiac variability, where experienced practitioners were found to have optimal HRV levels (Lehrer, Sasaki, & Saito, 1999).

A study which examined VT as a mechanism in ameliorating abdominal pain through breathing in children, Sowder, Gevirtz, Shapiro, & Ebert (2010) found that an *HRV biofeedback* was effective in increasing HRV of youth ages 5 to 17 compared to control groups. This practice entailed slow, deliberate breathing practice for 10 minutes daily.

iii. Considerations and implications for breathing instruction. In schools, parents and teachers may often ask a student to "take a deep breath" with the hope that doing so will help the student exhibit SR behaviors. Kajander and Peper (1998) found that teaching breathing techniques to children should involve great specificity in instruction. In their study, they found that it was insufficient to tell the children to "take a deep breath" because the children then tended to breathe with a large chest inhalation, possibly triggering a fight or flight response. Instead, the researchers taught the children belly breathing by placing a hand on their own abdomen (or even the abdomen of the instructor) to feel deep diaphragmatic breathing. Kajander and Peper (1998) also found it helpful to instruct the children to exhale fully when they were under stress. They note, "children report that [learning deep diaphragmatic breathing] has lasting benefit over other biofeedback techniques for relieving significant disorders such as chronic tension and migraine headaches, stomach aches, sleep disorders, feelings of anxiety and panic, and anger management" (Kajander & Peper, 1998, p.17).

Many SEL programs already integrate breathing techniques into their curricula. Second Step acknowledges the role of physiology in the identification of emotions and SR, by including belly breathing in a lesson on SR. To help students identify emotions, the program teaches a lesson entitled "We Feel Feelings in Our Bodies." However, these skills can be characterized as add-ons, or appendices to other strategies, equal to or as less important than cognitive strategies, rather than foundational, reflected in both their change model and in the amount of time devoted to learning these skills. For example, the scope and sequence of Second Step teaches explicit *breathing* in a small fraction of their lessons:

- K, 1, 3, 4, 5, 6: 1/25 (4% of lessons include breathing; Committee for Children, 2017)
- 1st: 2/25 (8% of lessons which include breathing; Committee for Children, 2017).

There are two ways that Second Step might more fully leverage the power of conscious breathing more fully: 1) by increasing the number amount of lessons devoted to teaching and practicing physiologically integrated practices — thus, for example, breathing techniques beyond *belly breathing* can be explored (see below). In these lessons, children begin to learn the ways in which *different* breathing techniques have varied impacts on their nervous systems and on their subsequent capacity to practice SR and other social-emotional competencies. 2) by including a short period of physiologically integrated practice into each lesson, or 3) by some combination of both of these.

Gard and colleagues (2014) suggest several breathing techniques from the Raja Yoga tradition, which could have positive correlations with SR capacities. These techniques could form parts of lessons on SR or could be standalone lessons in SEL interventions. Here I elaborate on their list.

1. Nostril breathing (nadi shodhana)
    a. Inhaling and exhaling through alternating nostrils.
    b. *Ujjayi* (epiglottal constriction)
2. Changing the depth or rate of breathing
    a. Fast (kapalbhati, bhastrika)
    b. Slow, calm.
3. Retention
    a. Inhaling, exhaling, holding
    i. With/without counting
4. Mouth breathing
    a. Through curled tongue or teeth
    b. Full open mouth exhale (lion's breath)
    c. Sigh
5. Humming (bee breath; bramari)
6. Laughing ("ha ha", "hoo hoo")

In addition to doing these techniques on their own, educators may wish to integrate breathing and yogic postures with inhales corresponding to body expansions (e.g., opening arms, arching back), and exhales corresponding to body contractions (e.g. closing arms, forward bend).

c. Mindfulness. Increasingly more youth development programs have begun to incorporate mindfulness as part of their intervention efforts (Greenberg & Harris, 2012). This parallels the exponential increase in studies on the myriad of benefits of mindfulness in the last two decades.

