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Links Between Screen Time, Montessori Preschool Exposure, and Working Memory

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Walden University
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Abstract

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

A high-quality, foundational education offers lifelong benefits for young children. The problem is that working memory in pre-school-aged children is declining and could be impaired by the extraneous cognitive load imposed during engagement with screen media apps and/or preschool programs. Although the pedagogical practices associated with Montessori preschool programs have been found supportive of cognitive load germane to learning and improved working memory, they have not been fully considered in relation to preschoolers' screen media use. The cognitive load created by screen media apps could affect their usefulness as learning tools. The purpose of this quantitative study was to discover any links between preschoolers' working memory function; passive, active and/or total screen time; and Montessori preschool program exposure. The study was conducted through the lenses of the executive function construct and cognitive load theory. Data on children's working memory and screen time were collected from a convenience sample of 60 parents: 30 Montessori, and 30 non-Montessori. Parents completed a one-time administration of BRIEF-P and Screen Time Questionnaires on behalf of their child. Findings from multiple regression analysis indicated no link between Montessori preschool exposure or parent-controlled total, passive, or active screen time; and young children's working memory, although a significant inverse relationship was found between active screen time and Montessori exposure. The results could inform virtual and hands-on pedagogical protocols that support working memory and improve pre-school-aged children's learning and preparation for life. Each incidence of successful learning for a precious young child is a positive social change.

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Dedication

This dissertation is dedicated to my children, Norene, Angela, Paul, and Jacoba, and the other children I have cared for and taught. I love you. That is the reason I have struggled to become a better person and tried to stay focused on the most important work.

Acknowledgments

I gratefully acknowledge the patience and guidance given by my dissertation chair, Dr. Jennifer Courduff, and methodologist, Dr. Jennifer Lapin. Thank you for helping me become more capable and allowing me to pass through this gateway to a more powerful voice.

I am also grateful for assessments that improved the quality of my dissertation study by university research reviewers Dr. Shereeza Mohammed and Dr. Kimberley Alkins, and form and style reviewer Dr. Tara Kachgal.

I will use everything I have gained during this eye-opening journey to empower young children and support their parents and other teachers.

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Chapter 1: Introduction to the Study

This study contributes new knowledge to the field of early childhood education through an examination of the effects on learners of combining new technological tools with educational practices already found to be effective. Through the lens of cognitive load theory (Sweller et al., 2011, 2019), I specifically examined the effect on working memory function in pre-school-aged children of a learning environment combining century-old Montessori education and use of decade-old passive and/or active screen media technology. Research indicates the lifelong benefits to human beings of a high-quality foundational education as young children (Bakken et al., 2017; Barnett, 1995; Christakis, 2017; Dodge et al., 2016; Gormley et al., 2017; Kim & Park, 2020; Kulic et al., 2019; Shafiq et al., 2018; Thompson, 2018; Weiland & Yoshikawa, 2013). In this study, I gathered and analyzed data on how a recent and evolving learning environment that includes young children's exposure to Montessori versus non-Montessori preschool combined with time spent using screen media at home affected the children's working memory function. It provides new knowledge on a phenomenon that has been understudied as it concerns the pre-school-aged learning population.

Human technological advances have risen sharply in the last half century. For example, scientists launched a human piloted rocket-propelled spacecraft to the surface of the moon on July 12, 1969, even though rudimentary technology offered only a "50-50 chance of making a safe landing" (Malley, 2011,19:00; see also Kendall, 2019). Also, human ingenuity does not stop after groundbreaking technology is developed for a specific purpose. People quickly apply new knowledge and inventions to other existing problems in innovative ways. For example, space travel pursuits yielded Teflon-coated fiberglass developed for spacesuits that is now used worldwide as a permanent roofing material, and the design for the space shuttle's main engine fuel pump was adapted to create a new artificial heart pump (J. R. Wilson & Ross, 2008).

Fast-moving technology developed for intimate and mass communications has also dispersed rapidly into human culture and been adapted for purposes such as purveying news, connecting loved ones through distance and time, and providing entertainment. Mass listening initially introduced with the radio (Marconi, 1895) evolved to simultaneously listening to and viewing content via television (Farnsworth, 1930). In the recent decade, a myriad of stationary and portable screen media devices, springing from the invention of Web 2.0 interoperability (DeNucci, 1999; Nations, 2022), have allowed for not only listening to and viewing content but interacting with it, both privately and publicly. Each of the mobile communication computer devices held in the pockets of 83% of the world population today have 1 million times the RAM, 7 million times the ROM, and 100,000 times the processing power of the computer guidance system that landed two men on the surface of the moon in 1969 (Kendall, 2019; Turner, 2022).

Those working to educate human beings have seized upon these new technological tools. Educators continuously innovate ways to harness and adapt newly invented technology to support deep and escalated learning (Cuban, 1986). Thomas Edison predicted in 1913 that motion pictures would replace textbooks and allow knowledge to be assimilated by learners with "one hundred percent efficiency" (F. J.

Smith, 1913, p. 24). Educator experience has revealed, however, that "improving education is not a simple matter of adopting a new technology" (Sweller et al., 2011, p. 222) because understanding of how students learn from technological tools lags far behind the technology advances themselves (Chandler, 2004; Hegarty, 2004; Sweller et al., 2019). It has fallen to educational innovators who "tinker" (Tyack & Cuban, 1995, p. 1) with the tools and resources available to them and researchers who study the effects of these tools and protocols to determine which instruments support human learning and why (see also Biasi et al., 2022). In Chapter 1, I provide an overview of the study, which includes background information, the problem and purpose of the study, the research question (RQ) and hypotheses, overviews of the theoretical foundation and nature of the study, and definitions of key terms. I also discuss the assumptions, scope and delimitations, limitations, and significance of the study. The results of the current study, which was conducted to address a gap in the literature, could inform pedagogical protocols that support ideal cognitive load and working memory function.

