Concentration in Preschool Settings:

Relation with Behavioral Measures, Physiological Response, and Teacher and Parent Report

Ian Becker

A Dissertation presented to the Graduate Faculty of the University of Virginia in Candidacy for the Degree of Doctor of Philosophy

Department of Psychology

University of Virginia

May, 2022

Dissertation Committee:

Angeline S. Lillard, Chair

Vikram K. Jaswal

Daniel T. Willingham

Tanya M. Evans

Table of Contents

Abstract

The ability to concentrate on schoolwork is critical for school readiness. Despite this, concentration is not a commonly used term in psychology, instead being captured by terms such as attention, cognitive load, and self-regulation. I argue these terms are components of concentration and that previous psychological research has not captured the essence of what we mean when we say a student is concentrated in a classroom. This is a descriptive and associative study investigating children's demonstrated concentration in and out of the classroom. We observed 24 preschool children (M = 4.51 years, SD = 0.69 years, range = 3-6 years, 13 female, 11 male) in two classrooms. All observations were completed in Montessori classrooms during periods of time when children were free to choose their own activities, allowing for an assessment of concentration based on children's self-directed, rather than teacher-directed, work. During observation, information on children's demonstrated concentration was collected using a recently developed scale for capture how deeply children are concentrating. What activities and how long children did each activity were also noted. Children's demonstrated concentration was assessed using more traditional measures of the components of concentration, using the statue task from the Developmental Neuropsychological Assessment (NEPSY) to measure self-regulation, a go/no-go task to measure selective attention, and physiological response measured by heart rate variability to measure cognitive load. Results showed that older concentration in a more stable manner when working on an activity, although they did not necessarily show deeper or longer concentration than their younger peers. Associations with out of classroom measures suggest the importance of considering concentration within context, including factors such as whether an activity is individually- or adult-directed.

Keywords: concentration, attention, cognitive-load, self-regulation, Montessori preschool

Introduction

Ask most teachers whether concentration is important for learning and they will say that of course it is, but that getting children to concentrate and remain concentrated is a difficult task. Concentration on schoolwork is undoubtedly important for learning and considerable development in ability to reach high levels of concentration happens during the preschool years. When discussing concentration, the term attention often also comes to mind. The terms concentration and attention are often used synonymously. In the psychology literature, the term attention has been used more frequently, starting with such early and important psychologists as Wilhelm Wundt and William James (Blumenthal, 1975; James, 1890). Although attention is used more in the psychology literature, concentration is a commonly used term colloquially. This paper will contextualize concentration in psychology terminology and support the use of this term as a bridge between constructs like attention that have been primarily studied in controlled laboratory settings and what happens in naturalistic settings. Concentration is a composite state that is comprised of many cognitive functions, namely sustained attention, selective attention, appropriate cognitive load, and self-regulation in a state of activity.

In this study, I will explore children's demonstrated concentration in preschool classrooms. I will specifically investigate children's demonstrated concentration during periods of free choice when children are demonstrating concentration they reach independently. Children's demonstrated concentration will be assessed by looking at time on-task and using a recently developed measure of concentration and differences in the concentration that children demonstrate by age will be analyzed (I. Becker & Lillard, 2021). To check validity of this measure and to better understand contributions and correlations of concentration with similar behaviors, I will correlate concentration measured during classroom observations to out of

classroom measures of attention and inhibition, a physiological measure of cognitive load, and teacher and parent reports of children's aptitude to attend. Through doing research on children's demonstrated concentration during independent work, I will establish a foundation for future work to look at environmental factors that support preschoolers' concentration and the relation between concentration and outcomes such as learning and wellbeing.

Concentration Versus Attention

As mentioned, the term attention is more commonly used in the psychology literature than concentration. There are a large number of ways in which attention has been studied. Attention is relevant to many different contexts and considerable research has looked at different specific contexts of attention, for example when attention needs to be selective, or sustained, etcetera. In this wide range of research, terms including concentration are often conflated and used interchangeably (Schmidt et al., 2016).

Concentration is commonly used colloquially to describe when an individual is completely absorbed in and focused on an activity. For example, a child so absorbed in reading a book that all else becomes uninteresting is often described as concentrated rather than described as attentive. To reflect this, concentration will be used here to describe a composite of concepts related to attention that capture the colloquial use of the term in a way that previous research has not. Attention related constructs are closely related. In alignment with the colloquial use of the term concentration, there is indication that teachers and parents see attention related constructs as one main idea. In one study, teachers were asked a collection of 29 different questions about children's learning strategies related to attentiveness, response novelty, response to correction, problem solving strategies, flexibility, reflectivity, initiative, self-direction, and cooperative learning (McDermott et al., 2002). A factor analysis of these items showed three factors that

were related to attention and persistence, attitude towards learning, and competence motivation. Here, the construct of attention and persistence reflects a similar meaning to concentration, and indeed one of the items in this category is “tries but concentration soon fades.” These questions have been used to show the same factor structure in other samples and cross culturally, supporting the generalizability of the idea that concentration is important for learning (Hu et al., 2021; McDermott et al., 2012; Wu et al., 2019).

Concentration has two critical characteristics: depth and duration. In the example of a child concentrated on reading a book, two key indicators that the child is indeed fully absorbed in the process of reading are that the child is orienting all cognitive resources towards reading, and that the child does this activity for a prolonged period of time. Depth of concentration is defined by the extent to which cognitive resources are being used for a particular activity and is also related to selective attention and self-regulation. Duration of concentration is defined simply by the time spent on a particular activity and is related to sustained attention. Each of these cognitive functions that define concentration will be described next.

Selective Attention

Most environments are laden with potential stimuli to attend to. A very important piece of effectively attending is selecting a particular stimulus to attend to. Selective attention is a term that describes the mechanisms that help individuals’ experience be centered on one thing rather than another (Driver, 2001). Selective attention was originally studied in regard to the cocktail problem, which describes the problem of being able to select out and listen to particular voices or sounds even in a noisy room full of conversation (Cherry, 1953; Driver, 2001). In the visual domain, the classic measure of selective attention is the flanker task, where participants are asked to identify the direction a particular arrow is pointed, while ignoring several flanking arrows that

are pointed in the same or opposite direction (Eriksen & Eriksen, 1974). The flanker task deals with a similar problem to the cocktail problem, where there is a background of several different arrows, and the individual needs to attend to only a particular one.

More relevant to education, individuals must usually selectively attend to one activity happening in the classroom over others, such as the teacher giving a lesson, or paying attention to work rather than being distracted by a peer. This selective attention is critical for the learning process. Ability to selectively attend develops considerably during the preschool years (Hanania & Smith, 2009). One way in which children's selective attention can be supported is through having fewer distractors present in the environment. Children in environments that have fewer distractions, such as posters on the walls, are better able to attend to lessons and show better recall from the lesson (A. V. Fisher et al., 2014).

Sustained Attention

Sustained attention is the ability to maintain attention on the same task for a prolonged period of time (Esterman & Rothlein, 2019; Warm et al., 2008). Vigilance is a term sometimes also used to mean the same thing. Early descriptions of vigilance come from early 1920s, and later was carefully studied during World War II, looking at why people missed signals from radar and sonar (Warm et al., 2008). Vigilance tends to decrease rapidly after about 15 min for adults, but decrease does vary by the cognitive demands of the task as well (Warm et al., 2008). The study of vigilance as sustained, consistent attention in children has been less studied, as even selective attention tasks are sometimes difficult for children to maintain interest on and attention to for long periods of time. However, some vigilance measures do exist using variations on tasks such as go/no-go tasks that ask children to attend to a simple activity for a prolonged period of time (Betts et al., 2006; Knox et al., 2012). Instead of vigilance, the term sustained attention is

used more frequently in the developmental literature, reflecting behaviors such as sustaining attention in a classroom instead of remaining vigilant to a simple and cognitively demanding task, though the general meaning of the terms is the same.

Of particular interest to the present discussion is research on sustained attention in classrooms, usually measured using time on-task. Time on-task may be measured either as the proportion of time spend on-task, or as the amount of time spent continuously on the same task. Although it is the latter that is more consistent with the traditional conceptualization of sustained attention, the complexity of classroom environments with numerous distractors makes both consistent with the idea of needing to maintain attention over the course of a class period. Time on-task has historically been an important measure in education both for research and school administration. This basic premise that time on-task is important for learning serves as the foundation for many education policies; for example, rules about school attendance and credit hours are designed to ensure students have dedicated a particular amount of time learning a subject (Anderson, 1984). Of course, time spent in a classroom is not necessarily equal to time on-task in which a student is attending to material, but the similarities in regard to time are clear.

Sustained attention to a single activity is important for learning. Individuals who are able to sustain their attention are capable of interacting with the same activity for a longer period of time. This allows for less need to remember previously covered material and allows for work to reach deeper complexity. Thus, individuals who spend more time on-task for a particular activity have thought more about it and thus also are likely to have learned more about the activity (Carroll, 1963; Roediger & Butler, 2011).

Cognitive Load

Cognitive load indicates the amount of cognitive resources that an individual allocates to a task at a particular time. Humans have a limited capacity to process information in working memory (Miller, 1956). Cognitive load theory expands this idea to propose that the amount of cognitive resources that any particular task uses is more important to consider than the complexity of a task (Sweller et al., 1998).

In the original paper on cognitive load theory, three main areas were identified as increasing cognitive load: aspects intrinsic to cognitive load itself, aspects extraneous to the task, and processes germane to the task (Sweller et al., 1998). Aspects intrinsic to cognitive load revolve around simply increasing the number of items necessary to keep in mind as part of the task, which items in working memory and thus cognitive load. For example, many classic experiments in working memory use tasks that require individuals to keep a certain number of items in mind; increasing this number increases cognitive load. Individuals often keep this information in mind through rehearsal (Craik & Watkins, 1973). However, using mnemonics or complex schemas to reduce multiple pieces of information into one piece of information can help decrease the number of items needed to keep in mind and also decrease cognitive load (van Merriënboer & Sweller, 2005). Aspects extraneous to the task include steps that are not necessary for the task itself, but necessary in identifying the task to be solvable. An example of this would be figuring out what parts of a word problem are relevant to a particular question, or figuring out a mnemonic to more easily recall the information. The final aspect is increase in cognitive load to processes germane to the task. For example, the cognitive load needed to help keep attention on a task. High cognitive load in this area has been shown to decrease individual's ability to rehearse information on memory tasks (Barrouillet et al., 2009).

Adults have a variety of methods for helping keep information in mind, such as learning to rehearse information. These skills have been learned over time and help reduce certain aspects of cognitive load. These same methods of keeping information in mind are needed for complex academic tasks. Further, the complexity of many academic tasks increases cognitive load. For example, in solving a math problem the specific numbers of the problem must be kept in mind, as well as the operations needed, and the actual operations must also be applied. The cognitive load of applying the operation may interrupt keeping all the relevant information in mind. In general, children become much better at cognitive tasks during the preschool years, forming a foundation for better managing cognitive load as they get older (Gathercole et al., 2004; Müller & Kerns, 2015). Cognitive load impacts working memory in different ways for children than adults, due to children's still developing strategies for managing information in working memory (Cowan, 2016). Young children are still learning many of these strategies to keep material in mind. As they learn to sustain attention on the same topic, they learn some of these strategies to help keep a topic in mind (Camos & Barrouillet, 2011). However, without these strategies, high cognitive load does not interrupt children's tasks in quite the same way as adults. That is, children may not use effective strategies to keep the numbers and problem in mind to begin with.

Cognitive load has been measured in a variety of ways using cognitive tasks, as well as sometimes being measured physiologically, either with direct frontal lobe signal, or through physiological arousal (Antonenko et al., 2010; Solhjoo et al., 2019). Regardless of how cognitive load impacts completing a task, optimal cognitive load is of a middling level. That is, if an individual is at the upper limit of processing capacity, fatigue will set in, or if cognitive load is low, the individual will be capable of far more complex and higher-level work and may be bored (Borragán et al., 2017; Westgate & Wilson, 2018). When working under high cognitive load,

individuals may become fatigued. Older children are learning the stamina to maintain high cognitive load for longer periods of time, so the duration that children can work under high cognitive load changes by age. (Graziano et al., 2011; Levy, 1980). With the importance of cognitive load to academic tasks and differences in age, cognitive load plays an important role in how children work with and complete classroom activities.

Self-Regulation

Self-regulation is a varied and complex construct. Generally speaking, self-regulation is the ability to alter a prepotent response in favor of a more desirable behavior (Baumeister et al., 2007). Where cognitive load is a descriptor of the cognitive resources an individual uses to process a particular situation, self-regulation is more a descriptor of how the processing happens (Seufert, 2018). There are a several approaches to self-regulation research. Some approaches emphasize self-regulation as a domain general construct (e.g. Baumeister et al., 2018), where others propose that self-regulation conceptualized in this way is too broad and that self-regulation is perhaps better defined as only the ability to alter a response in the case when there is a conflict between multiple goals (Inzlicht et al., 2020). The latter approach is called for by those seeking to describe the misalignment between different types of self-regulation measures. Specifically, there is often a misalignment between self-report measures of self-regulation that often ask about altering of prepotent response in regard to daily activities, and behavioral measures of self-regulation, such as the Stroop or flanker tasks (Eisenberg et al., 2019; Saunders et al., 2018). By defining self-regulation more narrowly as pertaining to instances where there is a conflict of goals, self-report measures remain under self-regulation and behavioral measures, which often emphasize attentional inhibition, are seen more as a separate and distinct construct. For the purposes of this paper, I will briefly discuss how a boarder approach of self-regulation

relates to the current research, as this has been an important way of seeing this construct in educational research, but then focus more closely on inhibition, which is an area that is often covered in self-regulation research, but does not fit as clearly under a narrower definition of this construct.

Self-regulation relates to concentration in two primary ways. First, it is important for choosing an activity and second, it is important to maintaining attention to that activity. The first of these aligns with the broader definition of self-regulation, that self-regulation is primarily the alteration of a prepotent response. At the onset of an activity, children need to self-regulate by choosing a particular activity over other potentially interesting activities. The ability to self-regulate when making a choice can have many positive health benefits, the classic example being choosing when not to eat sugary foods, or to resist potentially appealing but harmful activities, such as smoking (Baumeister et al., 2007). Given this, it is unsurprising that self-regulation broadly construed has been related to many positive long-term outcomes. A classic study measured self-regulation in a cohort of 1037 children in a variety of ways from ages 3 to 11 years old (Moffitt et al., 2011). The researchers found a long-term decrease in physical and mental health, wealth, and criminality. As these results suggest, self-regulation between domains is highly correlated (Edossa et al., 2018). Using this general approach to self-regulation, self-regulatory ability is considered one of the most important aspects of school readiness (Blair & Raver, 2015). That is, children need to be able to self-regulate and make positive academic choices such as choosing to do homework, or choosing to attend to the lesson in class.

A second way self-regulation is important for concentration is for inhibiting attention to potential distractors during an activity, thus prolonging attention to the activity. In the classroom, attentional inhibition is central to remaining focused on an activity (Barkley, 1997). The ability

to inhibit responses to distractors develops considerably across the preschool years (McCabe et al., 2004; Wiebe & Sheffield, 2012); tasks of inhibition that children struggle with at the beginning of preschool are often completed near ceiling by the end of preschool (Müller & Kerns, 2015). By elementary school, children who perform better on inhibitory control measures respond more quickly to tasks that demand higher cognitive load, presumably because they are better able to self-regulate attention to the important aspects of the problem (Avgerinou & Tolmie, 2020). This evidence from elementary students supports the interconnectedness of cognitive load and inhibitory control, further supporting them both being part of concentration as described here.

Regardless of how self-regulation is defined, it is clearly an important skill and there is indication that self-regulation, and more specifically inhibition, can be learned. Children from lower socioeconomic backgrounds often show lower self-regulation, so ways to support teaching self-regulation may be one way to help support these children (Raver, 2012). Interventions designed to teach self-regulation are usually based on practice, with the expectation of transfer to other activities. There is indication that self-regulation in the form of inhibitory control taught to preschool children can be supported through intervention (McClelland et al., 2019). Adults very clearly show this improvement and transfer to other skills with practice (Beames et al., 2017). For example, college students who practice self-regulation through holding a hand-grip for extended periods of time, inhibiting the desire to put the handgrip down, later self-regulate on their homework more and correspondingly have better end of semester grades (Job et al., 2015).

Given the general importance of self-regulation and its consideration as being one of the most critical aspects of school readiness, having an environment that support learning self-regulation is critical in early childhood. An environment where children have considerable

independence allows for clear opportunities to practice self-regulation. Of course, with preschoolers, this freedom should be within limits, helping scaffold their learning. Regardless, having chances to practice self-regulation remains important and studying self-regulation in an environment that supports it can help capture part of this important learning process.