Kabat-Zinn (1982), often credited with the wide dissemination of mindfulness in the Western world, first described the use of mindfulness-based stress reduction (MBSR)

in patients with chronic pain. Conceptions of mindfulness usually include intention, attention, and attitude as their foundational elements. Researcher's often use Kabat-Zinn's (1994) definition of mindfulness: "the awareness that arises through paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally" (p. 4).

i. SR and other social-emotional competency outcomes of mindfulness interventions. Mindfulness is correlated with a multitude of psychological well-being indicators such as positive emotions and optimism, and lower incidences of negative feelings, anxiety, and depression (Keng, Smoski, & Robins, 2011; Brown & Ryan, 2003). Participation in mind-body practices, such as yoga and meditation, has been shown to increase the capacity for children to exhibit SR. Practicing transcendental meditation in school settings has led to increases in self-control, especially in relation to anger (Rosaen & Benn, 2006). In a literature review of 11 transcendental meditation and mindfulness meditation programs, Wisner, Jones, and Gwin (2010) showed significant benefits of these methods for the development of self-regulatory capacities in adolescents. Importantly, based on their research, they suggest that even shorter practices (10 to 12 minutes), as long as they are done every day or several times per week, can be as beneficial as practices with standard lengths (15 to 20 minutes; Wisner et al., 2010).

Keng and colleagues (2011) examined the effects of mindfulness meditation reported in dozens of mindfulness intervention studies (including MBSR, mindfulness-based cognitive therapy, and dialectical behavioral therapy, which included mindfulness). These researchers posit several mechanisms through which mindfulness interventions might lead to improved indices of psychological health: in addition to behavioral SR, they noted desensitization to negative experience through exposure, attention control, and memory functioning (Keng et al., 2011).

Davidson and McEwen (2012) posit that the neurophysiological benefits associated with meditation practice are related to this increased self-regulatory capacity. A variety of studies have shown the impact of mindfulness practice on neurological substrates of SR. For example, Lazar and colleagues (2005) showed that meditation practice for adults showed cortical thickening in regions of the brain related to emotional and cognitive processing. Based on increased brain plasticity in youth, it is reasonable to assume that these benefits would transfer to youth populations as well.

Barnes, Davis, Murzynowski, & Treiber (2004) conducted a random-assignment study that compared the students in a mindfulness treatment intervention to control groups participating in 20-minute walks or 20-minute diet-education sessions. Students in the treatment group were asked to meditate 10 minutes at home and 10 minutes at school daily, with a weekly meditation instruction. The sessions lasted three months and decreased the resting and ambulatory blood pressure and heart rate in adolescents who participated in the intervention.

Peng, Mietus, Liu, Khalsa, Douglas, Benson, & Goldberger (1999) found increased HRV in practitioners of Chi-guided meditation (one-hour sitting with simple imagined visualization exercise) and of Kundalini yoga meditation (one-hour breathing and chanting). Figure 7 shows a representative graphic of two meditators' HRV before, during, and after meditation. Important features here are the consistent variability during meditation for both types of meditators. Equally important, HRV continues to be elevated after meditations are finished. Interestingly, in Chi meditation, although there is no manipulation of breathing, HRV is deeply affected by a shift in mental state.