Background

Both seminal and current research indicate that pre-school-aged children continuously learn during all experiences and in all surroundings (Bus et al., 2020; Caldwell, 1967; Christakis, 2017; Montessori, 1909/1964; Piaget, 1970; Plante & Gómez, 2018; Vygotsky, 1962; Woldehanna & Araya, 2017). Therefore, the places and activities they spend time in are part of every young child's early childhood learning environment (Christakis, 2017; Montessori, 1949/1989; Niklas et al., 2021). Electronic data delivered through a device with a viewing screen, or *screen media device*, is attractive to curious pre-school-aged children, and children have gained widespread use of screen media devices owned and controlled by their parents (Bus et al., 2020; Montessori, 1929/1970; Ribner et al., 2021; Rideout, 2017; Sharkins et al., 2016; Slutsky et al., 2021; Swartz, 2017).

Studies have shown that exposure to screen media changes the way pre-school-aged children explore their surroundings (Elkind, 2016; Slutsky & DeShetler, 2017; Slutsky et al., 2014, 2021). The result is the generation of an innovated learning and instruction environment for them (Beatty & Egan, 2020; Beschorner & Hutchison, 2013; Bus et al., 2020; Herodotou, 2018; McManis & Gunnewig, 2012; Neumann, 2016). Immersion in this environment can come at a cost. For instance, Csibi et al. (2021) discovered preschoolers to be a group at highest risk for smartphone-related addictive behavior (see also Domoff et al., 2019a). Studies have shown screen media to affect a user's awareness of outside surroundings. Regardless of the type of outside environment in which a user is located, the learning environment created within a screen media application is uniform for all users (Khan et al., 2019; Schindler et al., 2017). Indeed, headphones are frequently used to further tune-out sounds or activity going on outside the learning environment created by a screen media application (Hagood, 2011). This phenomenon has spurred the development of apps intended to increase learner concentration by taking advantage of the attention-focusing properties of screen media devices (Jeon et al., 2012; Wilmer et al., 2017). Whenever a young child engages with screen media apps, the learning environment offered by them replaces physical and mental exploration of the natural world (Leppänen et al., 2020).

Research also shows that the cognitive load (Sweller et al., 2011, 2019) created by a screen media application either supports or hampers working memory function and affects the usefulness of the application as a learning tool (C.-C. Chen & Huang, 2020; Huber et al., 2018; Lillard et al., 2015; L.-Y. Lin et al., 2015; Mayer, 2017). Longitudinal studies have associated both missing and added components in formal and informal preschool learning environments with decline in pre-school-aged children's performance on tests of working memory (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015; Zhao et al., 2022). However, some pedagogical practices engineered into century-old Montessori (1909/1964) learning environments have already been shown through research to support cognitive load germane to learning and to improve working memory function (Diamond & Lee, 2011; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard, 2017; Lillard & Else-Quest, 2006; Lillard & Heise, 2016). These educational practices include, for example, purposeful reduction of outside distractions and focus of tactile, multisensory attention on one new concept at a time (Blakey & Carroll, 2015; H.-H. Choi et al., 2014; Ginns et al., 2020; Paas & van Merriënboer, 2020; Sepp et al., 2019; Sweller et al., 2011). Yet a gap in the literature existed on the association, if any, between the working memory function of preschoolers exposed to a learning environment with both parent-controlled passive, active, and/or total screen time, and Montessori or non-Montessori preschool education.

Problem Statement

The problem is that working memory function is declining in pre-school-aged children and can be impaired by the extraneous cognitive load to working memory imposed during screen time and/or preschool programs (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015; Zhao et al., 2022). Little is known about how a learning and instruction environment encompassing both Montessori education and passive, active, and total amounts of screen time affects cognitive load and therefore working memory function of pre-school-aged children. Seminal and recent research has shown that rapid learning occurs during a child's preschool years and creates a foundation that affects the ease and success of subsequent learning (Kim & Park, 2020; Kulic et al., 2019; Piaget, 1970; Shafiq et al., 2018; Thompson, 2018; Vygotsky, 1962; Woldehanna & Araya, 2017). Therefore, innovative early childhood educators (both teachers and parents) have tried to incorporate potentially beneficial pedagogical tools and practices into their work with preschool children (Tyack & Cuban, 1995). For example, the unique materials and methods developed and introduced in the first Montessori preschool in 1907 resulted from Maria Montessori's careful observation of preschool children and her passion for improving the lives of the adults they would become (Montessori, 1909/1964; Standing, 1957/1998).

Since their invention, educators and curriculum developers have consistently adapted screen media devices with both passive and active applications for use by pre-school-aged children (Bus et al., 2020; Lovato & Waxman, 2016; Slutsky et al., 2021).

Early examples of screen media created specifically for children at home include (a) children’s cartoons, which were first televised in 1960 (Hanna & Barbera, 1960-1966), and (b) preschool education on television beginning with *Sesame Street* in 1969 (Cooney & Morrisett, 1969-present). iPad tablet computers released in 2010 were quickly integrated into young children’s pastimes because they were small enough to be carried and manipulated by a child’s hands (Bort, 2013). These new potential learning tools have become globally available to preschoolers through their parents, with 83% of worldwide households owning a smartphone in 2022 (IGI Global, 2021b; O’Dea, 2021; Ribner et al., 2021; Rideout, 2017; Sharkins et al., 2016; Swartz, 2017; Turner, 2022). As these technological advances have unfolded with increasing speed, the discipline of learning, instruction, and innovation has arisen from educational researchers’ need to discover how educational innovators successfully combine new pedagogical tools and practices with already effective, tried-and-true methods (Walden University, 2021). Recognizing that “creativity and critical thinking are driving forces behind human innovation and progress,” (Walden University, 2021, para. 1) researchers in the discipline of learning, instruction, and innovation have sought to “harness these processes to lead bold, new approaches to learning and development, build hands-on skills relevant to each step of the learning process, [and] explore how to best meet the needs of today’s global community of learners” (Biasi et al., 2022, p. 537). Researchers in the field of learning, instruction, and innovation are perched to discover how the power of creativity and critical thinking, inherent in each human being, can be supported and spurred-on by innovative screen media technological tools and high-quality pedagogical programs for young children.

However, according to the cognitive load theory, an educational tool or practice is only effective if it creates an ideal amount of cognitive load, neither under-stimulating nor overloading a learner's working memory (Sweller et al., 2011, 2019). The cognitive load must be germane to the learning at hand rather than extraneous to it (Sweller et al., 2019). Although some research has shown Montessori pedagogy to be effective at supporting ideal cognitive load and producing lasting benefits to learning (Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard & Heise, 2016), research has been mixed about the effectiveness of screen media devices as pedagogical tools for pre-school-aged children (Elkind, 2016; McHarg et al., 2020a, 2020b; Slutsky & DeShetler, 2017; Slutsky et al., 2021; Veraksa et al., 2021; Z. Zhang, Adamo et al., 2022; Zhao et al., 2022).