Flow: A Psychology Concept Similar to Concentration

One concept in the literature that has many similarities to concentration is flow. Like attention, there have been many definitions of flow, several of which include the term concentration. For example, one paper defines flow as "an episode of deep concentration" (Rathunde, 2015, p. 15) or another describes it as “a phase of intense concentration followed by a certain degree of joy” (Borderie & Michinov, 2016, p.23). Flow is similar to concentration in that it definitinally combines a variety of different, closely related constructs. Early in flow research, flow was defined broadly as “the holistic sensation present when we act with total involvement” (Csikszentmihalyi, 1975). More specificity is sometimes added, including that this happens when there is a balance of challenge and skill that is just right for a particular individual (Csikszentmihalyi, 1975, 2000). Others have added nine characteristics that occur in a state of flow: happy, cheerful, excited, alert, involved, active, success, satisfaction, and comfort (Csikszentmihalyi & Larson, 2014). However, many of these characteristics can also be viewed as outcomes and may not well describe a particular state. An additional issue is that some of the differences in definitions across studies change the types of activities in which an individual might reach flow. For example, some methods operationalize flow as any experience that is in the upper half of an individual’s repsonse on a flow quesitonnaire using the nine mentioned characteristics (e.g. Rathunde & Csikszentmihalyi, 2005). Or sometimes since attention and playfulness can facilitate total involvement, videogames have been used to create a state of high

attention with play to presumably experimentally create a state of flow (e.g. Engeser & Rheinberg, 2008; Keller et al., 2011). However, in both of these methods there are clear instances where an individual may not reach flow by other dfinitions, for example, not actually having the right balance of challenge and skill.

A full discussion of the benefits and limitation of flow as a research concept goes beyond the scope of this paper. However, flow research does provide two important imputuses for researching concentration. First, concentration is a state similar to flow, but as presented here is more narrowly defined. There have been many positive outcomes associated with flow, namely subjective wellbeing (Csikszentmihalyi, 2000; Richards & Huppert, 2011). The present research helps set up future research looking at outcomes implied by flow research, but does so by looking at a more narrowly defined state rather than the outcomes. Second, there has been very little research on flow with young children. This is likely because flow is largely defined as an experience that is subjective, and young children are still learning how to reflect, so flow is difficult to measure with children (see Addessi et al., 2006; Custodero, 1998 for examples of how some researchers have tried to use observational metrics of flow with young children). Research on flow-related ideas is still important with young children, particularly given the importance of development for long-term subjective wellbeing. Concentration may be a good way of addressing some of the limitations of flow research and doing so in a way that is conducive to working with younger children.

Returning to Concentration

To return to the definition of concentration, concentration is a state of being actively cognitively absorbed that requires attending to a particular thing to the exclusion of others and lasts for prolonged periods of time. Being cognitively absorbed comes with an alignment of

multiple aspects of an activity, for example a clear alignment of thoughts and actions. Depth and duration are two key characteristics of high concentration that may change as children learn to concentrate as they get older. For example, an individual who is highly concentrated on writing a story may be thinking about nothing but the story indicating deep concentration and may be writing for several hours at once indicating prolonged concentration. The act of concentrating requires, at a minimum, the cognitive processes described earlier. Depth of concentration is related to the extent an individual is selectively attending and correspondingly inhibiting responses to distractors, as well as the amount of cognitive resources used during a period of concentration. Duration of concentration is related to sustained attention.

Selective attention and cognitive load are central to depth of concentration and are facilitated by self-regulation. A state of concentration is centered on a single activity, needing an individual to selectively attend to that activity to the exclusion of others, which requires both the focusing of cognitive resources, causing a higher cognitive load and often requiring self-regulation to inhibit attention to distractors. It is worth noting that when an individual is deeply concentrated, attention to distractors may be low due to cognitive load being high rather than due to self-regulation (Baumeister & Vohs, 2007). For example, an individual writing may be thinking about nothing else but the story being written and how to communicate it, ignoring incoming emails or a bird singing outside due to being absorbed in the process rather than actively inhibiting attention to these distractors. Regardless of whether the inhibition of attention to distractors comes from high cognitive load or self-regulation, or more realistically a combination of both, the resulting behavior is similar and indicates deep concentration.

Depth is one characteristic of concentration, the second is duration. Duration of concentration is aligned with the ability to sustain attention on an activity. Like sustained

attention, duration of concentration indicates an individual is exhibiting some amount of concentration for a prolonged period of time. This requires many of the same skills and abilities as reaching deep concentration, just over time, so selectively attending only to a single activity and self-regulating attention to inhibit attending to distractors again are central. For example, the individual writing a story may have a moment of great insight, but ignoring a momentary distraction to note down the insight and continue writing is also an important characteristic of high concentration.

Learning to sustain attention, selectively attend, maintain high cognitive load, and self-regulate all happen through activity and in context as children develop. Most psychology research investigates these concepts in laboratory settings. Sustained attention and selective attention in particular are usually measured in laboratory contexts where extreme detail in regard to response accuracy and response time can be measured. Although measuring these characteristics in a particular laboratory task provides helpful insight and detail, attention in a classroom happens in a complex context. In classrooms, multiple aspects contribute to a child's interaction with material and the concept of concentration helps better capture this complexity. Investigation of how concentration changes across age in context can provide descriptive detail informative for understanding how children directly interact with activities in classrooms rather than assuming transfer of skills from laboratory tasks to classroom activities.

Implications for Researching Concentration

There are benefits to studying concentration as a combined construct, rather than studying the individual components of concentration. Accounting for multiple aspects of attention has benefits over simpler models when describing the complexities of the learning that happens in classroom settings (Fenesi et al., 2015). Importantly, combining the several related

ideas as described above better reflects a singular process that happens naturally in classrooms during learning. By combining these concepts, the implications of this process are more accurately reflected by the combined construct rather than any specific component. Learning is multifaceted, and has been acknowledge to be such for some time (e.g. Carroll, 1963). At a basic level, there are many things that are intuitively important to learning that research has robustly supported. As already described, two key examples are time attending to learning and depth of attention, corresponding loosely to sustained and selective attention. Combining these ideas into the concept of concentration to align with the colloquial use of the term importantly creates a concept that better captures the multiple cognitive process associated with attention as is relevant to complex and real-world learning. Since real-world learning is so complex, outcomes attributed to attention may indeed be strongly impacted by other factors related to and important to concentration. Using the framing of concentration better captures this real-world process. Combining related components of attention is not a new idea; others have used terms like just general attention or selective sustained attention to mean similar things (A. Fisher et al., 2013). However, concentration as described here is explicitly intended to be applicable and used to describe real-world settings.

Additionally, I bring in a component of self-regulation, which is less common in combined constructs of attention. As outlined above, self-regulation is brought in both as an important component to achieving the types of attention necessary for learning, but also to begin to address the idea that this process is one that happens not just in the moment, but over time. An emphasis on concentration rather than attention integrates the development of this additional important skill into the discussion of the way children are cognitively processing their work. Development of concentration and each of its components through the preschool years is

complex. The well-studied improvement in self-regulation during preschool further emphasizes the important development that may happen in regard to concentration as well. Additionally, the long-term benefits of effective development of self-regulation are far-reaching, impacting outcomes such as mental health, physical health, economic stability, and criminality (Moffitt et al., 2011). Learning to self-regulate to reach deep and prolonged concentration may help both reaching high concentration during future learning, as well as help learn self-regulatory skills that can transfer to other positive outcomes.

Consideration of depth and duration of concentration is important beyond any of the specific components of concentration individually. A clear example of this is in regard to self-regulation. An individual who is highly interested in an activity may need to spend less effort self-regulating to a task because interest in the task pulls attention back to the task if the individual becomes distracted (Lee et al., 2014; Sansone & Thoman, 2005). For example, an individual who is interested in a math problem may continually think about the problem, perhaps thinking about the problem during meal times. In this way, when activities are self-chosen, the effort put into self-regulating may be decreased. However, although the effort may be decreased by interest (Sansone & Thoman, 2005), concentration still remains high. In this example, concentration is certainly prolonged as the math problem is thought about more and there are likely moments of deep concentration from high cognitive load as the child tries to puzzle through an answer, even if self-regulation may be low. One study investigated a situation similar to this, where 10th grade students who were given a growth mindset intervention had higher cognitive load during learning, which in turn helped them learn the material better than their peers who did not receive the intervention (Xu et al., 2021). As the example and this study indicate, considering a specific aspect of concentration, such as just self-regulation, is limiting in

regard to how attention occurs in classroom settings and thus there is positive value to considering concentration as a more global construct.

The benefit of concentration also comes from it being particularly aligned with characteristics already considered important in school settings. Most modern education systems place emphasis on learning cognitive skills, and emphasize the cognitive components of learning over components such as emotional investment (Hirsh-Pasek, 2020; Robinson, 2001). Concentration aligns with this perspective, combining important components of the cognition involved in learning. As an additional benefit, the more general nature of concentration than simply attention does a better job of aligning with motivational theories as well. For example, reaching a state of high concentration implies that an individual is interested in the activity as self-regulation of attention is facilitated by interest (Lee et al., 2014).

Finally, by allowing concentration to be a broader construct than just attention, it is easier to identify observable characteristics to use in measurement in naturalistic settings. Many classic measures of the components of attention assume particular types of cognitive processing are happening. For example, using gaze in infants as a measure of attention assumes the infant is cognitively engaged with what they are looking at, or response time in adults roughly indicates how much they are distracted by non-task related thoughts (Driver, 2001; Graziano et al., 2011). In a classroom, capturing just one component like this would lose important moments in which cognitive processing is happening in vivo, and thus when a child may be indicating some concentration. For instance, time spent continuing to work with a material in a classroom does indicate a level of self-regulation to remain with the material. Similarly, if a distraction occurs nearby and the child remains with their work, this indicates concentration. Both of these indicators would support that a child is cognitively processing some aspect of their work, and

children of different ages may have different likelihoods of either observable characteristic. However, in a naturalistic setting it is unlikely that either of these specific characteristics are happening continuously, so by keeping concentration as a broader construct, both indicators, among others, can be used as indicators of concentration to capture this cognitive process. The specifics of measuring concentration will be discussed in the Methods section.

Montessori as a Case Study

Montessori pedagogy, founded by Dr. Maria Montessori, places particular emphasis on concentration. Montessori schools are well established globally, and are becoming more common in the public sector. Despite this, Montessori is a little studied educational system (Bagby & Renbarger, 2018a, 2018b). The term concentration itself is specifically used in Montessori writing (Montessori, 1918). One conceptualization of concentration in this writing is using graphs with axes indicating depth and duration of concentration, paralleled in the conceptualization of concentration here (Montessori, 1918). However, the method used to create these graphs is ambiguous within Dr. Montessori's writing and is not well documented. Central to Montessori pedagogy is the idea that the practice of self-regulating to reach concentration during independent work helps children learn the skills necessary for future learning and interacting empathetically with others (Montessori, 1918). With this central idea, Montessori education is characterized by periods of free choice where children have considerable freedom to choose what activities they do in order to support children learning to consistently reach high concentration as they progress through the preschool years. In this environment, Montessori teachers use concentration as an indicator that the work children do independently is supporting their learning. Since a goal of concentration in Montessori is to help children learn skills such as self-regulation, giving children free choice to do whatever activity they choose provides ample

opportunity to practice self-regulation and choose to concentrate. The considerable free choice present in Montessori classrooms makes these very unique educational environments. This specific environment both means that Montessori teachers often feel educational research in other contexts does not transfer well to their classrooms, creating particular demand for Montessori specific research. Given this context, there is a growing audience of practitioners interested in research that includes Montessori schools. The unique context also makes this an interesting environment for research, both as a unique pedagogy, and by providing an environment particularly conducive to observational methods.

The present study provides information beneficial to both teachers and researchers regarding children's demonstrated concentration. For teachers, this study will help by providing assessments of children's demonstrated concentration both descriptively and associatively. This helps provide information for Montessori teachers to compare their own experience to. Understanding differences in concentration across the different ages of preschoolers can also help inform expectations for children's ability to reach high concentration. For example, young children may demonstrate concentration through prolonged attention more than older children. With this knowledge, when looking for indicators of children's interest a teacher should look for different indictors for young children than older ones, but what these indicators are or how children demonstrate them is not yet known. Regardless, concentration is a critical part of implementing this pedagogy and any clearer research on young children's demonstrated concentration will help teachers compare their own observations to what others see.

For researchers, the descriptive nature of this study also provides interesting information as a foundation for future research. On a basic level, this is an observational study in preschools, and most research using observational measures of depth of concentration in classrooms has

been done in elementary schools, not preschools (e.g. Lauth et al., 2006). More specifically, this work forms a base to help future research looking at what specific activities best support children to actively concentrate in two ways. First, the descriptive nature of this study provides an initial estimate of children's demonstrated concentration on various categories of activities and how characteristics of concentration may differ by age. Second, by also associating several measures, this research better establishes how various measures of concentration and its subcomponents are related and thus gives a better understanding of how strong the observational measure of concentration I have been establishing is, or whether it needs additional work to reflect what is happening in classrooms (I. Becker & Lillard, 2021). Although the present study is not designed to measure long-term outcomes of concentration, it will provide a foundation for this work to take place in the future. Some research comparing Montessori to other pedagogical frameworks has found positive outcomes for children both academically, as well as being one of the environments that is most successful at supporting the development of children's executive functions, which includes self-regulation (Culclasure et al., 2018; Diamond & Lee, 2011; Lillard et al., 2017). These studies support that a pedagogical focus on concentration is beneficial, but investigation of children's demonstrated concentration in these studies was limited and it has not been shown if children were indeed concentrating in these environments. Continued research on children's demonstrated concentration will help create a stronger research base to support children's learning.

Present Study

My dissertation study is a descriptive and associative investigation of the concentration that children demonstrate during independent worktime in Montessori preschool classrooms. The primary question this study seeks to answer is: What is the depth and duration of preschool

children's demonstrated concentration during freely chosen activities in Montessori classrooms? In investigating concentration as it occurs in classrooms, I specifically look at depth and duration of concentration and how they may differ by age. Depth of concentration is related to the extent children are selectively attending and correspondingly inhibiting responses to distractors, as well as the amount of cognitive resources they use during a period of concentration. Duration of concentration is related to sustained attention. I assess depth of concentration in classrooms with a scale that I recently developed for that purpose (I. Becker & Lillard, 2021). Duration of concentration is measured using observed time on-task in classrooms.

A secondary purpose of this study is to provide initial validation for a new version of my concentration scale, by associating its use in classrooms with out of classroom measures of selective attention, inhibition, and cognitive load. The limitation of using out of classroom measures for understanding concentration is that they are not directly parts of concentration during independent classroom activity, instead capturing them during an adult-directed activity. However, since these are established measures that have been used in the past, they are important to use for validation and associative purposes, giving insight on how these established measures are associated with concentration in classrooms. Positive correlations between the new scale and the measures used to capture the components of concentration described here provide primary supportive evidence for the new scale. If these measures do not correlate with the new scale, both time on-task and teacher and parent measures provide additional information about concentration in contexts where children have independence. These help indicate whether the scale is invalid or whether differences seen may be due more to the independent versus adult directed context.

An important question is whether concentration is an observable state, or whether components of concentration that are more subjective, that is self-regulation and cognitive load,

make concentration too subjective an experience to capture observationally. Other studies have not studied concentration as described above. However, a few studies have compared observational measures and subjective measures of flow, which has similarities to concentration and is also a very subjective experience. There is conflicting evidence on whether flow can indeed be observed. One study found support that flow rated observationally is similar to subjective experience (Tordet et al., 2021). To measure flow in this study, researchers used the three terms: concentration (primarily meant to mean attention here), engagement, and frustration. They had both participants and observers rate these three items after adults played a videogame. They found a close relation between participants' own ratings and those of observers. This work was similar to an earlier study done with four adult participants that found comparable results (Borderie & Michinov, 2016).

A very small number of studies have tried to observe flow in children as well (Addessi et al., 2006, 2012; Custodero, 1998, 2005). However, these studies do not also measure subjective experience. One study that did attempt to capture children's experience both observationally and subjectively was done with 5th grade students and used the concept of attention, rather than flow (Peterson et al., 1984). Attending was measured in three ways: observation, student report, and student report of their cognitive processes. Results indicated that student report using both metrics of attention was more highly correlated to outcomes than other measures. In the framework presented above, this indicates the importance of not just attending, but also of higher cognitive processing that causes higher cognitive load. Correlations between observed attention and student self-report were not strong, but could have been conflated by cognitive load. This collection of findings suggests that concentration has potential to be measured observationally,

as concepts similar to it show strong correlations between observed ratings and subjective ratings.