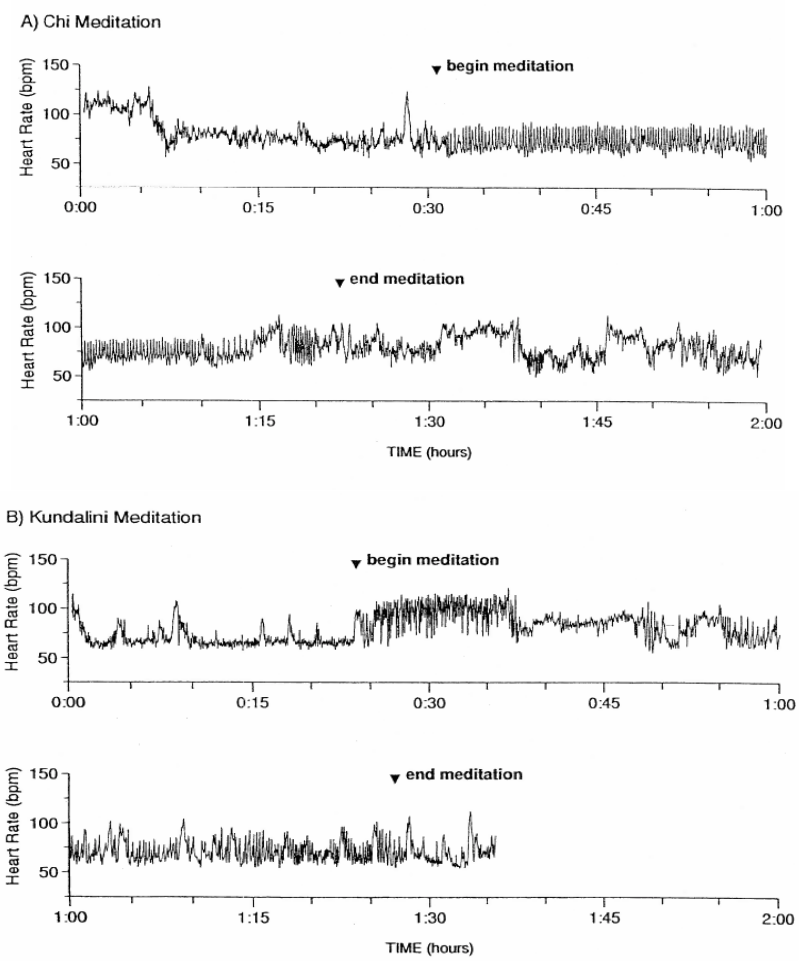

Figure 7. Representative instantaneous sinus rhythm heart rate time series, before, during, and after meditation for two meditation protocols: Chi meditation and Kundalini meditation. Notable features of these time series from different subjects are: the complex variability of the fluctuations, and the intermittent, prominent heart rate oscillations that correlated with respiration. From "Exaggerated Heart Rate Oscillations During Two Meditation Techniques," by C. K. Peng, J. E. Mietus, Y. Liu, G. Khalsa, P. S. Douglas, H. Benson, & A. L. Goldberger, 1999, *International Journal of Cardiology*, *70*(2), 104.

In these figures, HRV dramatically increases to optimal levels during meditation practice. Baumeister and colleagues' (2006) strength model of SR describes the empirically validated notion that capacity for SR can be exhausted by overuse as well as developed with practice — analogous to a muscle. If HRV, as a biomarker of SR, is also developable, participating in practices which improve HRV in meditation also improve HRV in other domains (e.g., resting or ambulatory). Chiesa and colleagues' (2013) finding that long-term meditators experience bottom-up, psychophysiological changes in

self-regulation supports the hypothesis that more practice in mindfulness may increase HRV in the long-run.

ii. Examples of mindfulness practices. When mindfulness is taught to children, the focus is often on regulating attention. The Chopra Center suggests asking the child to be as still as a frog sitting on a lily pad. The frog cannot move or its lily pad will tip over. The frog can only observe quietly without moving (Schairer, 2019). Imaginary visualization can be helpful for students in developing SR capacity (White et al., 2017). For example, when students pretend to be a superhero, they can persist with working on repetitive tasks for a longer time by withstanding distracting temptations (White et al., 2017).

The University of Portland's (2018) mindfulness curriculum for classrooms of elementary school students asks students to sit quietly, with eyes closed, first focusing on every surrounding sound, then on smell, touch, and feel. Finally, students open their eyes and focus on everything they can see. Each portion lasts up to 30 seconds (University of Portland, 2018).