Purpose of the Study

The purpose of this quantitative study was to examine the working memory function of preschoolers, in Montessori and non-Montessori learning environments, who engaged in varying amounts of parent-controlled passive, active, and total screen time for any relationship between preschoolers' working memory function (DV), Montessori preschool program exposure (IV), and amount of parent-controlled passive (IV), active (IV), and/or total screen time (IV).

Research Question and Hypotheses

The RQ, null hypothesis (H_0) and alternate hypothesis (H_a) read as follows:

RQ: Is there a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time; and working memory function in pre-school-aged children (DV)?

H$_{0:}$ There is no relationship between Montessori preschool program exposure, weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time (IV); and working memory function in pre-school-aged children (DV).

H$_{a:}$ There is a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time (IV); and working memory function in pre-school-aged children (DV).

The independent variables (IV) were (a) amount in days of Montessori preschool program exposure, (b) weekly amount in minutes of parent-controlled passive screen time, (c) weekly amount in minutes of parent-controlled active screen time, and (d) weekly amount in minutes of parent-controlled total screen time. The dependent variable (DV) was working memory function in preschool children. I measured working memory function based on parent responses on the Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P) questionnaire (Gioia et al., 2003b) converted into *T* scores. The BRIEF-P, published by Psychological Assessment Resources (PAR), is a standardized questionnaire adapted from the Behavior Rating Inventory of Executive Function (2000) for use by parents of pre-school-aged children (Gioia et al., 2003b). The

BRIEF-P enables assessment of executive function behaviors at home. Reliability, validity, and diagnostic utility for the BRIEF-P have been established and verified with peer-reviewed research studies (Gioia et al., 2003a; Greene et al., 2019; Herreras, 2019; Isquith et al., 2004, 2005; San Diego et al., 2022; H. Schneider et al., 2020; Sherman & Brooks, 2010). The completed BRIEF-P allows professionals to measure five areas of executive brain function based on parent responses to the questionnaire: (a) inhibit, (b) shift, (c) emotional control, (d) working memory, and (e) plan/organize (Gioia et al., 2003b). However, the current study incorporated only the calculated scores from the BRIEF-P's working memory subscale. Permission to use the BRIEF-P for this study is in Appendix A. Appendices B and C, respectively, contain the English- and Spanish-language versions of sample questions from the BRIEF-P.

I gathered data on preschoolers' school name; age; Montessori or non-Montessori preschool attendance; and amounts of parent-controlled passive, active, and total screen time. To gather these data, I created and administered an instrument called the Screen Time Questionnaire to parents. The instrument was validated by an expert reviewer. The English version of the Screen Time Questionnaire is in Appendix D with a Spanish translation in Appendix E.

Theoretical Foundation for the Study

The two theoretical bases for this study were the cognitive load theory (Sweller et al., 2011, 2019) and the construct of executive function (Lezak, 1982). In the 21st-century information age, most people, including young children, interact with the world via electronic screen media, so their construction of meaning is directly affected by screen time (Leppänen et al., 2020). The term *executive function* indicates a construct that links together a group of higher-level cognitive abilities that come to play during goal-directed behavior (Lezak, 1982, p. 281). One executive function that is critical to, and affects, all others is working memory (Ahmed et al., 2019, 2022; McKenna et al., 2017; Rothlisberger et al., 2013). The cognitive load theory (Sweller et al., 2011, 2019) offers insight on supporting working memory function and thereby supporting learning by providing an ideal amount of new information to the learner. Because the working memory can process only about four pieces of information at one time, an ideal amount of new, relevant information, or, in other words, an ideal amount of cognitive load to the working memory, supports learning. According to the cognitive load theory, when too much new information bombards a learner at once, the overload causes all learning to shut down.

Cognitive load theory is relevant in Montessori education, which encompasses carefully developed methods and materials that reduce the unnecessary or extraneous cognitive load on a young child's working memory (Bagby et al., 2012; Courtier et al., 2019; Denervaud et al., 2019; Gilder, 2012; P.A. Kirschner et al., 2011; Lillard & Else-Quest, 2006; Lillard & Heise, 2016; Paas & Sweller, 2012; Sweller et al., 2011, 2019; van Merriënboer & Sweller, 2005). Cognitive load theory is also relevant in determining the effects of different passive or active screen media applications on the learning of young children (de Jong, 2010; Lillard et al., 2015; Mayer, 2017; Rhodes et al., 2020; Squire, 2011). Cognitive load theory and working memory executive function provided a framework for this investigation of whether combined Montessori education exposure and varying amounts of passive, active, and total screen time influenced a pre-school-aged child's working memory function.

The RQ was, Is there a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time; and working memory function in pre-school-aged children (DV)? To answer the RQ, I collected data from the participating parent of each pre-school-aged child on (a) the child's working memory function, (b) hours and minutes of parent-controlled passive, active, and total screen time engaged in by the child for 1 week, and (c) the child's Montessori preschool program exposure as measured by days of attendance. Using IBM SPSS Statistics (Version 28; SPSS-28), I performed multiple regression analysis to determine the presence of any relationships between working memory function; passive, active, and total screen time; and days of exposure to a Montessori preschool program. According to cognitive load theory, a relationship between working memory function; Montessori preschool exposure; and amount of passive, active, and/or total screen time could indicate whether the screen time or Montessori preschool exposure created germane or extraneous cognitive load on the child's working memory and influenced their working memory function (Sweller et al., 2011, 2019). More detailed explanations of executive function, working memory, Montessori education, and particularly cognitive load theory are offered in Chapter 2.