In addition to there being some evidence that concentration can be observed, the context of the present study specifically supports the use of observational methods. Importantly, this study was completed with younger children in an environment where they have free choice. In an environment where children have free choice, there is not an expectation for interaction with any specific activity. This means that when children choose to do a particular activity, they are clearly demonstrating self-regulation to that specific activity. The academic activities that preschool children do also often require manual manipulation as well as being cognitively demanding, such as using manipulatives for math problems rather than calculating using mental math. The clear use of physical materials makes observing what children are doing clearer. For example, it is clear if a child is drawing purposefully and intentionally, creating specific shapes and images rather than unintentionally scribbling. This intention indicates use of cognitive resources. It is often possible to also see to some extent how purposeful a child is being; if they are very intentionally copying from a model this demonstrates more careful intention and use of cognitive resources than drawing more rapid and haphazard shapes, which in turn shows more than just unintentional scribbles. It may still be difficult to assess the full extent of cognitive load for any particular child, and some activities may be more difficult to analyze intention for, but indications of using cognitive resources in many activities common in preschool classrooms are observable. Observations in this manner do provide an important sense of depth of concentration. Thus, the specific population in the present study mitigated some of the limitations of observing concentration. Even though limitations remain, observational methods are best. Young children do not have the self-reflective capabilities yet to be able to accurately describe their mental

states, so inferences need to be made based on observed behavior (Flavell et al., 2000). Further, observation is the way in which teachers assess depth of concentration and the quality of student interaction with materials. Given that this method is aligned with pedagogical implementation, this method of research is meaningful even in cases where it does not fully capture depth of concentration.

The present study was done in Montessori classrooms. The specific structure of Montessori provides an environment that allows for clear observations of concentration; children typically have 2-3 hr of independent work time and are thus less likely to be interrupted in their work by adults or by specific classroom schedules (Montessori, 1918; A. K. Murray et al., 2019). Extended independent work time creates an environment where children need to self-regulate attention and have ample opportunities to sustain their attention to reach high concentration. Montessori classrooms are thus both physically and socially supportive of concentration. In addition, the fact that children operate fairly independently makes it clearer that when children have chosen to take a particular activity off of the shelf, they are self-regulating their attention to that activity.

Observing in a classroom also allowed for observations to capture what children do during a typical school day, compared to children in a laboratory setting, where they are likely less comfortable and could adjust their behaviors based on the new space and the specific material available. Additionally, classrooms are filled with materials designed to be interesting to this age group, facilitating children's choice to self-regulate attention on a particular activity. The complete collection of activities in a classroom is more than could be reasonably presented in a laboratory space.

Methods

Participants

Seven Montessori schools were invited to participate in the study. One school with two preschool classrooms agreed to participate; the remaining schools were hesitant to have researchers come into classrooms, or it was against their policies due to the COVID-19 pandemic that was ongoing during data collection. Participants were 24 children (M = 4.51 years, SD = 0.69 years, range = 3-6 years, 13 female, 11 male); there were 13 students in one classroom and 11 in the other. As identified by their parents, two children were of Hispanic or Latinx ethnicity (one identified as white Hispanic), and by race, four were black, one was mixed race, and 17 were white. Children were primarily from higher socioeconomic status, and their primary caregivers were highly educated: four had a 2-year degree or equivalent, six had a 4-year degree or equivalent, eight had a Master's or equivalent, and six had a Doctorate or equivalent. Secondary caregivers had a similar spread of educational attainment with two having some college or vocational training, two with 2-year degrees, 7 with a 4-year degree, 8 with a Master's, and 5 with a Doctorate. Income was fairly high with six families making less than $99,999, eight making between $100,000-149,999, and 10 making over $150,000. In one of the classrooms, the teacher changed partway through the year. In this classroom, one observation was done with the original teacher, and the other with the new teacher.

A full power analysis was difficult because very little research has examined children's demonstrated concentration in classroom settings, and that which has been done tends to be qualitative (e.g. O'Shaughnessy, 2016). Some research has looked at time on-task in Montessori settings, but results are descriptive (I. Becker et al., 2020; Hojnoski et al., 2008; Lillard, 2012).

Consequently, power was estimated by completing two power analyses looking at related questions, described below.

The first power analysis was based on Brocki and colleagues (2007) who compared children with and without ADHD symptoms, using both the statue task and go/no-go tasks at two different time points. Based on the two time points, to see group differences with 80% power and an alpha of .05 for the statue task would require 25 or 36 children and for the go/no-go task would require 57 or 48 children. The second power analysis was based on results from Winsler and Carlton (2003), who observed children's time on-task in both a classroom of 3-year-olds and a classroom of 4-year-olds. They observed each child every minute for 10 min. Each minute of observation was used as a unique data point in analysis. This form of analysis is not the most accurate representation of this data, as it does not properly account for lack of independence between observations done with the same child, instead simply using every minute as a unique observation. However, completing a power analysis under the same methods and assumptions, I would need 429 min (7.15 hr) of observation to see differences based on age.

These analyses provide some context with which to view the present sample size and observation time. We observed fewer students than our power analyses suggested, but observed them for more time than analyses suggested was needed.

Participating Classrooms

The school in this study was a private, Montessori school, accredited by the Association Montessori Internationale (AMI). Meeting requirements for this accreditation includes teachers being AMI trained, class sizes of 24-35 children, a full set of Montessori materials for the age level, and at least 2.5 hr of uninterrupted work time in the morning and in the afternoon (*Standards for AMI Montessori Classrooms*, 2022).

Classroom routines were slightly altered by COVID-19 regulations. Everyone wore masks throughout the year and classroom spaces were designed to encourage children to work further apart from each other than typical, such as spacing out work tables. During the 2020-2021 school year, the school had operated on a reduced schedule, but during data collection in the 2021-2022 school year had returned to a more typical schedule, with some accommodations. As children entered the room in the morning, they were greeted by a teacher, most commonly the teaching assistant, who would take their temperature and ask about their health as part of COVID-19 protocols. Children then put their outdoor gear away before fully entering the classroom (which is when observations began). Children typically arrived between 8:15-8:45. The morning ended with circle time that involved a full group activity (observations ended at the call for circle time). The activities included in circle time varied by day, but often included singing, show and tell, or sometimes a birthday celebration. The call for circle time was typically between 10:45-11:15.

The two participating classrooms had distinct classroom cultures. One classroom was well established, with a teacher who had been at the school for over 5 years and had decades of additional teaching experience. She had an established and practiced routine. The assistant in this classroom was new to the classroom and he was taking teacher training during the time of this study. Choices on instruction were made by the lead teacher, with the assistant playing a critical role in maintaining a clean environment for learning to occur. This classroom was a large, well-lit space. The normative expectation for children appeared to be primarily that they were either calmly working on an activity or were waiting, wandering the room, or choosing an activity individually. This classroom had slightly more older children (ages of children not participating in this study were not collected, but teachers commented on the age differences between the two

classrooms), many of whom were interested in talking with their friends without doing any particular activity; when this occurred, the teacher or assistant would encourage children to choose an activity to do.

The other classroom's teacher was new to the school, but she had 5 years of prior experience teaching Montessori. This teacher left partway through the school year, so the second observation was done with a different teacher. The replacement teacher was one of the office administrators, she had 2 years of prior Montessori teaching experience, and she was already an established member of the school community. The main assistant was also an established member of the community and she had been with the school for over 5 years. The physical space of this classroom was considerably smaller, despite having more students and the average age of children was younger. This classroom did not have as established a routine and had more frequent behavior problems, in part due to the smaller space and younger children who were still learning the classroom norms. To help manage misbehavior, additional assistants were often asked to join the room to keep a calm environment. Assistants were typically substitute teachers that the school commonly worked with, or school administrators. The less established routine meant that, particularly during earlier observations, teachers often spent less prolonged time working one-on-one with children, giving lessons quickly to allow time to maintain a calm environment. Teachers were also less likely to spend time prompting children who were quiet and not disruptive to choose an activity to engage with. The differences in classrooms did not detract from collecting data for our research questions about the concentration children demonstrated. However, given these differences, the classroom children were in was controlled for in all regressions.

Measures

Teacher and Parent Measures

Demographic Questionnaire. Demographic questions included date of birth, race and ethnicity, gender, parent education, and income; see Appendix A for the specific demographic questions.

Strengths and Difficulties Questionnaire (SDQ). The SDQ was completed by both teachers and parents for each student. This questionnaire is an established measure that has been normed across many populations. It captures a global perspective of children's behavior based on judgement by familiar adults. This measure does not capture behavior on any specific activity, but instead captures children's aptitude to behave in particular ways. The SDQ contains subscales for emotional symptoms (e.g., "Many worries or often seems worried"), conduct problems (e.g., "Often argumentative with adults"), inattention/hyperactivity (e.g., "Easily distracted, concentration wanders."), peer relationship problems (e.g., "Generally liked by other children" [reverse scored]), and prosocial behavior (e.g., " Helpful if someone is hurt, upset, or feeling ill"). It has good internal consistency, cross informant correlation, test-retest reliability, and has been externally validated comparing to other established measures (Goodman, 2001; Goodman & Scott, 1999). The inattention/hyperactivity subscale in particular captures information relevant to concentration, not capturing concentration specifically, but rather children's aptitude to concentrate. This subscale has been noted in regard to having especially strong criterion validity (Goodman & Scott, 1999).

Influences on children's attention often differ based on whether activities are done independently or are adult-directed. To better parallel the behavioral measures used and gain a better understanding of children's attention difficulties during particular activities, teachers and

parents completed the inattention/hyperactivity subscale twice, once with the directions, "Please respond to the following questions for when your child is doing a self-chosen activity on their own, such as taking a book off the shelf and looking through it;" the second time with the directions, "Please respond to the following questions for when your child is doing a short, organized activity directed by an adult, such as doing actions in a lesson or following directions on a craft project."

Classroom Measures

Time On-Task. Time on-task is usually measured observationally, and thus whether the student is on-task or not is partially a subjective opinion by the observer. Common measures of time on-task are impacted by laboratory research on selective attention. For example, gaze direction and looking time have been used as measures of selective attention and both have been used as indicators of time on-task. However, for many individuals, gaze does not provide a complete picture of time on-task. It is common for people to avert their gaze from faces and other visually complex objects when thinking. Although this happens as young as preschool, it is not a common behavior for young children (Doherty-Sneddon et al., 2002). Thus, the common use of gaze is a good indicator of task engagement for preschool children, though perhaps not for older individuals. In addition to gaze, other behaviors of attention on a task may also be used, such as taking notes or working with materials for an activity (e.g. Downer et al., 2010; Winsler & Carlton, 2003). These other factors can be a challenge to account for in classroom settings, as sometimes off-task behavior such as doodling or fidgeting, though clearly making attention to the lesson less selective, can actually be beneficial for learning in adults (Andrade, 2010). However, this finding does not hold when participants are asked to recall information presented visually instead (Chan, 2012). Further, given the preschool population of the present study, it is

far less likely that children have the capacity to self-regulate attention to a separate activity while fidgeting or doodling. Indeed, preschool children who use a fidget spinner show worse attention to other tasks (Graziano et al., 2020). Thus, although the limitations of observational measures due to their subjective nature remain when working with preschool populations, these limitations are of less concern with preschoolers than with older students.

Given the applicability of gaze direction as an indicator of attention for preschool populations, time on-task was measured using judgements of physical orientation and gaze. For each minute a child was observed, two pieces of information were noted: what material the child was working with, if any, and what type of activity the child was doing. First, the type of activity that the child completed each minute was noted. Active work included doing work as an individual or with peers, getting a lesson as an individual or with peers, and observing. Other codes included wandering the room, and an "other" category, which included activities such as going to the bathroom or horsing around that happened infrequently. Second, the material the child chose was noted. Montessori classrooms are typically organized into specific subject areas. The five most commonly used areas are: practical life, sensorial, language, math, and culture (*Montessori Early Childhood Programs*, 2022). For analyses, the subject area of children's activities was determined. Some instructors place Montessori activities under subject areas that do not fit as well with traditional views of academic subjects. For example, many Montessori instructors place painting under practical life, with the idea that the set up and clean-up of this work fit many practical life skills and that producing art is more a skill learning routine at this young age than producing a cultural product. Additional codes were thus added for more traditional academic areas as well. These additional codes were art, grace and courtesy, music, geography, and biology.Ratings of time on task for each minute allowed for calculation of both

total proportion of time on-task, as well as how long children continuously engaged with the same material.

Concentration Scale. The recently developed concentration scale was used to assess concentration observationally (I. Becker & Lillard, 2021). The scale was used for each minute children had an activity out during classroom observations and also during the time when children were participating in the behavioral tasks. On this scale, raters give children a score of 1-5 on each of five items: chaotic (lack of order and control; reverse coded), intentional actions, careful and slow actions, distracted by surroundings (reverse coded), and concentration; see Table 1 for relations with the components of concentration and Appendix B for more detail on specific items.

The two raters for this study had been involved in the creation of the scale, and had used earlier versions of the scale extensively with videos of preschool children in a variety of settings including free-play activities and during behavioral tasks. Before collecting data for this study, raters were trained again on the scale using similar videos; they practiced coding using the current version of the scale until they reached a kappa squared agreement of over .90 over 5 min of coding. To minimize drift in raters' scoring, raters repeated this training process with different videos after the first of two observations. All videos used for training were of situations comparable to those observed for the study.

Since observations were done in classrooms, having multiple observers in the same classroom would have been a burden on schools. Thus, to assess reliability between observers, reliability checks were completed at six timepoints throughout data collection: before data collection began, during the midway point of the first observation, after the first observation (after which winter break occurred), before the second observation, the midway point of the

second observation, and after data collection was completed. Kappa squared averaged across the six time points was .90. Internal reliability was also good, with a Cronbach's alpha = .84.

Table 1

Relations Between Scale Items and the Components of Concentration

Scale Item	Components of Concentration
Chaotic (lack of order and control)	Continuing to do a task purposefully instead of switching quickly between different tasks or different components of a task is thought to indicate *selective attention* to the task and *self-regulation* to keep attention on the same task.
Intentional Actions	The intention and extent to which a child's actions are goal-directed is believed to indicate thought put into the actions and *appropriate cognitive load*.
Careful and Slow Actions	To complete a task with care and precision is taken to indicate that children are deeply thinking about the task and have *appropriate cognitive load.* Slowing actions down to do the task well is hypothesized to also require *self-regulation* of motor movements.
Distracted by Surroundings	The extent to which a child is or is not distracted by surroundings captures *self-regulation* of attention to *selectively attend*.
Concentration	As a global measure of concentration, this scale item combines *all four components* of concentration.

Note. Sustained attention is minimally mentioned in these items. This scale is intended to capture depth of concentration. Sustained attention is primarily captured through continued use of the scale and assessing duration of the concentration children demonstrate over time.

Out of Classroom Measures

To gain an initial estimate of validation of the concentration scale, the components of concentration were also assessed using standard measures outside of classrooms. Children were taken out of class and given these assessments in a different room in the preschool.

Statue Task. The statue task from the Developmental Neuropsychological Assessment (NEPSY) is a measure of self-regulation, specifically inhibitory control (Korkman et al., 1998). Children held a designated pose (standing as if holding a flag) for 75 s, as if they were a statue. During this time, the experimenter made noises as potential distractions at four specified time points. Children were coded for the degree to which they inhibited motor movement during this time. For each 15 s interval, children scored a 2 if they fully inhibited movement and response to the distractors, a 1 if they moved once, and a 0 if they moved two or more times; scores were summed across the 10 intervals, so total scores could range from 0-20. As a subtest of the NEPSY, this task has been well validated; it also has good variability for preschool age children.

The NEPSY has just one trial of the statue task. However, both the concentration scale and HRV measurements benefit from children engaging with an activity for slightly longer time periods, so an additional trial was added (having children stand like a star), resulting in two 75 s statue poses; see Appendix C. Scores were coded by two raters and disagreements were discussed and resolved to reach a final score.

Go/No-go. To measure selective and sustained attention, children were given a version of the go/no-go task used in Berlin and Bohlin (2002), this task has been used in several studies with preschool children (see Pauli-Pott & K. Becker, 2011). Children were shown a series of blue and red triangles and squares in two blocks. They were first asked to press a button when a blue shape appeared, then when squares appeared. Stimuli are presented for 800 ms, and children

are given 1700 ms to respond. There are 1700 ms between trials, and 60 trials total. The go rate was 70%. Percent correct trials were used for analyses. Adults' performance on go/no-go tasks is typically assessed using response times on correct trials, measuring the extent to which participants attend closely enough to the task to press the button quickly on go trials. However, given children's less mature fine motor skills, it is common to use percent correct trials rather than response times (Davidson et al., 2006).

Heart Rate Variability (HRV). Cognitive load was measured during the statue and go/no-go tasks using HRV, which is one way to measure the physiological response that occurs during high cognitive load and has been effectively used with preschool children (Calkins & Keane, 2004; Holzman & Bridgett, 2017; Thayer et al., 2009). HRV was collected using a sampling rate of 500 Hz using the AIM 2 system by Cognionics and assessed using Kubios HRV, which uses a Fast Fourier transformation for calculation of HRV (Tarvainen et al., 2021). For analyses, the coefficient of variation of the standard deviation of inter-beat intervals (cvSDNN) was used. The coefficient of variation is a suggested correction factor of SDNN to account for respiration (de Geus et al., 2019). Consistent with research on HRV being impacted by high cognitive load, change in HRV was calculated between baseline and the statue task and go/no-go task.