Many different types of meditation have been practiced around the world for millennia; techniques abound. Within the *Raja* yoga discipline, there are four main traditions of meditation, *pratyahara* (including sensory withdrawal), *dharana* (single-pointed concentration), *dhyana* (open attention), and *samadhi* (integration or transcendental; Gard et al., 2014). Each of these types of meditation may influence different components of SR, and practitioners should be intentional with the type of practice they integrate into SEL programs - in addition, there should be flexibility depending on student and teacher needs.

Pratyahara: withdrawal of senses - engages practitioners to turn their attention inward to increase self-awareness without external distraction. In this practice, students

may close their eyes (or look down, if not comfortable), and turn their *gaze* towards inner experiences of thoughts, feelings, emotions. This type of meditation may be quite useful learning how to identify emotions, a prerequisite of SR and communication, problem solving, and conflict-resolution. Incorporating this practice regularly has been shown to improve self-awareness even beyond the duration of the practice.

Dharana entails calming the wandering of the mind by focusing on a single stimulus (e.g., the breath, sounds of the environment, parts of the body; Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012). This practice may be useful for increasing both awareness of environment and self-awareness *in relation to the environment*. These types of awarenesses may augment SR capacity by allowing youth to identify triggers and to separate reaction from stimulus and by inducing relaxation. This can be beneficial for cultivating attentional SR, particularly for students with attention deficit hyperactivity disorder (ADHD; Zylowska, et al., 2008).

Dhyana, or open-awareness meditation, often achieved by more experienced meditators, cultivates a feeling of union and connection with the objects of awareness and can be compared to flow state (Gard et al., 2014; Csikszentmihalyi, 1997).

Samadhi meditation refers to a state of total absorption, non-dual awareness and a knowingness of the object of awareness beyond name and form, and is conceived as non-duality and connection with all. This is described by Tarvis and Shear (2010) as a state that has been observed in laboratory settings to be associated with *respiratory suspension*, the temporary cessation of perceptible breathing, and an accompanying cessation of CO2 and O2 exchange in the blood.

iii. Considerations for mindfulness instruction. This paper makes a few recommendations for the integration of meditation practices into SEL programs. How an intervention is delivered may be as or more important than the type of intervention. To

ensure the successful integration of meditation into classrooms or SEL programs may consider spending enough time discussing benefits, asking questions, and connecting the benefits of the practice to the goals and desires of students, and making it a fun, rather than difficult experience (e.g., by preceding or following with a game, interesting conversation, or video).

In teaching meditation, it may be useful to use incremental adjustments in time and intensity of practice. For first timers, the practices can often seem boring and useless, especially for youth accustomed to hyperstimulation from media and technology. Baumeister and colleagues (2006) strength model of SR would liken it to a weight-lifting training program. Just as starting the first day with the heaviest weight or most awkward exercise may be off-putting and injurious to students, making the introductions to meditation longer than 1-3 minutes could potentially cause more frustration than benefit for students. Secondly, the type of meditation should be tailored to the development, abilities, and experience-levels of the students. Beyond length of time, rather than starting off with complete silence, teachers might begin by guiding meditations, either themselves or with recordings.

These adaptations in practice have been found to be especially beneficial for groups which may have special needs. Zylowska and colleagues (2008) studied the impact of an MBSR intervention on adults and adolescents diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). The ways in which they adjusted traditional MBSR mindfulness instruction to meet the needs of youth (and the fact that they did with favorable results), suggests the benefits of customizing practices for the needs of specific groups. Zylowska and colleagues (2008) adapted the following components of the training:

A psychoeducation on the clinical symptoms, neurobiology, and etiology of

> ADHD was provided; (b) sitting meditation periods were shorter than required in other similar programs (typically 45 min of at-home practice is recommended) and walking meditation could be substituted for sitting meditation; (c) mindful awareness in daily living was emphasized; (d) didactic visual aids were used to explain mindful awareness concepts; and (e) a loving–kindness meditation (an exercise of wishing well to self and others) was incorporated at the end of each session to address the low self-esteem problems often associated with ADHD. (p. 741)

Even for groups in normal conditions, these considerations and modifications can be used as *training wheels* for meditation - and may make or break the interest of students in participating in these practices.