Nature of the Study

This study was a quantitative survey investigation of preschool parents and children. To collect data, I administered a cross-sectional survey from a convenience sample of parents. The survey was comprised of (a) the Screen Time Questionnaire and (b) the BRIEF-P. The Screen Time Questionnaire, a survey instrument that I designed, was used to collect data from each parent on their child's (a) age, (b) school name, (c) number of days of school absence, (d) amount in hours and minutes of passive screen time over 1 week, (e) amount in hours and minutes of active screen time over 1 week, and (f) amount in hours and minutes of total screen time over 1 week. The Screen Time Questionnaire was validated by the expert review of the Walden University quantitative methodologist serving on the committee for this study. I used the BRIEF-P (Gioia et al., 2003b), which also was completed by parents, to assess the working memory function of children. Walden University Institutional Review Board (Walden University IRB) did not allow me to have contact with children, and the partnering school district did not allow me to involve teachers with data gathering for this dissertation research. Therefore, parents were the only authorized data gatherers for the study. Fortunately, the BRIEF-P, filled out by parents, is a widely used and accepted instrument for gathering data on pre-school-aged children's executive function, including working memory (Gioia et al., 2003a; Gioia et al., 2003b; Isquith et al., 2004, 2005; San Diego et al., 2022; H. Schneider et al., 2020; Sherman & Brooks, 2010).

All study participants were parents of pre-school-aged children who were enrolled in magnet school programs in the largest public school district in their state. Both preschool programs were located in the same medium-sized, midwestern U.S. city. I asked all participants to complete both questionnaires, but I did analyze data from participants who completed only one questionnaire. Half of participating families attended a magnet Montessori preschool program and the other half a magnet non-Montessori preschool program. Both magnet programs were populated with applicants from urban, suburban, and rural areas of the school district who were randomly selected for enrollment at each school during a publicly held lottery drawing.

The Montessori and non-Montessori programs were both nationally accredited and reviewed by overseers with equivalent standards. The Montessori preschool program was accredited by the American Montessori Society (AMS; 2022), which was in turn accredited by the Montessori Accreditation Counsel for Teacher Education (MACTE; 2022) and reviewed and overseen by the U.S. Department of Education (USDE; 2022). The non-Montessori preschool program was accredited by the National Association for the Education of Young Children (NAEYC; 2019), which was reviewed and overseen by the Council for Higher Education Accreditation (CHEA; 2019). Accreditation offered verification that congruent standards for teacher certification and developmentally appropriate early childhood education practices were followed by both schools. The student population and use of developmentally appropriate practices were equivalent between the two participating programs. The difference between the programs was that one followed Montessori pedagogical practices, and the other followed non-Montessori developmentally appropriate practices.

I investigated some factors that could impact a young child’s working memory function. The findings address a gap in the research literature by revealing either connection or lack of connection between several variables. The variables are (a) working memory function; (b) Montessori preschool exposure; and (c) amount of parent-controlled passive, active and/or total screen time (see Fabri & Fortuna, 2020; Ginns et al., 2016; Huber et al., 2018; Lillard et al., 2015; Sharkins et al., 2016; N. Veraksa et al., 2021; Z. Zhang, Wiebe et al., 2022; Zhao et al., 2022).

I might have assessed cognitive load in several ways, including via questionnaires about mental expenditure administered immediately after an activity or pupil dilation measurements taken during learning activity (Duchowski et al., 2018; Korbach et al., 2017, 2020; Paas et al., 2010; Sweller et al., 2011). However, all measures of cognitive load required direct researcher access to pre-school-aged children, which Walden University IRB regulations did not allow for this dissertation study. Ideal cognitive load is equivalent to a learner’s working memory capacity, and the terms *working memory* and *cognitive load* “are used synonymously” by seminal cognitive load theorists (Sweller et al., 2011, p. 45). As such, I used working memory as measured by parent responses on the BRIEF-P (Gioia et al., 2003b) as a proxy measure for cognitive load in this study.

Definitions

The independent variables, dependent variable, and terms with multiple or ambiguous meanings important to the clarity of this research report are defined in this section:

Active screen time: Media use that involves mentally or physically engaging in screen-based activities, such as playing video games or completing homework on a computer (Sweetser et al., 2012).

American Montessori Society (AMS): The largest accreditor of Montessori educational programs in the world. AMS is governed and accredited by MACTE, which is overseen by the USDE. AMS (2022) enacts strict standards, protocols, and procedures for accreditation of Montessori schools including one-on-one work with teachers and administrators and onsite visits.

Cognitive load: The amount of information the working memory can hold at one time. All information must be paid attention to and processed in the working memory before it is permanently stored in the long-term memory (Sweller et al., 2011). If the presentation of new learning creates too heavy a cognitive load, learning is slowed down or stopped, and tasks go unfinished (Sweller et al., 2019).

Cognitive load effects: The effects that different instructional strategies have on learning outcomes because of the levels of extraneous, intrinsic, and germane cognitive load they impose on a student's working memory (Sweller et al., 2011). Specific cognitive load effects are defined and described in Chapter 2.

Cognitive load theory: A theory created by John Sweller (1988) that states that because working memory has a limited capacity, instructional methods should be developed that avoid overloading it with information or distractions that do not contribute directly to the desired learning (Sweller et al., 2011).

C*ognitive theory of multimedia learning*: A theory developed by Richard Mayer (2014) that details specifically how a combination of pictures and words affects cognitive load and learning. The cognitive theory of multimedia learning incorporates cognitive load effects discovered through research using the lens of seminal cognitive load theory (Sweller, 1988) combined with learning through multimedia, largely with electronic, screen media devices and applications.

Council for Higher Education Accreditation (CHEA): An organization that oversees and promotes academic quality through formal recognition of higher education accreditation bodies that meet CHEA standards of "academic quality, accountability, transparency and effective organization and practice" (CHEA, 2019, p. 2). CHEA approval "serves as evidence to the public that the recognized accrediting organizations are credible sources of judgment about academic quality" (CHEA, 2019, p. 2). CHEA approval is not tied to involvement in any federal program or receipt of federal grant money.

Executive function: A construct linking together a group of higher-level cognitive abilities important for completing goal directed behavior (Lezak, 1982). These higher-level cognitive abilities include (a) working memory, (b) response inhibition, (c) sustained attention, (d) task initiation and switching, (e) emotional control, (f) planning and organizing, (g) flexibility, (h) metacognition, (i) goal directed persistence, and (j) time management (Barkley, 2012).

Extraneous cognitive load: Unnecessary information built into the way tasks and information are presented to a learner, or the instructional design, that overloads a student's working memory and inhibits learning (Sweller et al., 2019).

Germane cognitive load: The work required to create a mental schema, or organized category of information, for permanent storage of knowledge in a learner's brain (Sweller et al., 2011).