Two files needed to be discarded due to irregularities in the data and three children did not assent to using the HRV equipment, resulting in a total sample of 19 children with HRV data. For the statue task, one additional child's HRV data was removed as an outlier to allow for a normal distribution. Including this student's data did not change conclusions.

Procedure

Once school administrators and teachers agreed to participate, parents of all children in each classroom were asked for consent to have their child participate and were given the

demographic questionnaire and SDQ. Teachers were given the SDQ for each child partway through completion of the first observations. This allowed teachers time to get to know children who were newer to the class.

Two researchers worked with each classroom to help limit in person contact due to the ongoing COVID-19 pandemic. One researcher worked with children for the out of classroom measures, and one completed the observations. For the behavioral tasks, children were taken out of class individually by a researcher. The entire testing session was video recorded. During testing, the researcher first talked with the child to help build rapport and ask if the child was willing to play some games. After the child gave assent, the researcher described that during the games, the child would wear a small backpack and a few stickers with wires on them; they then had the child help put on the HRV sensors. The first activity was a 5 min clip from a video designed to hold children's attention for capturing baseline in fMRI scanners, and thus seemed suitable to establish baseline HRV in the present study (Vanderwal et al., 2015). Next, the researcher gave the statue task verbally, and finally the go/no-go task using a laptop. The researcher helped the child remove the HRV sensors and had the child help sanitize the space before returning to class. Concentration was coded later using the video recordings of this session.

For classroom observations, children were observed for the entire morning, from when they finished putting their outdoor gear away and entered the classroom to when they joined circle time at the end of the morning, which both classrooms had as an end of morning routine. Observations typically lasted 2-3 hr. Each child was observed during two different mornings to get a more comprehensive understanding of children's typical classroom behavior. Time between observations was on average 3.06 months apart (SD = 0.77, range = 1.20-4.56).

Analysis Plan

Analyses were done in three main sections: results from the concentration scale in classrooms, initial validity test on the concentration scale, and exploratory analyses regarding the relation between concentration and wellbeing. Here, I describe the pre-planned analyses for each section.

The primary purpose of this study is to investigate depth and duration of concentration in classrooms. For duration of concentration, proportion of time spent on each type of activity was analyzed, as well as how long children engaged with each activity. For both of these, differences by age were investigated. For depth of concentration, the five scale items were put into a regression predicting age of children to look at differences by age. Mean ratings on each of the items were also correlated to duration of concentration. An additional section was added post-hoc regarding variation in concentration from minute to minute.

A secondary goal of this study is to provide an initial estimate of validation of the concentration scale. For these analyses, all items from the concentration scale ratings were combined and correlated to each of the out of classroom measures and teacher and parent scores on both of the inattention/hyperactivity measures modified from the SDQ.

Finally, Montessori theory and flow research, suggest two outcomes of high concentration are learning and positive wellbeing (Csikszentmihalyi, 1991; Montessori, 1918). Although the primary purpose of this study was not to measure outcomes, within the measures already being used are two that are related to wellbeing: teacher and parent ratings on the SDQ, and baseline ratings of HRV. The SDQ is often used as an estimate of children's wellbeing (Vostanis, 2006). Baseline ratings of HRV are not as directly a measure of wellbeing as SDQ ratings, however there is evidence showing that change in baseline HRV ratings are an indicator

of wellbeing (Patron et al., 2020). Scores of depth and duration of concentration combined across the two observation days were used to predict a sum total of teacher and parent SDQ ratings as well as baseline HRV.

Many of the analyses run investigating differences by age were regressions. All regressions control for classroom. In reporting regressions, betas for the specific variables of interest are reported, as well as partial R^2 and t indicating the significance of each variable of interest. R^2 will be calculated using standardized generalized variance using the r2beta function from the r2glmm package in R (Jaeger, 2017).

Results

Concentration in Classrooms

Concentration will be investigated in three main ways. First, duration of concentration will be analyzed using analyses of the proportion of time children spend on different types of activities across the morning, as well as length of time spent on each activity. Second, depth of concentration will be analyzed using averages of each of the five different scale items both across the morning and looking at particular activities of interest. Third, during observations observers noted that scores on the concentration scale needed to be changed from minute to minute more for some children than they did for other children, reflecting variation in their levels of concentration. These differences between children appeared noteworthy enough to analyze. Analyses of change will be investigated, looking at number of changes in concentration scale ratings and magnitude of these changes. Differences across age will analyzed for each of these different aspects of the observations of concentration, controlling for classroom.

It should be noted that many of the summary variables used in analyses throughout this sub-section on concentration in classrooms were not pre-planned and ideas for these statistics

were generated throughout observations and analysis. Pre-planned analyses will be noted where relevant.

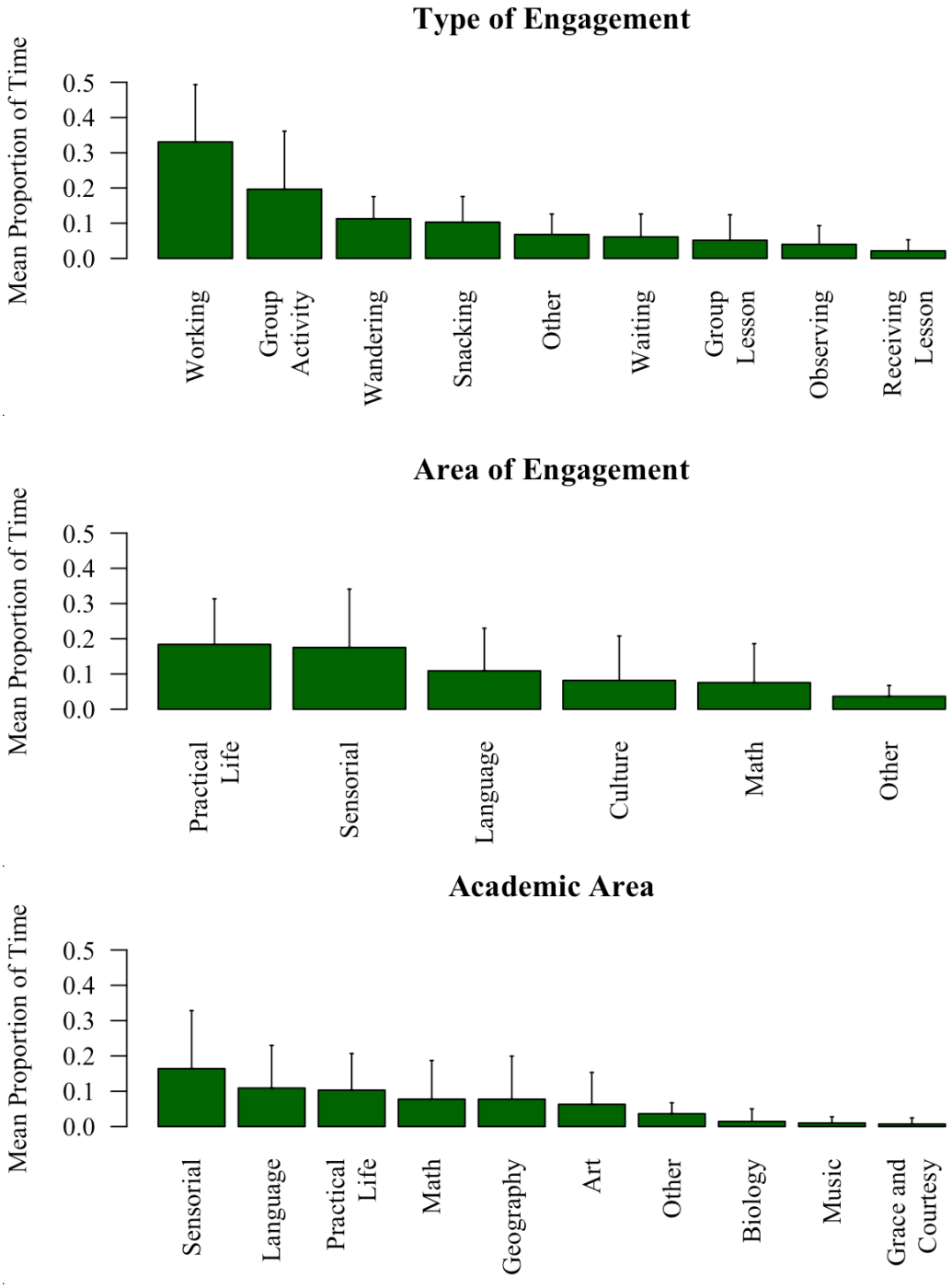
Duration of Concentration

First, duration of concentration was investigated, beginning with simple proportions of time spent on different types of work and then looking more specifically at length of time spent on each work. See Figure 1 for the proportion of time that children spent on each activity, each Montessori subject area, and each more traditional academic area. Children spent the majority of their time doing active work, with only a small proportion of time spent on less active work such as wandering around the room. Children in these classrooms spent the most time in the practical life and sensorial areas, followed by language and math. Puzzle maps were quite popular, this can be seen in the popularity of geography in the more traditional academic areas.

To compare to previous research (I. Becker, 2020), and gain a sense of differences by age, I completed regressions of the proportion of time spent on each activity by age; see Table 2. There was a trend of differences by age for activities in the "other" category, with these activities increasing with age. There was also a significant increase in waiting with age. Regressions across age for area of engagement and academic area showed no significant results, so these are not reported further.

Figure 1

Bar Graphs Indicating Proportion of Morning Spent on Activities



Note. Error bars indicate standard deviations.

Table 2

Analysis of Type of Engagement by Age

Type of Engagement	Beta	R^2, *t,* and *p*
Group Activity	-0.20	$R^2 < .01$, $t(22) = -0.70$, n.s.
Group Lesson	-0.87	$R^2 = .02$, $t(22) = -1.49$, n.s.
Observing	0.42	$R^2 < .01$, $t(22) = 0.51$, n.s.
Other	1.16	$R^2 = .02$, $t(22) = 1.85$, $p = .08$
Receiving Lesson	0.58	$R^2 < .01$, $t(22) = 0.44$, n.s.
Snacking	-0.34	$R^2 < .01$, $t(22) = -0.59$, n.s.
Working	-0.18	$R^2 < .01$, $t(22) = -0.67$, n.s.
Waiting	1.16	$R^2 = .03$, $t(22) = 2.49$, $p = .02$
Wandering	-0.15	$R^2 < .01$, $t(22) = 0.23$, n.s.
Working While Talking	1.51	$R^2 = .01$, $t(22) = 1.08$, n.s.

Note. Information reported here is from regressions accounting for the class children were in and individuals across observation days.

The duration of activity was investigated next. First, the number of consecutive minutes that each child engaged with the same material was calculated. This was calculated using object of engagement rather than type of work because sometimes children would be joined by a peer, changing the activity from individual to group work while still doing the same activity. Children on average spent 5.10 min per activity ($SD = 1.54$, range = 2.72-10.12) and this did not change across age, beta = 0.04, $R^2 = .02$, $t(22) = 1.65$, n.s.. To look at this further, maximum amount of time that children spent on any individual activity was also investigated. The average maximum

time each child spent on an activity was 28.83 min (*SD* = 12.24, range = 13.00-68.00). This did show trend of increase by age, beta = 0.01, R^2 = .19, $t(22) = 1.82$, $p = .08$. There were many different activities that children spent the most time on; see Table 3.

The above analyses assume continuation of an activity from minute to minute. However, sometimes children would take a break from an activity such as taking a bathroom break, or getting up from their work to ask the teacher a question, which often involved wandering the room for a minute or two to find the teacher and waiting for the teacher to be free to answer the question. I thus repeated the above analyses about length of continuous engagement allowing for bathroom breaks and non-work minutes to be included in the length of the activity. I chose to include the time spent taking these minor interruptions as part of the activity because children indicated a continued intention to work with the same material through the interruption. Results were quite similar. Children on average spent 5.57 min per activity (*SD* = 1.69, range = 2.98-10.47) and this did not change across age, beta = 0.02, R^2 = .01, $t(22) = 0.90$, n.s. The average maximum amount of time spent per activity was 29.85 min (*SD* = 13.16, range = 13.00-68.00) and this did not show any differences by age beta = 0.01, R^2 = .02, $t(22) = 1.31$, n.s.

Depth of Concentration

The concentration scale was designed to capture depth of concentration. As a first exploration of this scale correlations between each scale item were calculated for each child, then averaged across children; see Table 4 for these correlations. Most correlations were mid-range, with the correlation between careful and slow and distracted by surroundings being lowest and the correlation between chaotic and intentional being the highest.

Table 3

Engagement Areas During Maximum Length of Engagement

Area of Engagement	Number of Occurrences
Culture	4
Language	4
Math	5
Other (Snack)	18
Practical Life	7
Sensorial	12
Academic Area	**Number of Occurrences**
Art	3
Geography	4
Language	4
Math	5
Other (Snack)	18
Practical Life	4
Sensorial	12

Note. Information here is shown for maximum length of engagement without interruptions, activities were very similar when interruptions were included. A few children had multiple activities that were the same maximum time, so both were included in analyses. Snack was an option to engage with independently and since a large number of students had snack as their longest activity, so this was included as a separate area in this table, although it was not counted as working elsewhere.

Table 4

Correlations Between Scale Items

	Chaotic	Intentional	Careful	Distracted
Intentional Actions	.72			
Careful and Slow Actions	.33	.32		
Distracted by Surroundings	.43	.48	.13	
Concentration	.63	.67	.43	.50

Note. Significance levels were not calculated or noted for correlations between scale items. Consistent with other reported results, chaotic and distracted by surroundings are both reverse scored.

To analyze depth of concentration, means were for each of the five scale items across the entire morning. These five means were calculated then put into a regression together; see Table 5 for the beta values. The only item that changed significantly by age was distracted by surroundings, with older children being less distracted by their surroundings.

To look more closely at the relation between duration of concentration and depth of concentration, I also correlated the time children spent on each activity to their mean concentration ratings across that activity. These analyses used each activity as a data point rather than each child to look more specifically at characteristics of concentration across children rather than between them; see Table 6 for correlations. Correlations looked very similar for when breaks were included or not, with careful and slow actions and concentration both having significant correlations with the length of the activity.

Table 5

Betas of Regression Predicting Age by Mean Item Rating

Scale Item	Beta	R^2, *t,* and *p*
Chaotic	-0.07	$R^2 < .01$, $t(18) = -0.24$, n.s.
Intentional Actions	0.01	$R^2 < .01$, $t(18) = 0.07$, n.s.
Careful and Slow Actions	0.31	$R^2 = .02$, $t(18) = 1.47$, n.s.
Distracted by Surroundings	0.62	$R^2 = .07$, $t(18) = 4.22$, $p < .001$
Concentration	-0.30	$R^2 = .01$, $t(18) = -1.20$, n.s.

Note. Information reported here is from a single regression, also controlling for the class children were in. Consistent with other reported results, chaotic and distracted by surroundings are both reverse scored.

Table 6

Correlations Between Duration of Concentration and Depth of Concentration

	Chaotic	Intentional	Careful	Distracted	Concentration
Without interruptions	.06	.04	.30**	-.02	.23*
Inclusive of interruptions	.07	.05	.30**	-.02	.22*

Note. Consistent with other reported results, chaotic and distracted by surroundings are both reverse scored. $^{+}$ indicates $p < .10$, * for $p < .05$, ** for $p < .01$, and *** for $p < .001$

Changes in Concentration Rating

During observations, there were apparent differences between children on their stability of depth of concentration. Some children showed considerable change from minute to minute,

with scale scores commonly needing to be changed, where others remained more stable and scale scores typically stayed the same for several minutes at a time. To investigate differences in stability of depth of concentration, two analyses were done looking at changes in children's ratings, an investigation of total number of changes in concentration and magnitude of those changes. First, I looked at the number of times a scale score changed from minute to minute, dividing by the total number of minutes observed for each participant, to account for differences in length of the observation. This is essentially a measure of variance, but putting this into a regression analyzes variance based on each child rather than in comparison to the mean, as would happen in a traditional analysis of variance statistic. The number of changes did change across age for all five items, with all items decreasing in number of changes by age; see Table 7.

Table 7

Mean Scale Item Rating Predicting Number of Scale Changes

Scale Item	Beta	R^2, t, and p
Chaotic	-2.01	$R^2 = .13$, $t(22) = -6.05$, $p < .001$
Intentional Actions	-1.81	$R^2 = .12$, $t(22) = -6.14$, $p < .001$
Careful and Slow Actions	-1.72	$R^2 = .14$, $t(22) = -6.42$, $p < .001$
Distracted by Surroundings	-1.70	$R^2 = .16$, $t(22) = -8.42$ $p < .001$
Concentration	-1.78	$R^2 = .14$, $t(22) = -6.25$, $p < .001$

Note. Each item was run in a separate model. Information reported here is from regressions accounting for classroom and individuals across observation days. Consistent with other reported results, chaotic and distracted by surroundings are both reverse scored.