d. Yoga. Yoga is the Sanskrit word for union. Many practitioners and theorists hold that it is the union of body, mind, and spirit (or breath). During the physical practice of yoga, the breathing is regulated to match the movement being taken while the focus of the mind is directed to the movement as well, bringing the three together. In modern Western culture, the term yoga is associated with physical postures (Gard et al., 2014). Yoga refers to more than the practice of physical pose-holding (asana) or breath control. Yoga is a philosophy which gives life to the central pillar upon which this paper rests: that there is a cyclically causal relationship between body and mind which can be strengthened by giving attention to these mechanisms of this connection.

Referred by many as the father of yoga, Patanjali described yoga in the *Yoga Sutras* as a cognitive process having to do with the stilling the modulations of the mind (i.e., desires, comparisons, and impulses; Vivekananda, 2001). To achieve this, yoga depends on cognitive reframing knowledge, physical posture (asana), meditation, and breath control as integral aspects of yoga practice. Furthermore, in addition to improving

vagal tone, yoga asana practice reduces cortisol levels and allostatic load, a measure of the wear and tear on the body of long-term stress on the nervous system (Streeter, Gerbarg, Saper, Ciraulo, & Brown, 2012).

i. A review of yoga interventions. Sauer-Zavala, Walsh, Eisenlohr-Moul, and Lykins (2012), in a study of 141 undergraduates comparing the effects of easy yoga posture sequences, sitting meditation, and a body scan (i.e., the practice of placing sequential, nonjudgemental awareness on different body-parts), found that the first two practices were associated with greater changes in levels of emotion regulation when compared with the latter.

Taken to mean union, yoga is more than typical postures. In fact, there are many interventions that can bridge the gap between body and mind outside of a traditional yoga conception. Facial expressions of a given emotion lead individuals to experience this emotion (Ekman, 1984). Although small, the effect of facial feedback has been empirically shown to be significant in a variety of studies (Matsumoto, 1987). This type of intervention helps students conceptualize the intimacy of mind-body influence on each other. To this end, educators can challenge students to design their own *yoga-informed* practices or experiments, whereby they might observe the effects of bringing awareness, movement, or voluntary control to a given physiological act — whether that is moving limbs in a certain direction, following the breath, or trying out new facial expressions.

Hagen and Nayar (2014) recommend that yoga be offered at schools, preschools, and community centers and that it be treated as its own *fun* practice, not merely as a simplified version of an adult practice. They note that the possible benefits for youth who are distracted by the demands of modern society and its technology, as well as those with attention-deficit disorder.

Exercise, mindfulness, breathing, yoga, and other practices empirically shown to

influence the physiological components of SR strengthen and augment change models in SEL programs.

VII. Future Directions

The inclusion of biomarkers in SEL is in its infancy. The possibilities of integration are endless - future research is needed. Building on recommendations of Greenberg et al. (2015), Blair and Raver (2015), and those within this paper, researchers and practitioners should investigate relationships between SEL programming and biomarkers. Change in heart rate variability due to SEL may be short lived. Longitudinal research should investigate the duration of sustained impact on these measures, and the variables which lead to increased duration. Often, SEL programs are studied as full packages (e.g., Second Step, PATHS), thus making it difficult to investigate the individual factors that have led to improvements in outcomes (Rimm-Kaufman & Hulleman, 2015). Studies that investigate the correlations of *specific program components* on biomarkers, rather than entire programs, could shed light on the power of specific practices. This type of research enables designers to create super-SEL initiatives that integrate the most impactful practices - ones that transcend brands, theories, and leverage the power of empiricism to create stronger impact for youth outcomes. Also, this research allows educators to customize interventions to match the needs of students.