Intrinsic cognitive load: The complexity of new learning, or more specifically, how many interacting elements are inherent in the learning content. Learning content with an intrinsic cognitive load having low element interactivity requires fewer working memory resources than learning content with high element interactivity (Sweller et al., 2011).

Learning environment: The context within which a human being learns including physical environment; relationships; curriculum; teaching; assessment of learner progress; personal health; teacher competence, preparation, and support; leadership and management of teachers and physical facilities; collaboration with student families; and collaboration with encompassing communities (NAEYC, 2019).

Likert-type scale: A type of rating scale that is used to measure agreement, frequency, attitudes, opinions, quality, and importance. Three to seven items are usually used in the scale (Glen, 2015). Here is a scale used in this study:

1 = *Never*, 2 = *Sometimes*, and 3 = *Often*.

Magnet school programs: Free public schools that allow students to concentrate on specialized themes at school, such as New Tech; Montessori; Science, Technology, Engineering, Art, and Math (STEAM); or International Baccalaureate (National School Choice Week Team, 2021).

Media: Communication channels through which individuals disseminate news, music, movies, education, promotional messages, and other data (Market Business News, 2019).

Mobile screen media device: A portable, handheld computer with a touch screen that is small enough to be held in one or both hands and has computing, communication, information, internet, and interconnectivity capabilities similar to bigger computers (Techopedia, 2021).

Montessori Accreditation Council for Teacher Education (MACTE): A body that accredits Montessori teacher education programs and is overseen by the USDE (MACTE, 2022).

Montessori pedagogy: The method and practice of teaching using the step-by-step procedures, hands-on learning materials, and philosophical mindset created by Maria Montessori (1914/1965) and currently standardized and perpetuated by MACTE (2022) accredited teacher training programs and schools. This definition also includes Montessori education and practices.

Montessori preschool: An early childhood education program serving children between 3 and 6 years of age that holds current accreditation from a Montessori school accreditation organization governed by MACTE (2022).

National Association for the Education of Young Children (*NAEYC*): The largest accreditor of early childhood programs in the world (NAEYC, 2019). The association provides guidelines with strict standards, protocols, and procedures for accrediting early childhood programs to ensure that developmentally appropriate practices are followed in accredited programs. NAEYC is overseen by CHEA, an entity that is recognized the U.S. government (NAEYC, 2019).

Non-Montessori preschool: A non-Montessori early childhood program serving children between 3 and 6 years of age that is currently accredited by the NAEYC (2021). It is not accredited by any MACTE-governed accreditor.

Normalization: A term coined by Maria Montessori to describe the condition when a pre-school-aged child's movements and observable intentions exhibit coordination, concentration, order, and independence (Montessori, 1909/1964, 1948/1967, 1949/1972).

Passive screen time: Media exposure that involves sedentary screen-based activities and passively receiving information from screen-based media, such as watching TV or videos (Sweetser et al., 2012).

Pre-school-aged child: A child between 3 and 6 years of age who has not yet entered first grade (Department of Education, 2021).

Preschool program: An educational program serving children between 3 and 6 years of age who will not turn 7 years old during the current school year, when school attendance is compulsory (Department of Education, 2021).

Screen media: Media that is produced for or distributed via the screen, including cinema, TV, and computer screens, and small screens on smartphones and other handheld devices such as tablets (Harrison, 2015; IGI Global, 2021b).

Screen media application: Application software that can be used by a computer, mobile device, or tablet to perform useful tasks. It can be called a software application, application program, application or app (IGI Global, 2021a).

Screen media device: Any electronic device having a visual screen through which visual screen media is distributed, including cinematic, television, and computer screens, and the small screens on a smartphone and other handheld devices (IGI Global, 2021b).

Screen time: Time spent using a screen media device and engaging with its content including, but not limited to, television viewing, computer use, game play, and educational activity (Domingues-Montanari, 2017).

Total screen time: The total amount of time spent using a screen media device and engaging with its content including, but not limited to, television viewing, computer use, game play, and educational activity (Domingues-Montanari, 2017).

U.S. Department of Education (USDE): A department in the Cabinet of the United States government established by Congress in Public Law 96-88 (Department of Education Organization Act, 1979) and headed by the United States Secretary of Education. The USDE "approves agencies that the Secretary of Education determines to be reliable authorities as to the quality of education or training provided by institutions of higher education and publishes a list of nationally recognized accrediting agencies" (USDE, 2021, para. 3). To be eligible for approval by the USDE, an accrediting agency must have a link to a federal program (USDE, 2022).

Web 2.0: A term first coined by DeNucci (1999) that gained popular use about 2004. Web 2.0 describes the second stage of internet development when, through the combined innovations of thousands of worldwide web developers, static web pages were transformed to interactive pages with user-generated content, collaboration, and communication, as in, for example, wikis and social media (Nations, 2022).

Working memory: A limited-capacity executive function used for immediately storing, integrating, and manipulating about four to seven chunks of information at one time (G. A. Miller, 1956).

Assumptions

I surveyed participating families whose pre-school-aged children attended magnet Montessori or non-Montessori preschool programs in the same public school district encompassed within a 20-mile radius in a medium-sized, midwestern U.S. city. The pre-school-aged students were randomly selected from all applicants to participate in each magnet program through a lottery drawing. As researcher, I accepted the following assumptions, which could not be proven true within the confines of the study.

1. The children in families participating in the study were similar to other children their age, and therefore results of this study can be generalized to the larger population of pre-school-aged learners.
2. The parents filling out the BRIEF-P and Screen Time Questionnaire were honest and straightforward.
3. Parents filling out the BRIEF-P and Screen Time Questionnaire understood the questions well enough to answer them accurately.

4. The BRIEF-P was reliable and valid, as indicated in previously published validity and reliability studies (Isquith et al., 2004, 2005; Sherman & Brooks, 2010).
5. The Montessori preschool program enrolling participants was following the guidelines for authentic Montessori classroom practices as outlined by their accreditors, AMS (2022) and MACTE (2022), overseen by the USDE (2022), and described in Chapter 2 of this study.
6. The non-Montessori preschool program enrolling participants in this study was following the guidelines for developmentally appropriate practice as outlined by their accreditor, NAEYC (n. d.), and overseen by the CHEA (2019).
7. The Screen Time Questionnaire was valid and reliable as attested to by an expert reviewer.
8. The SPSS-28 multiple regression analysis protocol that was used to analyze the data of this study was robust enough to provide valid results even though the data collected were not normally distributed, the DV and IVs did not have a linear relationship, and the IVs of total, passive, and active screen time were highly correlated with each other. I further address statistical assumptions for the study in Chapters 3 and 4.