To investigate this finding further, I also looked at the magnitude of change, creating a difference score from minute to minute, removing all times where there was a change of zero and creating a mean of the resulting changes. The magnitude of change also changed by age, but differently for each item; see Table 8. Most noteworthy are the significant magnitude of change for chaotic, intentional actions, and concentration.

Concentration Scale Validity

The sample collected is too small to do a formal assessment of validity. However, the associative measures that can be done with this study do provide important information indicating some sense of validity for the concentration scale. Analyses throughout this section are pre-planned.

Table 8

Mean Scale Item Rating Predicting Magnitude of Changes

Scale Item	Beta	R^2, *t,* and *p*
Chaotic	-0.62	$R^2 = .06$, $t(22) = -2.99$, $p = .006$
Intentional Actions	-0.53	$R^2 = .05$, $t(22) = -2.37$, $p = .03$
Careful and Slow Actions	-0.53	$R^2 = .01$, $t(22) = -1.42$, n.s.
Distracted by Surroundings	-0.04	$R^2 = .02$, $t(22) = 0.24$, n.s.
Concentration	-0.91	$R^2 = .04$, $t(22) = -2.21$, $p = .04$

Note. Each item was run in a separate model. Information reported here is from regressions accounting for the class children were in and individuals across observation days. Consistent with other reported results, chaotic and distracted by surroundings are both reverse scored.

Before comparing the various out of classroom items to the concentration scale, each was investigated briefly alone, looking for changes across age. For the statue task, sum scores were created for each trial, with a minimum possible score of 0 and maximum of 10. Scores on trial 1 (M = 6.74, SD = 2.99) were fairly similar to scores on trial 2 (M = 5.67, SD = 3.17). A correlation between the two trials was .8, $p < .001$, so these were added together for later analyses. There was a trend of increase by age of statue task scores, beta = 0.05, R^2 = .17, $t(21)$ = 2.05, p = .05.

For the go/no-go task percentage correct response was calculated. Percentage correct appeared to decrease between trial 1 (M = .69, SD = .26) and trial 2 (M = .43, SD = 30) with children showing some fatigue. However, correlations between the two trials was fairly high at .58, p = .006, so for ease of further analyses the two trials were combined. There were no differences in go/no-go responses by age, beta = -0.04, $R^2 < .01$, $t(21)$ = -0.07, n.s..

For HRV, I looked at HRV change from baseline using the coefficient of variation for the standard deviation of inter-beat intervals. A one-sample t-test showed a significant decrease in HRV from baseline to the statue task, $t(14)$ = -5.36, $p < .001$. There were no significant differences in HRV from baseline to the go/no-to task, $t(15)$ = 1.45, n.s.. Given these very different findings, the two will be kept separate for further analyses. There were no significant effects by age.

To compare the scale to results on other measures, a simple mean score was created for all items from the concentration scale. Concentration was also rated during each of the tasks and a similar mean score was created for concentration during each task. These concentration ratings were correlated with the four variables described above. In addition, for the SDQ items, parents and teachers scores have unique interpretations for both individually directed and adult directed

responses, so these were kept separate; see Table 9 for SDQ ratings. See Table 10 for this correlation table. A few correlations of note include a moderate (.32) but with this sample size insignificant correlation between the concentration ratings on the two days, a significant correlation (.77) between the concentration scale rating done during the statue task and statue task scores, and a moderate correlation (-.44) between statue task scores and HRV during the statue task. There was also a trend of stronger correlations with out of classroom ratings of concentration than in classroom ratings, and stronger correlations of the concentration scale with teacher SDQ ratings than parent SDQ ratings. It should be noted that ratings of concentration using the SDQ were framed as challenges concentrating, so lower numbers suggest higher ability to self-regulate attention and concentrate. Teacher and parent ratings were also highly correlated within raters (.75 for teachers and .82 for parents).

Exploratory Analyses Regarding Wellbeing

This study was not intended to measure specific outcomes, however some exploratory analyses were done looking at wellbeing related measures namely teacher and parent ratings on the SDQ and baseline ratings of HRV. Total SDQ ratings were calculated by summing all scores on the different subscales, using a mean of the two inattention/hyperactivity subscales so as not to weight these additionally. Similar to the lower correlations for the sections of the SDQ used previously, scores differed between teachers (M = 11.60, SD = 6.98) and parents (M = 21.79, SD = 3.67). I found no significant relation with measures of the scale used in the classroom and teacher SDQ ratings, beta = -0.57, $R^2 < .01$, $t(20) = -0.06$, n.s., parent SDQ ratings, beta = 4.26, $R^2 = .04$, $t(20) = 0.88$. n.s., nor the coefficient of variation of SDNN, beta = 0.32, $R^2 < .01$, $t(13) = 0.05$ n.s. Duration of concentration significantly predicted teacher SDQ ratings, but did not predict parent SDQ ratings or baseline HRV; see Table 11.

Table 9

Ratings of Concentration by Teachers and Parents

	Self-Directed Scores	Other-Directed Scores
Teacher Ratings	3.00 (2.59)	3.12 (2.85)
Parent Ratings	2.88 (2.33)	3.38 (2.36)

Note. Table shows means and standard deviations in parenthesis. These ratings are scores using the questions from the inattention/hyperactivity subscale of the SDQ, asking specifically about self-directed and other-directed activities. Scores are out of a possible 0-6.

Table 10

Correlation Table Looking at Associations with the Concentration Rating Scale

	CS-1	CS-2	Chg-1	Chg-2	Mag-1	Mag-2	CS-ST	CS-G	ST	G/NG	HRV-ST	HRV-G	Self-T	Other-T	Self-P
CS-2	.32														
Chg-1	-.01	-.02													
Chg-2	-.33	-.26	.21												
Mag-1	-.38+	-.10	.38+	.17											
Mag-2	-.44*	-.50*	-.02	.47	.23										
CS-ST	-.19	.16	.25	-.35	.16	-.07									
CS-G	.39+	.19	.23	.13	.01	.05	.58**								
ST	-.19	-.08	.33	-.21	.19	-.17	.77***	.24							
G/NG	.12	.06	<-.01	.13	-.12	.19	-.15	.11	-.04						
HRV-ST	-.27	-.12	-.04	-.03	.05	.24	-.30	-.16	-.44+	-.08					
HRV-G	-.09	-.36	-.15	.30	-.24	.74	-.25	-.07	-.36**	.17	.37				
Self-T	-.46*	-.14	-.29	.44*	.15	.55	-.40+	-.59**	-.28**	-.11	-.27	.11			
Other-T	-.32	-.01	-.05	.18	.26	.34	-.25	-.48*	-.31	-.11	<.01	.04	.75***		
Self-P	.11	-.02	-.13	.20	-.06	-.19	-.29	.00	-.27	-.20	.15	-.06	.16	.13	
Other-P	-.14	.17	-.22	.29	.20	-.07	-.19	-.07	-.30	-.41+	.27	-.02	.32	.25	.82***

Note. CS-1 and CS-2 are mean ratings on the concentration scale for observations 1 and 2 respectively, Chg-1 and Change-2 are change counts for observations 1 and 2, Mag-1 and Mag-2 are magnitude of changes in observation 1 and 2, CS-ST and CS-G are mean ratings on the concentration scale used during the statue task and go/no-go tasks respectively, ST is score on the statue task, G/NG is scores on the go/no-go task, HRV-ST and HRV-G are HRV measured during the statue task and go/no-go task, Self-T and Other-T are concentration as assessed by the teacher on the inattention/hyperactivity subscale of the SDQ for self-directed and other directed activities respectively, Self-P and Other-P are concentration as assessed by parents on the inattention/hyperactivity subscale of the SDQ for self-directed and other directed activities. $^{+}$ indicates $p < .10$, * for $p < .05$, ** for $p < .01$, and *** for $p < .001$

Table 11

Exploratory Analyses Investigating Duration of Concentration Predicting Wellbeing

Measure	Beta	R^2, *t,* and *p*
Teacher SDQ Combined Ratings on All Subscales		
Mean length of engagement	-3.11	$R^2 = .29$, $t(21) = 3.09$, $p = .005$
Maximum length of engagement	-0.21	$R^2 = .14$, $t(21) = -1.94$, $p = .07$
Mean length of engagement with interruptions	-2.68	$R^2 = .17$, $t(21) = -2.97$, $p = .007$
Maximum length of engagement with interruptions	-0.20	$R^2 = .12$, $t(21) = -1.77$, $p = .09$
Parent SDQ Combined Ratings on All Subscales		
Mean length of engagement	-0.36	$R^2 = .01$, $t(21) = -0.57$, n.s.
Maximum length of engagement	0.02	$R^2 = .01$, $t(21) = 0.35$, n.s.
Mean length of engagement with interruptions	-0.10	$R^2 < .01$, $t(21) = -0.18$, n.s.
Maximum length of engagement with interruptions	0.03	$R^2 = .01$, $t(21) = 0.44$, n.s.
Coefficient of Variation SDNN		
Mean length of engagement	0.03	$R^2 < .01$, $t(14) = 0.05$, n.s.
Maximum length of engagement	-0.01	$R^2 < .01$, $t(14) = -0.13$, n.s.
Mean length of engagement with interruptions	0.01	$R^2 < .01$, $t(14) = 0.01$, n.s.
Maximum length of engagement with interruptions	< .01	$R^2 < .01$, $t(14) < -.01$, n.s.

Note. Information reported here is from regressions accounting for the class children were in. For these analyses, mean length of engagement was averaged across the two observation days and only the maximum length of engagement between the two observations days was used.

Discussion

The aim of this study was to investigate concentration demonstrated by young children in naturalistic settings. Concentration is an important precursor to learning and as such the ability to self-regulate attention to concentrate is an important one to develop for school readiness. Concentration is a composite state defined by self-regulation of attention that is sustained and selective, accompanied with appropriate cognitive load in a state of activity. Given the complexities of concentration and the importance of this state in school and academic contexts, considerable benefit comes from studying concentration within school environments. As opposed to a laboratory setting, school environments have the same distractors and activities that children typically interact with. This study provides an initial exploration of the concept of concentration in preschool settings, serving mainly as a descriptive study. The specific question this study answered was: What is the depth and duration of preschool children's demonstrated concentration during freely chosen activities in Montessori classrooms? I specifically chose to work in Montessori classrooms because the free choice common to this setting made it conducive to studying children's demonstrated concentration on activities that required self-regulation and had less structure from a teacher or adult. We observed preschool children during a typical morning in the classroom, looking at the duration of time they spent on tasks and coded for depth concentration.

A secondary purpose was to investigate the use of a new scale for coding depth of concentration, designed for observational research in preschool settings. To serve this secondary purpose, this study also included associative analyses between concentration in classrooms and other measures of the components that comprise concentration.

Concentration in Classroom Settings

Duration of Concentration

Children spent the majority of time doing individual work, followed by group activities. In contrast, children spent little time working while talking, receiving a lesson, and observing. To put these findings in context, a brief comparison to other studies in Montessori contexts is helpful. Across studies, the two most prevalent types of engagement are individual work and group activities. Montessori preschool children spend a large percentage of time doing individual work, ranging across the two previous studies and this one from 33-50% (I. Becker et al., 2020; Hojnoski et al., 2008). The prevalence of group activities is more varied, ranging from 12-53% of the time. The study that found the least time spent doing individual work also found the most time doing group activities (e.g. Hojnoski et al., 2008), suggesting that time spent doing individual work was replaced with group activity in the classrooms studied. Time spent receiving a lesson was comparable across studies, ranging from 6-10% of the time. This number corresponds quite closely to the proportion of time a teacher can spend working with each student individually. Together, these finding show that the emphasis placed on individual work in Montessori preschools bears out in reality: a large proportion of children's time is spent doing individual work. Group activities are less emphasized in Montessori pedagogy, which may explain the larger range of observed time doing group activities in class.

Within the observed categories, there was a trend of older children in the present study to spend more time doing activities in the "other" category. This category included activities like talking to friends while not having any material out, or horsing around, activities that were not designated activities in the classroom and were less common. When coding, this category arose most often when children were only talking with their friends. The trend of older children spending more time in the other category likely indicates older children spending more time only talking to peers without doing designated activities. These older children often had a lot to say to their peers, and this finding parallels the development of social competencies and social motivation throughout preschool (Over, 2016; Santos et al., 2014). Older children also spent more time waiting. This corresponded to anecdotal evidence of older children appearing to have more foresight at wanting to do a particular activity as well as doing more complex lessons where they had to periodically wait for feedback from the teacher.

These findings differ from previous findings in similar Montessori contexts, where older children spent less time observing (I. Becker et al., 2020). This may partially be because observing was not particularly supported in the classrooms in the present study. Children were encouraged to observe if they wished, but there were often limitations set on observing, such as only allowing one student to observe another at any time. Both current and previous findings indicate some amount of change in what activities are done as children get older and that older children have internalized norms of the classroom, either knowing the routine of work and not needing to observe how to do it as much, or waiting to do the work they intend. However, the differences between studies suggests this is context specific, aligning with the common truism that children are quite good at learning the norms of the specific context they are in (Cantor et al., 2019).

Students in this study spent less time continuously engaged with each activity than student in previous research done in similar contexts. Previous research found children in Montessori preschools spent 9.96 min (*SD* = 4.61) on each activity, about double the current findings of 5.5 min (I. Becker et al., 2020). However, the estimate in the previous study made assumptions about what activities children were doing during times observers were taking breaks from coding. In the present study, children were observed every minute. This meant that moments of change were captured more frequently, so children doing an activity for only one or two minutes, likely brought down the mean. Indeed, when activities that only lasted a minute were removed, the average time spent on activity increased to 7.82 min (*SD* = 3.30), which is much closer to previous findings. The small difference between current and previous findings once activities that only lasted a minute were removed suggest differences are primarily due to methodological differences. It is possible some difference seen between results are also due to changes in environment from the COVID-19 pandemic. However, anecdotally differences between the two studies appeared more in the types of activities children did than the length of time spent on activities. Within the COVID-19 context, children appeared more interest in social activities, which is seen in the popularity of activities in the other category.

Regarding maximum amount of time spent on work, there was a trend of older children spending a larger maximum amount of time on work. However, trends between ages were less pronounced when breaks like bathroom breaks were included. This suggests that there is indeed minimal difference between children across ages in regard to the length of time they spend on work.

Depth of Concentration

Depth of concentration was measured using a recently developed scale designed to measure depth of concentration observationally (I. Becker & Lillard, 2021). There were two key findings regarding depth of concentration. First, older children were less distracted by their surroundings than their younger peers. This suggests a particular learning of the ability to inhibit attention to distractors as children get older. Second, there was a correlation between length of engagement and deeper concentration as indicated by ratings on the items careful and slow actions and concentration. This indicates that certain aspects of depth of concentration increased along with duration of concentration, that is when concentration is high it is so both in regard to duration of concentration and depth of concentration.

Depth of concentration also shows indication of context specificity. There was a reasonable correlation between depth of concentration measured between the two days, but this correlation was not significantly different from zero. Because concentration is a state reached within a particular context and the context changed from observation to observation with children doing different activities each day, the lack of significant correlation between observation days may be due to contextual changes between days. Children do have particular aptitudes to concentrate more or less, as is implied when measuring traits such as those measured in the SDQ. The high correlation, despite being non-significant, also supports some consistency within children, taking into account differing contexts by day. Ratings of concentration were generally more similar to teacher and parent ratings and out of classroom measures on the first observation rather than the second. The first observation was temporally closer to the time parents and teachers completed the measures and the out of classroom measures, suggesting that

temporal context may also make a difference and that there was some change during the roughly 3 months between observations.

Changes in Concentration

During observations, there were apparent differences between children on their stability of depth of concentration. Some children showed considerable change in apparent depth of concentration from minute to minute, where others remained more stable, changing depth of concentration more gradually over time. The analyses regarding these changes were particularly interesting. Older children showed less changes from minute to minute on all scale items and showed smaller magnitude of change on chaotic and intentional actions. There was also a trend of older children having smaller magnitude of change for careful and slow actions as well as concentration. These findings suggest that older children's demonstrated concentration is more behaviorally consistent and stable. Older children on average appear to be concentrated in more similar ways from minute to minute and when changes do occur within doing the same activity, change are smaller. In particular, they appear to have more consistent apparent purpose in activities that they do, apparent in the lower magnitudes of change for chaotic and intentional actions.

Combining the finding that there are minimal differences by age regarding depth and duration of concentration with changes in stability of concentration, indicates that older children show more consistent behavior during concentration, but are not necessarily concentrating more than their younger peers. That is, although young children may on average concentrate just as deeply and work just as long on activities as older children, there are still critical differences in their concentration. For example, a young child drawing may spend a half hour drawing. Over the course of this time, this child may spend some time deeply concentrated, indicated by

slowing down hand movements to draw an image with a clear goal of perhaps drawing a specific image with intention to depict a story. However, at other points during this half hour, this child may have become fatigued and rest by taking extra time to choose a different color crayon. In contrast, an older child may spend a similar half hour drawing, but would demonstrate much more consistency in concentration. An older child may be more likely to have a crayon on paper for each minute of the half hour, but not take as much time to slow down their movements to draw an image with precision. Both the younger and older child in this example have the same duration of concentration and similar mean depth of concentration, but their concentration appears very different.