VIII. Conclusion

In the last two decades, there has been an explosion of attention on designing and implementing well-being programs in schools. Although the social-emotional learning (SEL) programs and fields that have informed these efforts can be siloed in their methodologies, frameworks, curricula, and objectives, there are a few underlying commonalities. One important commonality across these fields is the emphasis on self-regulation as a competency or strength worthy of development. In SEL, self-regulation

and other competencies and strengths have been primarily evaluated through non-physiological self-reporting or observational assessments. However, self-regulation is a psychophysiological phenomenon. This paper has presented a model, bidirectional causation Upward-Spiral Model for the Integration of Biomarkers and Mind-body Practices in Social-Emotional Learning Programs and Evaluations, which illustrates the benefits of including psychophysiological measures such as vagal tone and heart rate variability within the scope of SEL program assessments. In addition, this model challenges programs to deeply incorporate practices that influence self-regulatory capacities from a physiological bottom-up approach, namely through exercise, breathing techniques, mindfulness, and yoga.

To assess the underlying foundation of a building is to ensure its sturdiness. Analogously, starting and ending with a physiologically informed foundational understanding of the integrated nature and components of self-regulation, educators are in better positions to design, deliver, and assess the impact of SEL programs, and can more effectively facilitate the thriving of youth.

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Appendix A

Positive Psychology & Positive Education

Positive psychology (PP) has been described by one of the field's pioneers as the study of what makes life worth living (Peterson, Park, & Sweeney, 2008) and brings together a multitude of research on optimal human functioning, broadening the scope of typically applied psychology on pathologies, disabilities, and disorders. It moves from a space of pure functioning to a life of thriving and can be implemented with a variety of healthy populations, expanding the focus of psychology a clinical focus. Seligman and Csikszentmihalyi (2000) have envisioned the field of positive psychology as a supplement, not a substitute for traditional psychology. Both are needed, if perhaps at different times, to varying degrees, in a variety of contexts.

Positive psychology developed as a call to reorient the field of psychology toward focusing on fostering strengths, rather than on relieving pathologies (Seligman & Csikszentmihalyi, 2000; Lyubomirsky, King, & Diener, 2005). Notably, positive psychologists have begun to examine correlations between psychophysiological measures of well-being like VT, and the development of important social-emotional proclivities, such as social connectedness and positive emotions (Kok & Fredrickson, 2010).

Positive psychology research began less centered on children and adolescents, and more on adults' strengths and subjective well-being (Diener & Diener, 2009). Recently, PP has increasingly incorporated important developmental and youth considerations into its empirical, interventional, and theoretical scopes (e.g., Kirschman, Johnson, Bender, & Roberts, 2009; Furlong, Gilman, & Huebner, 2009; Seligman & Adler, 2018; Seligman & Adler, 2019).

Positive education has been defined simply as "education for both traditional skills and happiness" (Seligman, Ernst, Gillham, Reivich & Linkins, 2009, p. 293). Many

components in the frameworks and interventions of PP can be seen as proclivities (e.g., optimism, gratitude, and grit) that, while alterable, are to some degree more evident in some individuals than others, much like personality traits. However, research and practice from within positive education has inspired a wide range of SEL deliveries, such as growth-mindset interventions, incorporation of grit in education, optimism and resilience, character strengths interventions (Dweck, 2008; Duckworth, Peterson, Matthews, & Kelly, 2007; Seligman, 2011; Shoshani & Steinmetz, 2014; Reivich & Shatté, 2002; Reivich, & Gillham, 2010).

Seligman challenges educators and parents to consider the questions, *what should schools teach?* And *what do schools actually teach?* (Seligman, 2011). If there is a gap between the answers to these questions, positive education seeks to fill it.

Appendix B

Social Competence

Social competence (SC) is not its own conceptual development framework; like SEL, it is an umbrella of theories, practices, frameworks, and fields. SC is built on the conceptual frameworks of social information-processing models and theories of emotional intelligence, emotion-processing theory, social development theory, and social cognitive theory (Bierman & Motamedi, 2015; Bierman & Montminy, 1993; Crick & Dodge, 1994; Waters & Sroufe, 1983; Tolan et al., 2016) SC can be defined as "effective functioning within social contexts (Cavell, 1990), and focuses primarily on the skills and practices that youth can learn to become better at building relationships and solving conflicts with others. Implicit within this framework are skills that target cognitive skills which enable this type of social functioning (Greenspan, 1981; Dodge & Murphy, 1984).