These assumptions were necessary because study data were gathered from a convenience sample of the pre-school-aged population located in a fixed geographic area. As the researcher, I had to reasonably assume that (a) children in this population were similar to all children, (b) the survey and analysis instruments were valid and robust, (c) the preschool programs were following the basic guidelines for quality outlined by their accrediting agencies, and (d) the participants answered questionnaires to the best of their abilities with integrity and accuracy.

Scope and Delimitations

The research problem indicated gathering data on the working memory function of children in learning environments that combined Montessori or non-Montessori preschool education with parent-controlled total, passive, active, and/or total screen time. Internal validity was strengthened because only participants enrolled in preschool programs authenticated through national accreditation monitored by the USDE (2022) and CHEA (2019) were solicited for participation. The Montessori preschool program providing participants was accredited by the AMS (2022), a MACTE (2021) governed accreditor and the largest Montessori school accrediting body in the world. The non-Montessori preschool program was nationally accredited by NAEYC (n. d.), the world's largest preschool program accreditor. Accreditation of an early childhood program requires the teachers and administrators of the program to agree to maintain uniform standards and educational practices as indicated by the accreditor's guidelines. Accrediting organizations also perform onsite inspections to ensure adherence to their standards (AMS, 2022; NAEYC, n. d.). Accreditation means the Montessori programs had committed to follow Montessori pedagogy as designed by Maria Montessori and outlined in Chapter 2 (Montessori, 1909/1964). AMS (2022) or NAEYC accreditation of the participating preschool programs strengthened internal validity of the study by making it more likely that significant differences in working memory function between the Montessori and non-Montessori participants occurred because of the type of preschool program, with each type adhering to standards clearly defined and in the public record.

Since I gathered data about children from parents who were not necessarily trained early childhood educators, I chose the BRIEF-P and created the Screen Time Questionnaire to be relatively simple and quick to fill out. Sample questions from BRIEF-P can be found in Appendix B. The Screen Time Questionnaire is available in Appendix D. Spanish translations can be viewed in Appendices C and E. The simplicity of the instruments and their availability in Spanish improved the internal validity of this study by increasing the likelihood that all participants understood the questions clearly enough to provide accurate answers.

The scope of this study included male and female preschool children between 3 and 6 years of age who were enrolled in one of two public, magnet early childhood programs and living with their parents in a medium-sized, midwestern U.S. city during the 2021-2022 school year. The programs were (a) a public, magnet Montessori preschool program and (b) a public, magnet, non-Montessori preschool program. Diversity statistics for students in the school district where the study was conducted were nearly equivalent to diversity statistics in the United States as a whole (see Table 1 in Chapter 3). Also, national accreditation of both the Montessori and non-Montessori preschool programs means that they were likely to have followed educational practices and standards very similar to other programs holding the same accreditations. The qualities of (a) typical diversity and (b) national accreditation strengthen the generalizability of current study findings to other U.S. populations of preschool children and parents with exposure to nationally accredited preschool programs. The Chief of Elementary School Leadership (COE) for the partnering school district granted permission to conduct this study in the district's two public magnet early childhood programs, which can be viewed in Appendix F.

As per the study design, my target for study participation was to gather data from 100 respondents or 50 students from each school. However, 60 total respondents, 30 per school, signed up and completed at least one of the two study questionnaires. A G*Power 3.1.9.7 (G*Power; Buchner et al., 2020) analysis conducted for this study indicated that with 74 total parent participants, the study would have had less than a 5% chance ($p \leq .05$) of mistakenly rejecting the H_0 and revealed any relationship between the DV and IVs with 95% accuracy. However, although 74 participants did indeed sign up for participation in the study, only 60 participants completed the study questionnaires. With 30 participants per school, or 60 parent participants, the study had less than a 7% chance ($p \leq .07$) of mistakenly rejecting the H_0. With 60 participating parents, the study revealed any relationship between Montessori preschool exposure, amount of parent-controlled passive, active, and/or total screen time, and working memory function with 93% accuracy, according to G*Power (see Tables 2 and 3 and Figure 1 in chapter 3 for G*Power analysis statistics).

The two questionnaires I used to gather data were both filled out by parents of the pre-school-aged children. I used the BRIEF-P, a measure of executive function in preschool-aged children, to gather data on working memory function. Although I gathered data on other executive brain functions with the BRIEF-P, such as inhibit, shift, emotional control, and plan/organize, this study only reflected analysis of the data gathered on working memory (Gioia et al., 2003b). Working memory function is at the foundation of cognitive load theory, the theoretical lens of this study (Sweller et al., 2011). Using the second instrument, the Screen Time Questionnaire, I gathered data about each child's preschool program enrollment, attendance, and weekly amount of parent-controlled passive, active, and total screen time. The data I collected with the Screen Time Questionnaire provided insight on children's use of parent-controlled passive, active, and total screen time and amount of Montessori preschool exposure. This level of detail about screen time was more specific than if I had only gathered data about total screen time, but less specific than if I had gathered data on particular screen media applications, such as specific video games, or types of screen media devices, such as smartphones.

Limitations

The study had several limitations. Use of a convenience sample of volunteers rather than random selection of participants meant that results of the study could only reveal associations between variables, not causation. The absence of random selection meant that factors other than type of preschool enrollment and time spent using screen media at home could have caused variations in working memory function, which also weakened internal validity. BRIEF-P test reviews have confirmed its reliability and content validity, but no measure is perfect (Sherman & Brooks, 2010). Also, through the

Screen Time Questionnaire, I requested information that showed a snapshot of each child's parent-controlled passive, active, and total screen media use and asked for tallies on that use from parents. The accuracy of the collected data relied on the vigilance of parent observation of their own child's screen time and also on parent memory. Children may have had screen time outside a parent's presence while in the care of other family and non-family members without the parent's knowledge. Without each participating parent's direct observation and timed and immediate recording of their child's use of screen media, the construct validity of the study may have been weakened.