A key area in which concentration may develop then is through regulating behavior to be more stable. Self-regulation helps children selectively attend, maintain appropriate cognitive load, and sustain this attention. It is clear that self-regulation develops considerably across preschool and increased stability in how children concentrate suggest this is present in the ways that they concentrate as well (McCabe et al., 2004; Wiebe & Sheffield, 2012). Younger children may not have the self-regulatory ability to know how to pace themselves and thus have shorter periods of higher selective attention with higher cognitive load, like drawing very slowly and intently, that fluctuate with moments of fatigue, perhaps spending more time choosing a new crayon, as they reset to continue. Simply looking at depth or duration of concentration do not capture this full story and may not capture how much development of concentration happens during the preschool years.

Validity of Concentration Scale

A secondary purpose of this study was to investigate relations between the concentration scale used to measure depth of concentration and out of classroom measures of selective

attention, cognitive load, inhibition, and teacher and parent report. If these relations are strong, they could provide preliminary evidence for the validity of this scale; both concurrent validity measured during out of classroom tasks, criterion validity with teacher and parent report, and construct validity regarding a combination of these analyses. Specifically, the statue task was used as a measure of self-regulatory inhibition, the go/no-go task as a measure of selective attention, and HRV as a measure of cognitive load. Teacher and parent reports of children's aptitude to concentrate were assessed using an adapted version of the inattention/hyperactivity subscale on the SDQ.

It is first worth mentioning results regarding the out of classroom tasks alone. There was a trend for statue task scores to increase by age. There was also a decrease in HRV between baseline and the statue task, indicating high cognitive load during this task. There were no differences across age in the magnitude of this change. The go/no-go task showed no differences by age and no decrease in HRV during the task. These findings, along with low expected correlations of the go/no-go with other measures, suggests that children did not fully engage with this task. Anecdotally, children also did not seem as engaged in this task as the statue task. Indeed, the mean concentration scores across all items were about half a point lower out of five on the go/no-go task (3.66) than the statue task (4.01). This was the last activity in the out of classroom procedure, which included watching a video to assess baseline HRV in addition to completing the statue task, so children were likely also fatigued by the time they reached this task. The go/no-go thus likely did not accurately capture children's ability to selectively attend. Future research could address this limitation by counterbalancing the out of classroom tasks across participants.

During this study, children's demonstrated concentration was assessed both during self-directed activity in Montessori classrooms and in adult-directed activities during out of classroom testing. Given this context, the questions related to concentration from the SDQ were asked to parents and teachers twice, once regarding self-directed activity and once regarding other-directed activity. Within raters, both parents and teachers had a high correlation on reports of children's aptitude to concentrate, seeing children's ability to concentrate on self-directed and other-directed activities as similar. However, as has been the case in other studies, there was less consistency between raters (Kennerley et al., 2018; A. L. Murray et al., 2018). This limited inter-rater reliability may come from noise in the measure; one possible source of noise is extraversion that might manifest more in other-directed activities (Martel et al., 2010). Teacher ratings in both types of activities were most correlated with parent ratings regarding other-directed activities, with low correlations for individually-directed activities. This suggests that the type of individual activity that parents were considering was different from what teachers see in the classroom. For example, children playing individually with toys at home may appear quite different than when working on a math problem in the classroom.

Correlations between the SDQ and other measures of the components of concentration were mostly non-significant. The primary exception was the correlation between teacher's ratings of children's self-directed concentration and scores on the statue task. Notably, this correlation was only significant for answers about self-directed activity, suggesting that even though the statue task was directed by a researcher, self-regulation may be better aligned with teacher's perceptions of self-directed activities. There was also a marginally significant correlation between parent ratings on other-directed activities and the go/no-to task. In Montessori classrooms, activities are usually independently chosen and more self-directed.

Given this context, parents may have had a better sense of how much their children follow directions. With the fatigue children showed in the go/no-go task, perhaps this correlation indicates children's willingness to follow directions to do a task despite fatigue. However, given children's apparent fatigue during this task, this correlation likely does not indicate as much in regard to their concentration or likelihood to concentrate.

Correlations between out of classroom measures and the concentration scale were mixed, although they support an interpretation of concentration as context specific. Concentration rated during the statue task significantly correlated with statue task scores. There was also a moderate, although not significant, correlation to HRV during the statue task, The low correlations with the go/no-go are unsurprising given the aforementioned challenges related to this task. These findings provide moderate support for concurrent validity of the scale.

Findings in classroom also provide moderate support for criterion validity with a significant correlation between teacher reports of self-directed concentration and concentration scale scores measured in the classroom as well as changes in scale scores. However, this finding is limited by this correlation being the strongest primarily for the first observation day. One explanation for this finding is that teacher and parent ratings were done closer to the first observation day than the second, and children's behaviors changed during the roughly 3 months between observations. Future research should explore reliability of this scale over time, comparing similarities for shorter timeframes, such as only a few days or weeks. Of interest also would be collecting parent and teacher ratings of children's aptitude to concentrate twice, close to two different time points, to see if relations with concentration scale scores remain similar as children's behaviors change.

Regarding construct validity of the concentration scale, the combination of associations analyzed for the present study provide minimal support, with the scale being most closely associated only with the measure used for self-regulation (the statue task) and one of the measures of children's aptitude to concentrate (teachers' SDQ ratings regarding self-directed activity). Assessment of construct validity from the present study is limited by a decreased sample for HRV, with some children refusing the HRV equipment, and the apparent fatigue of children during the go/no-go task. To better establish or refute construct validity of this scale, further research and data collection would be needed. Future research could also provide a more extensive battery of measures for the components of concentration to more comprehensively capture children's abilities on these skills, perhaps collecting data over multiple days to minimize fatigue.

The explanation regarding validity of the concentration scale primarily focused on out of classroom measures and in classroom measures separately, aligns well with a description of concentration as context specific. However, there were also many correlations that were not strong that might be expected to be for full validity of this scale. Correlations between out of classroom measures and concentration measured in the classroom were minimal. If aptitude to concentrate is consistent across contexts, then these measures should align with in classroom measures of concentration as well. There is some indication from previous work that children's ability to selectively attend and sustain attention correlates to academic outcomes, although much of this work uses teacher and parent report (Polderman et al., 2010). Self-regulation is also considered to span contexts (Baumeister et al., 2018; Blair, 2003). There is less research in regard to cognitive load at this young age, but similar reasoning seems likely. Another explanation may thus be simply that the concentration scale captured some sense of

concentration in context, but did not fully capture concentration nor children's aptitude to concentrate. Aptitude to concentrate may have been better captured by teacher's ratings, as this spanned contexts, relating both to the statue task and concentration scale ratings. The broader applicability of teacher ratings parallels previous findings that teacher ratings align well with standardized academic outcome measures, showing similar findings on measures related to classroom contexts and less so for home environments, although this does not capture the detail of what is happening during any specific activity (Reid et al., 2014; Vitiello & Williford, 2021).

Concentration, as a state rather than trait, is context dependent. There were many differences in context between the activity that happened in the classroom and the out of classroom session. As mentioned, one clear difference was that the in classroom activity was more self-directed and the out of classroom session was other-directed. Considerable research and theory on motivation shows that locus of control plays an important role in how children complete activities (i.e. Lepper et al., 1973; Ryan & Deci, 2000). Further, children were used to the classroom environment more than working with a stranger, which may have influenced behavior (Dhami et al., 2004). Whether or not context specificity supports validity of the concentration scale used in this study, this does suggest the continued need to consider context specificity in future research on concentration, especially in regard to in classroom versus out of classroom contexts.

Exploratory Analyses Regarding Wellbeing.

Exploratory analyses were done investigating the relation between high concentration and wellbeing. Montessori theory proposes that concentration supports wellbeing in several ways (Montessori, 1949). At a simple level, concentration facilitates learning. Learning helps individuals interact in the world with more information and allows individuals to make more

informed choices, which can support wellbeing. Additionally, learning can be a rewarding experience, increasing immediate enjoyment as well (Ainley & Hidi, 2014). The enjoyment experienced through the effective learning that can happen during concentration in turn encourages children to concentrate more in the future, teaching a cycle of learning to increase concentration. To reach high concentration, the components of concentration are also necessary. The self-regulation needed in particular can also support wellbeing (Moffitt et al., 2011). The ability to self-regulate can support wellbeing through making positive long-term choices, for example choosing to concentrate on homework over playing a video game, or choosing to eat healthier foods. The theorized relation between concentration and wellbeing is additionally supported by flow theory (Csikszentmihalyi, 2000; Richards & Huppert, 2011). Flow research primarily demonstrates relations between subjective wellbeing and states similar to concentration, but does provide additional theoretical support.

Within the measures used for this study were two measures of wellbeing: global SDQ ratings from teachers and parents and baseline HRV. Teacher and parent report provide a sense of the frequency of children's behavioral challenges, which could indicate mal-being, and positive behaviors such as constructive relations with peers that are indicators of wellbeing. Global SDQ ratings are often used as an estimate of children's overall wellbeing (Vostanis, 2006). Baseline ratings of HRV are not as directly a measure of current wellbeing as SDQ ratings, however baseline HRV ratings are an indicator of long-term wellbeing (Patron et al., 2020). High baseline HRV indicates higher relaxation during a resting state, indicating lower stress and greater wellbeing (Thayer et al., 2009). Lower stress in turn is predictive of greater ability to readily adapt to environmental changes and also less stress in the future (Thayer et al., 2012; Wass et al., 2019).

Data from the current study showed no significant findings with depth of concentration measures. Duration of concentration measures were predictive of global SDQ ratings from teachers, although not for parents nor for baseline HRV. Since teachers work closely with children, they have a concrete understanding of their behavioral challenges in the classroom and this finding indicates that concentration, at least duration of concentration, is related to current wellbeing. However, it is also possible that the centrality of this theory in Montessori pedagogy influenced the responses from teachers and those children who they deemed as more apt to concentrate also received higher ratings on the other subscales of this measure. The lack of significance with parent SDQ ratings suggests this as the simplest explanation for present findings. There is ample opportunity to further explore this theory. Future research could investigate concentration predicting wellbeing longitudinally as well as perhaps investigating depth of concentration in different contexts, such as during play, as having different strength in predicting wellbeing. Future research should also look at more proximal concepts such as academic outcomes, like knowledge learned during periods of concentration.

Limitations

A key limitation of this study is that it was done with such a small sample size, with a small number of children, only in two classrooms, and one school. However, differences across the sample support the generalizability of findings. Given the local area and sample size, there was an acceptable demographic variance in children in this study. Even though they were in the same school, the two classrooms also differed. One classroom had a very experienced lead teacher that had been at the school for some time, where the other had two teachers across the course of this study and was a much less established classroom. An additional limitation to this small sample was that it limited the statistics that could be run. Running more complicated

analyses such as structural equation models that would have helped better take into account noise would have been unstable with such a small sample.

It should also be noted that data was collected during the 2021-2022 academic school year during the COVID-19 pandemic. All individuals in school were masked and classroom routines were slightly different than normal. These changes have influenced social development (Araújo et al., 2021). With much people's faces covered, children have been not had the same information available to read social cues. This certainly impacts interactions with teachers, and can also impact the work that children do. For example, in practicing sounds for writing, children do not have a visual cue of how the teacher forms the sound which in turn provides less information to help make practicing sounds independently interesting. With decreased social interaction from the pandemic, it is also possible that children were particularly interested in socializing when in the classroom, perhaps increasing the instances of the other category in our findings, particularly for the older children who are developmentally more socially inclined.

One apparent limitation of this study may be that it was done only in a Montessori context. However, as mentioned there were strong methodological reason for this. Montessori classrooms provide a prime environment to study concentration in naturalistic settings where children consistently need to self-regulate their own attention. The theoretical underpinnings of concentration as an important part of the learning process and other outcomes like wellbeing are true regardless of setting. Further, the findings here support the idea that children adapt their concentration needs to the classroom environments they are in. Although the limited settings in this study may be seen as limiting generalizability of specific findings, children's adaptability is certainly a constant finding in research (Cantor et al., 2019).

Conclusion

I have proposed the importance of concentration as a construct to be studied in psychology. To capture the complexities of how the term concentration is commonly used, I define concentration as a composite state with the primary components of sustained attention, selective attention, appropriate cognitive load, and self-regulatory inhibition. These components develop considerably during the preschool years and are critical for school readiness.

The complexities of concentration make it critical to study in context, a claim supported by the results of this study. Here, concentration was investigated in preschool classrooms, specifically during times when children had free choice, allowing for the study of concentration as it occurs when children need to self-regulate their own attention. Children indeed showed development of this ability to self-regulate: older children showed more stable concentration during activities than their younger peers. However, depth and duration of concentration did not significantly differ by age, suggesting children are building the skills necessary to be able to concentrate in a more stable fashion. Freedom to work on materials of their own choosing may help young children have the time to engage with activities to develop these skills. The duration with which children concentrate also shows implications for their wellbeing. Teachers should consider these findings in instructing young children, giving children time doing activities independently to develop skills needed for concentration that can support children's long-term wellbeing.

References

Addessi, A. R., Ferrari, L., Carlotti, S., & Pachet, F. (2006). Young children's musical experiences with a flow machine. *International Conference on Music Perception and Cognition*, 1658–1665.

Addessi, A. R., Ferrari, L., & Carugati, F. (2012). Observing and measuring the flow emotional state in children interacting with the MIROR platform. *Proceedings of the 12th International Conference on Music Perception and Cognition and the 8th Triennal Conference of the European Society for the Cognitive Science of Music*, 20–30.

Ainley, M., & Hidi, S. (2014). Interest and enjoyment. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), *International Handbook of Emotions in Education* (pp. 205–227). Routledge.

Anderson, L. W. (1984). *Time and School Learning*. Routledge.

Andrade, J. (2010). What does doodling do? *Applied Cognitive Psychology*, *24*(1), 100–106. https://doi.org/10.1002/acp.1561

Antonenko, P., Paas, F., Grabner, R., & van Gog, T. (2010). Using electroencephalography to measure cognitive load. *Educational Psychology Review*, *22*, 425–438. https://doi.org/10.1007/s10648-010-9130-y

Araújo, L. A. de, Veloso, C. F., Souza, M. de C., Azevedo, J. M. C. de, & Tarro, G. (2021). The potential impact of the COVID-19 pandemic on child growth and development: A systematic review. *Jornal de Pediatria*, *97*(4), 369–377. https://doi.org/10.1016/j.jped.2020.08.008

Avgerinou, V. A., & Tolmie, A. (2020). Inhibition and cognitive load in fractions and decimals. *British Journal of Educational Psychology*, *90*, 240–256. https://doi.org/10.1111/bjep.12321

Bagby, J. H., & Renbarger, R. (2018a). Montessori education and practice: A review of the literature, 2014-2017 (Part 1). *Montessori Life*, *30*(2), 48–53.

Bagby, J. H., & Renbarger, R. (2018b). Montessori education and practice: A review of the literature, 2014-2017 (Part 2). *Montessori Life*, *30*(3), 50–56.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barrouillet, P., Gavens, N., Vergauwe, E., Gaillard, V., & Camos, V. (2009). Working Memory Span Development: A Time-Based Resource-Sharing Model Account. *Developmental Psychology*, *45*(2), 477–490. https://doi.org/10.1037/a0014615

Baumeister, R. F., Tice, D. M., & Vohs, K. D. (2018). The strength model of self-regulation: Conclusions from the second decade of willpower research. *Perspectives on Psychological Science*, *13*(2), 141–145. https://doi.org/10.1177/1745691617716946

Baumeister, R. F., & Vohs, K. D. (2007). Self-regulation, ego depletion, and motivation. *Social and Personality Psychology Compass*, *1*(1), 115–128. https://doi.org/10.1111/j.1751-9004.2007.00001.x

Baumeister, R. F., Vohs, K. D., & Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science*, *16*(6), 351–355. https://doi.org/10.1111/j.1467-8721.2007.00534.x

Beames, J. R., Schofield, T. P., & Denson, T. F. (2017). A meta-analysis of improving self-control with practice. In D. de Ridder, M. Adriaanse, & K. Fujita (Eds.), *International Handbook of Self-Control in Health and Well-Being* (pp. 405–417). Routledge.

https://www.taylorfrancis.com/books/9781317301424/chapters/10.4324/9781315648576-32

Becker, I. (2020). Patterns of concentration in Montessori preschools: Investigating concentration when children are free to choose their own work [Unpublished master's thesis]. *University of Virginia*.

Becker, I., Basargekar, A., & Lillard, A. S. (2020, April 17). *What Do Children Choose to Do? An Observational Study of Children in Montessori Classrooms* [Poster Session]. AERA Annual Meeting (conference canceled), San Francisco. http://tinyurl.com/wnjzcex

Becker, I., & Lillard, A. S. (2021, April 8). *A Scale for Assessing Preschoolers' Concentration* [Symposium]. AERA Annual Meeting., held virtually.