SC emerged from an interest in the ways that children understand and manage social situations (Tolan et al., 2016). It is based on three main assumptions: that a) individuals who are not accepted by peers have not learned to behave in ways that are appropriate or rewarding, b) that the individuals can be taught skills to help with integration, and c) as they learn the skills, they will experience increased acceptance from peers (Ladd & Mize, 1983). Because of its emphasis on developing foundational social skills, SC-related models have been the predominant developmental learning model for early education settings where programs usually center around teaching effective communication, self-regulation, and problem solving skills (Bierman & Montminy, 1993).

Appendix C

Positive Youth Development: A Brief History and Synopsis

While school reform and youth development efforts and research have historically centered largely around removing problems and addressing singular issues (i.e. crime and drug response and prevention) many of these interventions proved to be ineffective and even sometimes exacerbate issues (Catalano, Hawkins, Toumbourou, 2008). Positive youth development (PYD), even before the inception of Positive Psychology was born from the realization that programs which incorporated multiple skill-sets as singular-problem programs proved to be limited in their impact (Catalano, Berglund, Ryan, Lonczak, & Hawkins, 2004).

Programs that focused solely on a singular-problem came under attack in the 1980's by researchers who advocated a more holistic approach to youth development. They advocated for considerations of youth-environment interactions and strengths-building as an integral approach to programs and made the claim that healthy youth development required more than just avoiding drugs, violence, and teenage pregnancy and other problem-behaviors. On the contrary, PYD promoted strong social and emotional skills as protective factors against problem behaviors and the foundation for a life of wellbeing (W.T. Grant Consortium, 1992). In fact, prevention science has found that many youth outcomes, whether positive or negative, have the same protective and risk factors (i.e. resiliency is both a protective factor against depression but also a predictor of success in other areas (Brunwasser, Gillham, & Kim, 2009; Weissberg & Greenberg, 1998; Howell, Krisberg, Hawkins & Wilson, 1995).

While the operational definitions of PYD differ across different programs and settings - for example, the 5 C's model: *connection*: the feeling of belonging to people and institutions; *confidence*: positive self-concept; *character*: embodiment of integrity

and other important virtues; *competence*: effectively function in work, school, and social situations; and *contribution*: leadership and making a difference (Lerner, Phelps, Forman, & Bowers., 2009).

Guerra and Bradshaw (2008) identify five main social competencies from literature in PYD: (1) a positive sense of self, (2) self-control, (3) decision-making skills, (4) a moral system of belief, and (5) prosocial connectedness. These have been the foundation of several programs within the prevention and positive youth development (PYD) field (Guerra and Bradshaw, 2008).

Appendix D

"Serious Limitations of Self-Report and Teacher Report Questionnaires"

(Duckworth & Yeager, 2015, p. 239)

1. **Misinterpretation by participant:** Student or teacher may read or interpret the item in a way that differs from researcher intent
2. **Lack of insight or information:** Student or teacher may not be astute or accurate reporters of behaviors or internal states (e.g., emotions, motivation) for a variety of reasons
3. **Insensitivity to short-term changes:** Questionnaire scores may not reflect subtle changes over short periods of time
4. **Reference bias:** The frame of reference (i.e., implicit standards) used when making judgments may differ across students or teachers
5. **Faking and social desirability bias:** Students or teachers may provide answers that are desirable but not accurate

Serious Limitations of Performance Tasks

1. **Misinterpretation by researcher:** Researchers may make inaccurate assumptions about underlying reasons for student behavior.
2. **Insensitivity to typical behavior:** Tasks that optimize motivation to perform well (i.e., elicit maximal performance) may not reflect behavior in everyday situations.
3. **Task impurity:** Task performance may be influenced by irrelevant competencies (e.g., hand–eye coordination)
4. **Artificial situations:** Performance tasks may foist students into situations (e.g., doing academic work with distracting video games in view) that they might proactively avoid in real life.