I conducted the study during the COVID-19 pandemic. This timing presented the possibility that engagement in screen time was different than in typical years (Susana et al., 2021), and affected generalizability of study results on the effects of young children's screen media use in typical years. Also, social distancing restrictions in some ways disrupted the character of the preschool education provided in the city where the study was conducted. State legislators permitted school gatherings for preschool and elementary age children during both the 2020-2021 and 2021-2022 school years, despite the COVID-19 pandemic. Pre-school-aged children attended the participating preschool programs in-person, 6 hours a day, 5 days a week. However, time spent in preschool programs was altered by social distancing, with children required to remain 6 feet apart for 4 months and interact only within cohorts of four or five children for the remaining 8 months of school attendance in 2020-2021 and again in the 2021-2022 school year. Importantly, faces of all children and adults were covered by masks when indoors that only allowed eyes to be exposed. Clearly, these restrictions altered typical practices of all early childhood programs when compared to practices during other two-year periods. Dramatic play; socialization skills; and communication that involves physical contact, reading facial expression, and assessing body language during verbal interaction are typical practices in preschool programs. These typical experiences in a young child's life were of necessity modified in all programs that remained open during the COVID-19 pandemic. COVID-19 restrictions were mandated by state laws and school-district-wide policies and were the same for both early childhood programs that participated in the current study.

Finally, my biases could have potentially influenced study outcomes. First, I was employed part-time in the participating non-Montessori preschool program during the study, although not working in a classroom with any of the children who participated in the study. Second, I have a master's degree in Montessori education and am a certified Montessori early childhood teacher.

Reasonable measures were taken to address limitations. The potential effects of my biases as a certified Montessori educator working in the non-Montessori preschool program participating in the study were mitigated since no children in my class were invited or allowed to participate in the study. Although I enrolled a convenience sample rather than employing random selection, the convenience sample consisted of volunteers drawn from a school district with a population typical of U.S. diversity as shown in Table 1. Also, student applicants were assigned to the two participating magnet schools through a random, lottery drawing. However, the COVID-19 pandemic was ongoing during study data collection. Along with humans worldwide, parents and teachers of young children participating in the study could only do their best to provide high quality, healthy, and positive experiences for their children while taking precautions, such as mask wearing, to keep the children alive. The teachers and administrators at both participating schools had to strike a hard balance in attempts to follow (a) developmentally appropriate practices for early childhood education and (b) restrictive COVID-19 safeguards at the same time.

Significance

Early childhood educators increasingly recognize the important role played by executive function skills in successful cognitive, academic, and developmental outcomes for young children (Rothlisberger et al., 2013). Executive functions are defined as cognitive abilities that support goal directed behavior (Ackerman & Friedman-Krauss, 2017). Working memory function is at the foundation of all other executive functions, and its development is particularly pronounced from ages 3 to 4 years (Ahmed et al., 2019, 2022; Blakey & Carroll, 2015; McKenna et al., 2017; Rothlisberger et al., 2013). Studies show, however, a decline in working memory function among pre-school-aged children when their learning environments are missing supportive pedagogy or include factors that increase extraneous cognitive load (Conway et al., 2019; de Wilde et al., 2016; Passalunghi & Costa, 2016; Zhao et al., 2022). Educators’ support of working memory function through cultivation of ideal cognitive load in mindfully chosen learning environments could produce positive social change by improving pre-school-aged childrens’ learning and attainment of life skills (Ackerman & Friedman-Krauss, 2017; Sweller et al., 2011, 2019). Previous research findings indicate that relationships exist between the cognitive load inherent in the activities of children, such as time spent using screen media or being exposed to authentic Montessori programs, and the development of optimally functioning working memory (Blakey & Carroll, 2015; Lillard, 2012; Lillard & Heise, 2016; Lillard et al., 2015, 2017; Nathanson et al., 2014). Important to note is that all children exposed to formal preschool programs, either Montessori or non-Montessori, spend much of their time in parent-controlled learning environments with almost all U.S. children having access to screen media devices (Herodotou, 2018; IGI Global, 2021b). By bringing attention to a learning environment that combines exposure to formal Montessori or non-Montessori preschool and parent-controlled passive and active screen time, I intended to illuminate a more accurate picture of a preschool child's learning environment than can be had with findings focused on either exposure to formal preschool or parent-controlled use of screen media alone. A gap in the literature has existed, however, as little has been known about how a learning and instruction environment encompassing both exposure to Montessori preschool education and parent-controlled passive, active, and total screen time affected cognitive load and therefore working memory function of pre-school-aged children. Study results fill this gap in the literature and could contribute to pedagogical protocols that align use of screen media technology and early childhood pedagogy with ideal cognitive load to support the working memory function of pre-school-aged children (Matheson & Hutchinson, 2014; Sharkins et al., 2016).

Summary

Screen media devices have transformed human communication and knowledge acquisition worldwide. The pervasive presence of screen media devices has naturally led to their parent-controlled use by young children and altered the environments where young children spend their time. Since early childhood is a unique time of rapid, foundational human learning, research was needed to determine how a parent-controlled learning environment with varying amounts of screen time combined with a pre-school-age child's other learning settings to affect their development and learning. Filling a gap in the literature and with a view through lenses of cognitive load theory and the construct of executive function, study results offered insight on the relationships between preschoolers' working memory function, parent-controlled passive, active, and total screen time, and exposure to Montessori versus non-Montessori preschool education.

The literature review in Chapter 2 provides theoretical foundations for this study and delineates why the study was needed by providing evidence of a gap in the research literature. The literature review presents descriptions of the construct of executive function (Lezak, 1982) and specifically working memory (Baddeley & Hitch, 1974). Cognitive load theory (Sweller, 1988, 2016; Sweller et al., 2011, 2019) as developed by its seminal theorists and researchers is delineated in detail, especially 17 cognitive load effects on working memory and how they manifest in Montessori pedagogy (Montessori, 1909/1964, 1914/1965, 1948/1967) and screen media applications (Mayer, 2017; Mayer & Fiorella, 2014; Mayer & Moreno, 2003).