Berlin, L., & Bohlin, G. (2002). Response inhibition, hyperactivity, and conduct problems among preschool children. *Journal of Clinical Child & Adolescent Psychology*, *31*(2), 242–251. https://doi.org/10.1207/S15374424JCCP3102_09

Betts, J., Mckay, J., Maruff, P., & Anderson, V. (2006). The development of sustained attention in children: The effect of age and task load. *Child Neuropsychology*, *12*(3), 205–221. https://doi.org/10.1080/09297040500488522

Blair, C. (2003). Behavioral inhibition and behavioral activation in young children: Relations with self-regulation and adaptation to preschool in children attending Head Start. *Developmental Psychobiology*, *42*(3), 301–311. https://doi.org/10.1002/dev.10103

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, *66*(1), 711–731. https://doi.org/10.1146/annurev-psych-010814-015221

Blumenthal, A. L. (1975). A reappraisal of Wilhelm Wundt. *American Psychologist*, *30*(11), 1081–1088. https://doi.org/10.1037/0003-066X.30.11.1081

Borderie, J., & Michinov, N. (2016). Identifying flow in video games: Towards a new observation-based method. *International Journal of Gaming and Computer-Mediated Simulations*, *8*(3), 19–38. https://doi.org/10.4018/IJGCMS.2016070102

Borragán, G., Slama, H., Bartolomei, M., & Peigneux, P. (2017). Cognitive fatigue: A time-based resource-sharing account. *Cortex*, *89*, 71–84. https://doi.org/10.1016/j.cortex.2017.01.023

Brocki, K. C., Nyberg, L., Thorell, L. B., & Bohlin, G. (2007). Early concurrent and longitudinal symptoms of ADHD and ODD: Relations to different types of inhibitory control and working memory. *Journal of Child Psychology and Psychiatry*, *48*(10), 1033–1041. https://doi.org/10.1111/j.1469-7610.2007.01811.x

Calkins, S. D., & Keane, S. P. (2004). Cardiac vagal regulation across the preschool period: Stability, continuity, and implications for childhood adjustment. *Developmental Psychobiology*, *45*(3), 101–112. https://doi.org/10.1002/dev.20020

Camos, V., & Barrouillet, P. (2011). Developmental change in working memory strategies: From passive maintenance to active refreshing. *Developmental Psychology*, *47*(3), 898–904. https://doi.org/10.1037/a0023193

Cantor, P., Osher, D., Berg, J., Steyer, L., & Rose, T. (2019). Malleability, plasticity, and individuality: How children learn and develop in context. *Applied Developmental Science*, *23*(4), 307–337. https://doi.org/10.1080/10888691.2017.1398649

Carroll, J. B. (1963). A model of school learning. *Teacher College Record*, *64*(8), 723–733.

Chan, E. (2012). The negative effect of doodling on visual recall task performance. *University of British Columbia's Undergraduate Journal of Psychology*, *1*, 1–6.

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. *The Journal of the Acoustical Society of America*, *25*(5), 975–979. https://doi.org/10.1121/1.1907229

Cowan, N. (2016). Working memory maturation. *Perspectives on Psychological Science*, *11*(2), 239–264. https://doi.org/10.1177/1745691615621279

Craik, F. I. M., & Watkins, M. J. (1973). The role of rehearsal in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, *12*, 599–607.

Csikszentmihalyi, M. (1975). Play and intrinsic rewards. *Journal of Humanistic Psychology*, *15*(3), 41–63. https://doi.org/10.1177/002216787501500306

Csikszentmihalyi, M. (1991). *Flow*. Harper Perennial.

Csikszentmihalyi, M. (2000). *Flow: The Psychology of Optimal Experience*. Global Learning Communities.

Csikszentmihalyi, M., & Larson, R. (2014). Validity and reliability of the experience-sampling method. In *Flow and the Foundations of Positive Psychology*. Springer. ttps://doi.org/10.1007/978-94-017-9088-8_3

Culclasure, B., Fleming, D. J., Riga, G., & Sprogis, A. (2018). An evaluation of Montessori education in South Carolina's public schools. *The Riley Institute at Furman University*.

Custodero, L. A. (1998). Observing flow in young children's music learning. *General Music Today*, 21–27.

Custodero, L. A. (2005). Observable indicators of flow experience: A developmental perspective on musical engagement in young children from infancy to school age. *Music Education Research*, *7*(2), 185–209. https://doi.org/10.1080/14613800500169431

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

de Geus, E. J. C., Gianaros, P. J., Brindle, R. C., Jennings, J. R., & Berntson, G. G. (2019). Should heart rate variability be "corrected" for heart rate? Biological, quantitative, and interpretive considerations. *Psychophysiology*, *56*(2), e13287. https://doi.org/10.1111/psyp.13287

Dhami, M. K., Hertwig, R., & Hoffrage, U. (2004). The role of representative design in an ecological approach to cognition. *Psychological Bulletin*, *130*(6), 959–988. https://doi.org/10.1037/0033-2909.130.6.959

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959–964. https://doi.org/10.1126/science.1204529

Doherty-Sneddon, G., Bruce, V., Bonner, L., Longbotham, S., & Doyle, C. (2002). Development of gaze aversion as disengagement from visual information. *Developmental Psychology*, *38*(3), 438–445. https://doi.org/10.1037/0012-1649.38.3.438

Downer, J. T., Booren, L. M., Lima, O. K., Luckner, A. E., & Pianta, R. C. (2010). The Individualized Classroom Assessment Scoring System (inCLASS): Preliminary reliability and validity of a system for observing preschoolers' competence in classroom

interactions. *Early Childhood Research Quarterly*, *25*(1), 1–16. https://doi.org/10.1016/j.ecresq.2009.08.004

Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology*, *92*(1), 53–78. https://doi.org/10.1348/000712601162103

Edossa, A. K., Schroeders, U., Weinert, S., & Artelt, C. (2018). The development of emotional and behavioral self-regulation and their effects on academic achievement in childhood. *International Journal of Behavioral Development*, *42*(2), 192–202. https://doi.org/10.1177/0165025416687412

Eisenberg, I. W., Bissett, P. G., Enkavi, A. Z., Li, J., MacKinnon, D. P., Marsch, L. A., & Poldrack, R. A. (2019). Uncovering the structure of self-regulation through data-driven ontology discovery. *Nature Communications*, *10*. https://doi.org/10.1038/s41467-019-10301-1

Engeser, S., & Rheinberg, F. (2008). Flow, performance and moderators of challenge-skill balance. *Motivation and Emotion*, *32*(3), 158–172. https://doi.org/10.1007/s11031-008-9102-4

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143–149. https://doi.org/10.3758/BF03203267

Esterman, M., & Rothlein, D. (2019). Modes of sustained attention. *Current Opinion in Psychology*, *29*, 174–180. https://doi.org/10.1016/j.copsyc.2019.03.005

Fenesi, B., Sana, F., Kim, J. A., & Shore, D. I. (2015). Reconceptualizing working memory in educational research. *Educational Psychology Review*, *27*(2), 333–351. https://doi.org/10.1007/s10648-014-9286-y

Fisher, A., Thiessen, E., Godwin, K., Kloos, H., & Dickerson, J. (2013). Assessing selective sustained attention in 3- to 5-year-oldchildren: Evidence from a new paradigm. *Journal of Experimental Child Psychology*, *114*(2), 275–294. https://doi.org/10.1016/j.jecp.2012.07.006

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children: When too much of a good thing may be bad. *Psychological Science*, *25*(7), 1362–1370. https://doi.org/10.1177/0956797614533801

Flavell, J. H., Green, F. L., & Flavell, E. R. (2000). Development of children's awareness of their own thoughts. *Journal of Cognition and Development*, *1*(1), 97–112. https://doi.org/10.1207/S15327647JCD0101N_10

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177–190. https://doi.org/10.1037/0012-1649.40.2.177

Goodman, R. (2001). Psychometric properties of the Strengths and Difficulties Questionnaire. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(11), 1337–1345. https://doi.org/10.1097/00004583-200111000-00015

Goodman, R., & Scott, S. (1999). Comparing the Strengths and Difficulties Questionnaire and the Child Behavior Checklist: Is Small Beautiful? *Journal of Abnormal Child Psychology*, *27*(1), 17–24. https://doi.org/10.1023/A:1022658222914

Graziano, P. A., Calkins, S. D., & Keane, S. P. (2011). Sustained attention development during the toddlerhood to preschool period: Associations with toddlers' emotion regulation strategies and maternal behaviour. *Infant and Child Development*, *20*, 389–408. https://doi.org/10.1002/icd.731

Graziano, P. A., Garcia, A. M., & Landis, T. D. (2020). To fidget or not to fidget, that Is the question: A systematic classroom evaluation of fidget spinners among young children with ADHD. *Journal of Attention Disorders*, *24*(1), 163–171. https://doi.org/10.1177/1087054718770009

Hanania, R., & Smith, L. B. (2009). Selective attention and attention switching: Towards a unified developmental approach. *Developmental Science*, *13*(4), 622–635. https://doi.org/10.1111/j.1467-7687.2009.00921.x

Hirsh-Pasek, K. (2020). *A new path to education reform: Playful learning promotes 21st-century skills in schools and beyond*. 1–25.

Hojnoski, R. L., Margulies, A. S., Barry, A., Bose-Deakins, J., Sumara, K. M., & Harman, J. L. (2008). Analysis of two early childhood education settings: Classroom variables and peer verbal interaction. *Journal of Research in Childhood Education*, *23*(2), 193–209. https://doi.org/10.1080/02568540809594655

Holzman, J. B., & Bridgett, D. J. (2017). Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: A meta-analytic review. *Neuroscience & Biobehavioral Reviews*, *74*, 233–255. https://doi.org/10.1016/j.neubiorev.2016.12.032

Hu, B. Y., Wu, Z., Winsler, A., Wu, Y., & Fan, X. (2021). Teacher–child interaction and preschoolers' learning behavior in China: A piecewise growth model. *Early Education and Development*, *32*(5), 677–694. https://doi.org/10.1080/10409289.2020.1798719

Inzlicht, M., Werner, K. M., Briskin, J. L., & Roberts, B. W. (2020). Integrating models of self-regulation. *Annual Review of Psychology*, *72*(3), 319–345. https://doi.org/10.1146/annurev-psych-061020-105721

Jaeger, B. (2017). *R2glmm* (0.1.2) [R]. https://CRAN.R-project.org/package=r2glmm

James, W. (1890). Attention. In *Principles of Psychology* (Vol. 1, pp. 402–458). Henry Holt and Co.

Job, V., Friese, M., & Bernecker, K. (2015). Effects of practicing self-control on academic performance. *Motivation Science*, *1*(4), 219–232. https://doi.org/10.1037/mot0000024

Keller, J., Bless, H., Blomann, F., & Kleinböhl, D. (2011). Physiological aspects of flow experiences: Skills-demand-compatibility effects on heart rate variability and salivary cortisol. *Journal of Experimental Social Psychology*, *47*(4), 849–852. https://doi.org/10.1016/j.jesp.2011.02.004

Kennerley, S., Jaquiery, B., Hatch, B., Healey, M., Wheeler, B. J., & Healey, D. (2018). Informant discrepancies in the assessment of attention-deficit/hyperactivity disorder. *Journal of Psychoeducational Assessment*, *36*(2), 136–147. https://doi.org/10.1177/0734282916670797

Knox, A., Schneider, A., Abucayan, F., Hervey, C., Tran, C., Hessl, D., & Berry-Kravis, E. (2012). Feasibility, reliability, and clinical validity of the Test of Attentional Performance for Children (KiTAP) in Fragile X syndrome (FXS). *Journal of Neurodevelopmental Disorders*, *4*(1), 1–12. https://doi.org/10.1186/1866-1955-4-2

Korkman, M., Kirk, U., & Kemp, S. (1998). *NEPSY: A Developmental Neuropsychological Assessment*. The Psychological Corporation.

Lauth, G. W., Heubeck, B. G., & Mackowiak, K. (2006). Observation of children with attention-deficit hyperactivity (ADHD) problems in three natural classroom contexts. *British Journal of Educational Psychology*, *76*(2), 385–404. https://doi.org/10.1348/000709905X43797

Lee, W., Lee, M.-J., & Bong, M. (2014). Testing interest and self-efficacy as predictors of academic self-regulation and achievement. *Contemporary Educational Psychology*, *39*(2), 86–99. https://doi.org/10.1016/j.cedpsych.2014.02.002

Lepper, M. R., Greene, D., & Nisbett, R. E. (1973). Undermining children's intrinsic interest with extrinsic reward: A test of the "overjustification" hypothesis. *Journal of Personality and Social Psychology*, *28*(1), 129–137. https://doi.org/10.1037/h0035519

Levy, F. (1980). The development of sustained attention (vigilance) and inhibition in children: Some normative data. *Journal of Child Psychology and Psychiatry*, *21*(1), 77–84. https://doi.org/10.1111/j.1469-7610.1980.tb00018.x

Lillard, A. S. (2012). Preschool children's development in classic Montessori, supplemented Montessori, and conventional programs. *Journal of School Psychology*, *50*(3), 379–401. https://doi.org/10.1016/j.jsp.2012.01.001

Lillard, A. S., Heise, M. J., Richey, E. M., Tong, X., Hart, A., & Bray, P. M. (2017). Montessori preschool elevates and equalizes child outcomes: A longitudinal study. *Frontiers in Psychology*, *8*, 1783. https://doi.org/10.3389/fpsyg.2017.01783

Martel, M. M., Goth-Owens, T., Martinez-Torteya, C., & Nigg, J. T. (2010). A person-centered personality approach to heterogeneity in Attention-Deficit/Hyperactivity Disorder (ADHD). *Journal of Abnormal Psychology*, *119*(1), 186–196.

McCabe, L. A., Cunnington, M., & Brooks-Gunn, J. (2004). The development of self-regulation in young children: Individual characteristics and environmental contexts. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 340–356). Guilford Press.

McClelland, M. M., Tominey, S. L., Schmitt, S. A., Hatfield, B. E., Purpura, D. J., Gonzales, C. R., & Tracy, A. N. (2019). Red light, purple light! Results of an intervention to promote school readiness for children from low-income backgrounds. *Frontiers in Psychology*, *10*, 2365. https://doi.org/10.3389/fpsyg.2019.02365

McDermott, P. A., Leigh, N. M., & Perry, M. A. (2002). Development and validation of the preschool learning behaviors scale. *Psychology in the Schools*, *39*(4), 353–365. https://doi.org/10.1002/pits.10036

McDermott, P. A., Rikoon, S. H., Waterman, C., & Fantuzzo, J. W. (2012). The Preschool Learning Behaviors Scale: Dimensionality and external validity in Head Start. *School Psychology Review*, *41*(1), 66–81. https://doi.org/10.1080/02796015.2012.12087376

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81–97.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences*, *108*(7), 2693–2698. https://doi.org/10.1073/pnas.1010076108

Montessori Early Childhood Programs. (2022, March 28). American Montessori Society. https://amshq.org/About-Montessori/Inside-the-Montessori-Classroom/Early-Childhood

Montessori, M. (1918). *The Advanced Montessori Method—I: Formerly Entitled Spontaneous Activity in Education*. Clio Press.

Montessori, M. (1949). *The Absorbent Mind*. Montessori-Pierson Publishing Company.

Müller, U., & Kerns, K. (2015). Development of executive function. In S. L. Liben & U. Müller, *Handbook of Child Psychology and Developmental Science: Cognitive Processes* (7th ed., Vol. 2, pp. 1–53). Wiley-Blackwell.

Murray, A. K., Daoust, C. J., & Chen, J. (2019). Developing instruments to measure Montessori instructional practices. *Journal of Montessori Research*, *5*(1), 75–87. https://doi.org/10.17161/jomr.v5i1.9797

Murray, A. L., Booth, T., Ribeaud, D., & Eisner, M. (2018). Disagreeing about development: An analysis of parent-teacher agreement in ADHD symptom trajectories across the elementary school years. *International Journal of Methods in Psychiatric Research*, *27*(3). https://doi.org/10.1002/mpr.1723

O'Shaughnessy, M. (2016). The observation scientist. *NAMTA Journal*, *41*(3), 57–99.