5. **Practice effects:** Scores on sequential administrations may be less accurate (e.g., because of increased familiarity with task or boredom)
6. **Extraneous situational influences:** Task performance may be influenced by aspects of environment in which task is performed or by physiological state (e.g., time of day, noise in classroom, hunger, fatigue)
7. **Random error:** Scores may be influenced by purely random error (e.g., respondent randomly marking the wrong answer).

Appendix E

Basics of Vagal Tone

Through its role in myelinating of a portion of the vagus nerve, VT helps to develop a *vagal brake* to inhibit the activation of lower components of the autonomic nervous system, which would lead to fight-or-flight or immobilization responses under stress. Having high VT increases a mammal's resistance to stressful situations — an essential component of the capacity to self-regulate. More broadly, VT has been established as important biomarkers for many aspects of well-being: physical, social, emotional, and psychological, explored below.

Porges (2012) explores the psychophysiological underpinnings of SR, as they relate to autonomic flexibility or balance, indexed by VT, which refers to the ability of the autonomic nervous system to respond to and adapt to external and internal stressors. Autonomic flexibility involves the balancing of both parts of the ANS: PNS, regulating the rest-and-digest functions, and the SNS, taking care of heart rate, blood pressure, pupil dilation, sweating, and other functions related to action automatically. The simultaneous functions of the PNS and SNS help to achieve a sort of homeostasis in the body; healthy autonomic function depends on the continual balancing of PNS and SNS activation within the autonomic nervous system. When the fight-or-flight response is triggered by the SNS and appropriate action has been taken, it is the job of the PNS, through the relaxation response, to calm the body and brain. The balanced activation of PNS and SNS enables individuals to exhibit SR behaviors and capacities.

How is VT measured?

The traditional way of measuring VT has been with electrocardiogram (ECGs) of HRV. Because circadian rhythms, sleep cycle, and body temperature affect HRV, the *gold standard* for clinical evaluation of HRV is an ECG taken over a 24-hour period

(Shaffer, McCraty, & Zerr, 2014). However, shorter time periods can be assessed with reliability (Shaffer and Ginsberg, (2017). ECGs can be cumbersome and expensive to administer. Consequently, this paper does not recommend the use of ECGs in SEL program assessment. There currently are many new technologies for measuring HRV in a quicker, more cost-effective manner, such as commercially available modern wrist computers, ranging between $27 and $100.

HRV can be measured in a variety of conditions — during simple physical movements or controlled breathing (Kleiger, Stein, & Bigger, 2005). In the case of movement, in a resting state, the patient performs a simple movement or such as head lifting or standing from a lying position; in the case of controlled breathing, changes in heart rate are assessed for congruent changes in respiration rate. For an individual with healthy VT, changes in these types of actions should induce a significant change in heart rate. For those with hyperactive SNS activation, where VT is not strong, the heart rate change is not readily observed (Kleiger et al., 2005). Measuring HRV can be a feasible way for researchers to evaluate the impact of a given SEL intervention on VT, an established underlying physiological mechanism of SR.

HRV measures which denote low SR capacities are often observed during periods of emotion evocation, and not in many other stimulus conditions (Shahrestani, Stewart, Quintana, Hickie, & Guastella, 2015). Therefore, when assessing HRV as a biomarker for SR, researchers might consider combining HRV measures with a social stress task, such as the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993), evoking emotion to get a meaningful indicator of SR.

A note about the relationship between Respiratory Sinus Arrhythmia and HRV: RSA, commonly used synonymously as HRV, refers to the extent to which HRV is determined by inhalation and exhalation; usually inhaling speeds up heart rate, and

exhaling does the opposite. The reduction in heart rate as a product of breathing in or out is a function of vagal nerve activity, with higher vagal nerve activity associated with a greater effect on the slowing of the heart (Uijtdehaage & Thayer, 2000).