Over, H. (2016). The origins of belonging: Social motivation in infants and young children. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1686), 20150072. https://doi.org/10.1098/rstb.2015.0072

Patron, E., Calcagnì, A., Thayer, J. F., & Scrimin, S. (2020). The longitudinal negative impact of early stressful events on emotional and physical well-being: The buffering role of cardiac vagal development. *Developmental Psychobiology*, dev.22066. https://doi.org/10.1002/dev.22066

Pauli-Pott, U., & Becker, K. (2011). Neuropsychological basic deficits in preschoolers at risk for ADHD: A meta-analysis. *Clinical Psychology Review*, *31*(4), 626–637. https://doi.org/10.1016/j.cpr.2011.02.005

Peterson, P. L., Swing, S. R., Stark, K. D., & Waas, G. A. (1984). Students' cognitions and time on task during mathematics instruction. *American Educational Research Journal*, *21*(3), 487–515. https://doi.org/10.3102/00028312021003487

Polderman, T. J. C., Boomsma, D. I., Bartels, M., Verhulst, F. C., & Huizink, A. C. (2010). A systematic review of prospective studies on attention problems and academic achievement: Attention problems and academic achievement. *Acta Psychiatrica Scandinavica*, *122*(4), 271–284. https://doi.org/10.1111/j.1600-0447.2010.01568.x

Rathunde, K. (2015). *Creating a Context for Flow: The Importance of Personal Insight and Experience*. 15–27.

Rathunde, K., & Csikszentmihalyi, M. (2005). Middle school students' motivation and quality of experience: A comparison of Montessori and traditional school environments. *American Journal of Education*, *111*(3), 341–371. https://doi.org/10.1086/428885

Raver, C. C. (2012). Low-income children's self-regulation in the classroom: Scientific inquiry for social change. *American Psychologist*, *67*(8), 681–689. https://doi.org/10.1037/a0030085

Reid, E. E., Diperna, J. C., Missall, K., & Volpe, R. J. (2014). Reliability and structural validity of the teacher rating scales of early academic competence. *Psychology in the Schools*, *51*(6), 535–553. https://doi.org/10.1002/pits.21769

Richards, M., & Huppert, F. A. (2011). Do positive children become positive adults? Evidence from a longitudinal birth cohort study. *The Journal of Positive Psychology*, *6*(1), 75–87. https://doi.org/10.1080/17439760.2011.536655

Robinson, K. (2001). *Out of Our Minds: Learning to be Creative*. Capstone Publishign Ltd.

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Sansone, C., & Thoman, D. B. (2005). Interest as the missing motivator in self-regulation. *European Psychologist*, *10*(3), 175–186. https://doi.org/10.1027/1016-9040.10.3.175

Santos, A. J., Vaughn, B. E., Peceguina, I., Daniel, J. R., & Shin, N. (2014). Growth of social competence during the preschool years: A 3-Year longitudinal study. *Child Development*, *85*(5), 2062–2073. https://doi.org/10.1111/cdev.12246

Saunders, B., Milyavskaya, M., Etz, A., Randles, D., & Inzlicht, M. (2018). Reported self-control is not meaningfully associated with inhibition-related executive function: A Bayesian analysis. *Collabra: Psychology*, *4*(1), 39. https://doi.org/10.1525/collabra.134

Schmidt, M., Benzing, V., & Kamer, M. (2016). Classroom-based physical activity breaks and children's attention: Cognitive engagement works! *Frontiers in Psychology*, *7*, 1474. https://doi.org/10.3389/fpsyg.2016.01474

Seufert, T. (2018). The interplay between self-regulation in learning and cognitive load. *Educational Research Review*, *24*, 116–129. https://doi.org/10.1016/j.edurev.2018.03.004

Solhjoo, S., Haigney, M. C., McBee, E., van Merrienboer, J. J. G., Schuwirth, L., Artino Jr., A. R., Battista, A., Ratcliffe, T. A., Lee, H. D., & Durning, S. J. (2019). Heart rate and heart rate variability correlate with clinical reasoning performance and self- reported measures of cognitive load. *Scientific Reports*, *9*, 1–9. https://doi.org/10.1038/s41598-019-50280-3

Standards for AMI Montessori Classrooms. (2022, April 28). Association Montessori International. https://amiusa.org/schools/standards-for-ami-montessori-classrooms/

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251–296.

Tarvainen, M. P., Lipponen, J. A., Niskanen, J.-P., & Ranta-aho, P. O. (2021). *Kubios HRV* (3.5.0) [Computer software]. Kubios.

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, *36*(2), 747–756. https://doi.org/10.1016/j.neubiorev.2011.11.009

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine*, *37*(2), 141–153. https://doi.org/10.1007/s12160-009-9101-z

Tordet, C., Erhel, S., Wodey, E., Jamet, E., Nardi, N., & Gonthier, C. (2021). The Flow Observational Grid: An observation-based solution to assess flow states. *Journal of Happiness Studies*, *22*, 3069–3089. https://doi.org/10.1007/s10902-021-00356-7

van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions. *Educational Psychology Review*, *17*(2), 147–177. https://doi.org/10.1007/s10648-005-3951-0

Vanderwal, T., Kelly, C., Eilbott, J., Mayes, L. C., & Castellanos, F. X. (2015). Inscapes: A movie paradigm to improve compliance in functional magnetic resonance imaging. *NeuroImage*, *122*, 222–232. https://doi.org/10.1016/j.neuroimage.2015.07.069

Vitiello, V. E., & Williford, A. P. (2021). Alignment of teacher ratings and child direct assessments in preschool: A closer look at teaching strategies GOLD. *Early Childhood Research Quarterly*, *56*, 114–123. https://doi.org/10.1016/j.ecresq.2021.03.004

Vostanis, P. (2006). Strengths and Difficulties Questionnaire: Research and clinical applications. *Current Opinion in Psychiatry*, *19*, 367–372. https://doi.org/10.1097/01.yco.0000228755.72366.05

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human Factors*, *50*(3), 433–441. https://doi.org/10.1518/001872008X312152

Wass, S. V., Smith, C. G., Daubney, K. R., Suata, Z. M., Clackson, K., Begum, A., & Mirza, F. U. (2019). Influences of environmental stressors on autonomic function in 12-month-old infants: Understanding early common pathways to atypical emotion regulation and cognitive performance. *Journal of Child Psychology and Psychiatry*, *60*(12), 1323–1333. https://doi.org/10.1111/jcpp.13084

Westgate, E. C., & Wilson, T. D. (2018). Boring thoughts and bored minds: The MAC model of boredom and cognitive engagement. *Psychological Review*, *125*(5), 689–713. https://doi.org/10.1037/rev0000097

Wiebe, S. A., & Sheffield, T. D. (2012). Separating the fish from the sharks: A longitudinal study of preschool response inhibition. *Child Development*, *83*(4), 1245–1261. https://doi.org/10.1111/j.1467-8624.2012.01765.x

Winsler, A., & Carlton, M. P. (2003). Observations of children's task activities and social interactions in relation to teacher perceptions in a child-centered preschool: Are we leaving too much to chance? *Early Education & Development*, *14*(2), 155–178. https://doi.org/10.1207/s15566935eed1402_2

Wu, Z., Hu, B. Y., & Fan, X. (2019). Cross-cultural validity of Preschool Learning Behavior Scale in Chinese cultural context. *Journal of Psychoeducational Assessment*, *37*(1), 125–130. https://doi.org/10.11077/0734282916651538

Xu, K. M., Koorn, P., de Koning, B., Skuballa, I. T., Lin, L., Henderikx, M., Marsh, H. W., Sweller, J., & Paas, F. (2021). A growth mindset lowers perceived cognitive load and improves learning: Integrating motivation to cognitive load. *Journal of Educational Psychology*, *113*(6), 1177–1191. https://doi.org/10.1037/edu0000631

Appendix A: Demographic Questions

Please answer the following questions by putting a checkmark by your answer:

- What is your child's date of birth?
- What gender does your child identify as?
    - Female
    - Male
    - Other (please specify):_____
- Does your child identify as Hispanic, Latinx, or Spanish origin?
    - No, not Hispanic, Latinx, or Spanish origin
    - Yes, Hispanic, Latinx, or Spanish origin
    - Do not wish to respond
    - Definitions:
        - **Hispanic, Latinx, or Spanish Origin.** A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race.
- What race does your child identify as? (You may select multiple options if you child identifies as mixed race or multiple races.)
    - White
    - Black or African American
    - American Indian or Alaska Native
    - Asian
    - Native Hawaiian or Other Pacific Islander
    - Other (please specify):

  - Do not wish to respond
  - Definitions:
    - **White.** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
    - **Black or African American.** A person having origins in any of the Black racial groups of Africa.
    - **American Indian or Alaska Native.** A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment.
    - **Asian.** A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
    - **Native Hawaiian or Other Pacific Islander.** A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

- What is the highest level of education that your child's primary caregiver has completed?
  - Less than high school diploma
  - High school diploma, GED, or equivalent
  - Some college or vocational training
  - 2-year-college degree (e.g. Associate's degree, or equivalent)
  - 4-year-college degree (e.g. Bachelor's degree, or equivalent)
  - Master's degree, or equivalent

  - Doctoral degree, or equivalent

- What is the highest level of education your child's other parent or guardian (if applicable) has completed?
  - Less than high school diploma
  - High school diploma, GED, or equivalent
  - Some college or vocational training
  - 2-year-college degree (e.g. Associate's degree, or equivalent)
  - 4-year-college degree (e.g. Bachelor's degree, or equivalent)
  - Master's degree, or equivalent
  - Doctoral degree, or equivalent
- Annual household income before taxes:
  - Less than $25,000
  - $25,000 to $34,999
  - $35,000 to $74,999
  - $75,000 to $99,999
  - $100,000 to $149,999
  - $150,000 to $199,999
  - $200,000 or more

Appendix B: Concentration Scale

The concentration scale has five items measuring different aspects of concentration. These items are chaotic (lack of order and control), intentional actions, careful and slow actions, distracted by surroundings, and concentration. Having five items rather than just a single item of concentration helps create additional variability and better accounts for the entire situation of a child concentrating. The scale was designed for raters to score each item every minute during live coding. Each of the items and how they are scored is described next in further detail.

Chaotic (Lack of Order & Control)

Chaotic should be interpreted as a lack of order and control. It is rated based on how much the child's actions follow a logical pattern; specifically, how ordered actions are in terms of having an organized method and clear sequence. This item accounts for the behavioral control the child demonstrates in regard to self-discipline and self-regulation to remain on-task. Both order and control are facilitated by the child having a clear goal, so in rating this item, it is helpful to define or have a sense of the goal that a child is working towards. The definitions for each level of the scale are:

- 1: There is a goal driving the child's actions and they move between tasks systematically. It is obvious to the coder what the goal is. There is a high level of order and control. A child should not receive a 1 if the goal is completely driven by an adult.
- 2: There is a goal driving the child's actions, but actions are not obviously systematic. There still is a higher level of order and control behind the child's actions.
- 3: The child has some sense of direction in their tasks, but the goal is unclear. There is a moderate sense of order and control.

- 4: There is a minimal sense of direction in the child's actions. If there is a goal it is not obvious and does not seem to be driving the child's actions. There is minimal sense of order and control.
- 5: There is no sense of direction, order, or control in the child's actions. They do not seem to be using any objects for their original or a newly intended purpose.

Intentional Actions

Intentional actions is defined by the specific goal that a child is working towards. The goal here is a self-made goal. Materials do not need to be used for their original purpose and this item should not be marked down based on correctness, only rated based on the goal the child appears to have defined. To score high on this item, the child should have not just a goal, but also a sense of purpose, that is a clear aim motivating their actions. The specific levels are defined as:

- 1: The child lacks purpose in their work and does not use materials in a manner that will help them achieve their goal.
- 2: There is minimal purpose behind a child's actions. Materials are not used in a way to help the child achieve their goal.
- 3: The child at times completes their work with purpose, but not consistently. Materials are at times used in a way to help them achieve their goal.
- 4: The child mostly completes their work with purpose. Materials are used in a way to help them achieve their goal.
- 5: The child completes their work with clear purpose. Materials are used in a way to help them achieve their goal.

Careful and Slow Actions

Careful and slow is a measure of how methodical the child is being in their actions. This incorporates mistakes, so if multiple mistakes are made this is a sign of a lack of care. This item also accounts for the pace of actions and scores should be decreased for particularly rushed actions. In accounting for correctness, children's ability should be taken into account. For example, a child who struggles to color in the lines should not be marked down if the child still shows care and is doing the actions slowly in an attempt to remain within the lines. The specific levels are:

- 1: Actions are rushed and sporadic. There is lack of care and control in their actions.
- 2: Actions are often rushed, but there is sometimes care placed in actions. Control is low.
- 3: The work is done at an average pace, but actions may be occasionally sporadic or rushed. Some care is placed into their work, and few mistakes may occur. The child is mainly in control of their actions.
- 4: There is a high level of care placed in the majority of actions. A singular mistake may occur. Actions are mainly slow, but definitely not rushed. Actions must be slow enough to maintain accuracy. The child is almost completely in control.
- 5: Actions are slow and methodical. There is an obvious sense of care and control in the work being completed.

Distracted by Surroundings

This item is a measure of the amount of distractibility that the child demonstrates. In rating this item, new materials are not considered a distraction if the child could be considered moving onto a new activity. For example, if the child puts away the materials for an activity before moving onto a new one, this is not distraction. However, if the child leaves an activity

without clearly ending it, the new activity counts as a distraction. The specific definitions of each level are:

- 1: A child is fully engaged in the task with under 5 s of distraction.
- 2: A child is mainly engaged in the task with little distraction. The child does not leave the object of engagement. Around 10 s of distraction.
- 3: Moderate distraction is observed, but the child does not leave the object of engagement. Around 20 s of distraction.
- 4: High levels of distraction are observed causing extended periods of disengagement. Around 30 s of distraction.
- 5: The child falls out of engagement due to heightened distraction and/or the child never engages in the activity/work due to distraction. More than 30 s of distraction.

Concentration

The final scale item is simply a measure of global concentration and is a judgment of concentration across the observed minute. The specific levels are:

- 1: There is a lack of focus. There are no signs of engagement.
- 2: There is little focus on the work, but some engagement is present.
- 3: The child is generally attentive to the work, attention may switch between subcomponents of the task. The child is moderately engaged.
- 4: The child keeps attention on the task and is clearly engaged in the material.
- 5: The child is intensely focused and engaged in their work. The child is actively working to be engaged. The child appears to be in a state of flow.

Examples

In understanding this scale, it may be helpful to have a few examples of how these codes would work for some typical classroom situations. First, an example of clear concentration. A child is painting, singing to herself while working, and seems almost lost in her work. She is very carefully selecting each color and is using gentle brush strokes. This child should receive a 1 for chaotic, as she has a clear goal and demonstrates a high level of order and control. She should receive a 5 for intentional actions, as again there is a clear goal that she is purposefully moving towards and is using materials to help achieve that goal. She should receive a 5 for careful and slow actions, as her painting is done with extreme care. She is not distracted from her work by her surroundings, so should receive a 1 in this category. Finally, she should receive a 5 for concentration, as she is clearly concentrating. Although the child's singing may not be related to the painting, since she is clearly concentrated and working towards her goal, this is not considered distraction.

Another situation commonly seen in classrooms is a child reading in a corner who seems to be flipping through the pages of a book too quickly to be actually reading, but is very focused on flipping pages. This child should receive a 2 for chaotic, as he has a clear goal even if it may not be immediately clear to the rater whether the goal is looking at the pictures, practicing flipping pages, or something else. He should receive a 5 for intentional actions, as the page flipping is clearly being done with an end goal in mind and the book is being used to accomplish this goal. He should receive a 3 for careful and slow actions, as he is working at a fairly fast pace. The child is in control of his actions, just doing so at a rapid pace and more quickly than may be typical. Since the child is focused on the book and is not distracted by surroundings, he should receive a 1 in this category. He should receive a 4 in concentration, as he is focused on

work and attending to work, but not so much that he appears in a state of flow. Clear and consistent engagement makes this a 4 instead of a 3.

Finally, a situation where concentration is perhaps a bit lower. A child has materials for an activity out in front of her, but although she touches the materials, her attention is clearly on a peer sitting next to her and she expresses desire to work with what her peer is working on, but is not allowed to as her peer is doing that activity right now. This child would receive a 3 for chaotic, as there is purpose in her actions through observing her peer, however there is a lack of higher order and control based on her not doing the activity in front of her. She would receive a 4 for intentional actions, as her intention to do the activity her peer is working on is clearly demonstrated. She would receive a 3 for careful and slow actions, as her work is of average pace. She is highly distracted from the work in front of her by her peer's work, so would receive a 5 for distracted by surroundings. She would receive a 1 for concentration, because she is not at all concentrated on the activity she is currently doing; even though her actions have some sense of a goal, they are not directed at the activity she currently has out.

Appendix C: Statue Task

The NEPSY statue task has children stand as if holding a flag for 75 s. I added a second trial using comparable directions, administration, and scoring. This second trial had children stand like a star, with feet slightly wider than shoulder width apart, and hands spread out and to the sides, elbows tucked in by the body. Directions for the second trial were the same as for the first simply replacing “like a statue holding a flag” for “still like a star.”

For believability, the order of distractions on the second trial was altered: at 10 s the researcher tapped the clipboard on the table once, at 20 s the researcher dropped a pencil on the table, at 30 s the researcher coughed twice out loud, at 50 s the researcher said “oops”, and at 75 s the experimenter ended the trial by saying, “time’s up.”