Chapter 2: Literature Review

In the last decade, the proliferation of several technological tools has placed electronic screen media devices into the hands of more than three-quarters of the world's population (Pew Research Center, 2021). U.S. smartphone ownership rose from 35% in 2011 to 85% by 2021, and, in the same year, 97% of the country's residents owned a cellphone of some kind (Pew Research Center, 2021). These screen media devices have found their way into the hands of young children. Because exposures and activities in the early years lay the foundation for lifelong brain function and learning, the effect on young children of time spent using screen media is an important field of study (Gilmore et al., 2018; Klingberg, 2013: McHarg et al., 2020a, 2020b; Paudel et al., 2017; Slusky et al., 2019; A. Veraksa et al., 2021; N. Veraksa et al., 2021; Z. Zhang, Adamo et al., 2022; Zhao et al., 2022). Many educators, fascinated by the newness of these media, have appropriated innovative technologies in their classrooms (Redding et al., 2013). However, a new or innovative way of offering information to a learner is not necessarily a better way. The field of learning, instruction, and innovation arose because researchers were determined to find out whether deviations from standard educational practices enabled greater learning outcomes, with devotion of equal or lesser time and resources (Redding et al., 2013; Walden University, 2021). The current study fits within the field of learning, instruction, and innovation because it involved data gathering on the effect on working memory of a learning environment for pre-school-aged children that combined Montessori or non-Montessori preschool exposure and parent-controlled passive, active, and total screen time, which is culturally and technologically new.

Educational researchers are particularly concerned about the amount of extraneous cognitive load purveyed by both passive and active screen media applications on the working memory of a learner (Mayer, 2017; Mayer & Fiorella, 2014; Mayer & Moreno, 2003). Detrimental impacts on learners' working memory affect the usefulness of the applications as learning tools. Some factors in the learning environments of pre-school-aged children, such as inadequate pedagogical structure or content and extraneous cognitive load created by negative emotion, impede working memory function and cause it to decline (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passalunghi & Cost, 2016; Peng & Fuchs, 2017; Thiery et al., 2016; Zhao et al., 2022). On the other hand, Montessori learning environments have maintained stable pedagogical practices for over a century and have been shown through research to support positive, long-term learning effects (Brown & Lewis, 2017; Diamond & Lee, 2011; Dohrmann et al., 2009; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard & Else-Quest, 2006; Lillard & Heise, 2016; Lillard et al., 2017; Mallett & Schroeder, 2018). Some positive learning effects occur because Montessori educational practices support an ideal amount of germane cognitive load on the working memories of young learners (Courtier et al., 2019; Denervaud et al., 2019; Fabri & Fortuna, 2020; Ginns & Kydd, 2020; Ginns et al., 2016, 2020). The problem is that working memory function is declining in pre-school-aged children and can be impaired by the extraneous cognitive load to working memory imposed during parent-controlled screen time and/or exposure to preschool programs (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016;

Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015; Zhao et al., 2022).

Synopsis of Current Literature Establishing the Relevance of the Problem

Electronic content provided on screen media devices and available in the majority of U.S. homes is attractive to curious pre-school-aged children and has gained widespread use by them at home (IGI Global, 2021a, 2021b; Leppänen et al., 2020; Sharkins et al., 2016; Swartz, 2017). Exposure to screen media has changed the way pre-school-aged children explore their surroundings (Csibi et al., 2021; Beatty & Egan, 2020; Bus et al., 2020; Elkind, 2016; Slutsky & DeShetler, 2017; Slutsky et al., 2021) and created a new learning environment for them (Beschorner & Hutchison, 2013; Herodotou, 2017; McManis & Gunnewig, 2012; Neumann, 2016). Peer-reviewed studies show that the cognitive load (Sweller et al., 2011, 2019) created by a screen media application can aid or hinder working memory function and limit the potential of the application to support intentional learning (C.-C. Chen & Huang, 2020; Huber et al., 2018; L.-Y. Lin et al., 2015; Lillard et al., 2015; Mayer, 2017). Elements missing or present in a pre-school-aged child’s learning environment are associated with decline in working memory function, according to researchers (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015).

However, research indicates that some pedagogical practices engineered into Montessori (1909/1964) learning environments produce ideal cognitive load and improve working memory function (Diamond & Lee, 2011; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard & Else-Quest, 2006; Lillard & Heise, 2016). These educational practices include reduction of outside distractions and focus of multisensory attention on one new concept at a time (Blakey & Carroll, 2015; Sweller et al., 2011, 2019). A gap in the literature existed due to a lack of research on the working memory of preschoolers exposed to parent-controlled passive, active, and/or total screen time and Montessori education. Findings of the current study on the working memory function of pre-school-aged children learning with both Montessori and non-Montessori programs and parent-controlled passive, active, and total screen time could inform pedagogical protocols that support ideal cognitive load.

Justification for the Study

This study was needed because young children are a unique and vulnerable learning population whose developing brains can be affected by all exposures that they experience through their senses (Kim & Park, 2020; Kulic et al., 2019; Piaget, 1970; Shafiq et al., 2018; Slutsky et al., 2021; Thompson, 2018; Vygotsky, 1962; Woldehanna & Araya, 2017). The human brain builds and organizes itself in adaptation for life to come in the early years based on the stimuli that enters from a young child's environment (Montessori, 1949/1989; Osher et al., 2020). Working memory is the small window through which sensory data can enter and be permanently stored in the brain, so supporting working memory function enables learning (Sweller et al., 2011, 2019). This study may provide insight on elements in a pre-school-aged child's learning environment that either support working memory or contribute to its decline, in particular type of formal preschool program exposure and amount and type of parent-controlled screen time.

Montessori preschool education has maintained a philosophical and pedagogical focus on providing an environment that is not only rich in sensory input that supports learning but that involves movement and uses the senses, such as the stereognostic and proprioceptive senses (Montessori, 1914/1965, 1948/1967). This multisensory pedagogy supports germane cognitive load and working memory (Sweller et al., 2011, 2019). Montessori educators preserved this focus throughout the 20th century with the intent to support the kind of natural, optimal brain development human beings evolved to have (see Darwin, 1859, 1871; Montessori, 1909/1964). Passive screen media have traditionally used sight and sound to purvey information, without use of other senses or purposeful movement. Research has not shown passive screen media technology to be as productive a learning tool as its early inventors had predicted, especially in young children (B. Y. Hu et al., 2020; Kirkorian et al., 2008; Mander, 2002; Rhodes et al., 2020; F. J. Smith, 1913; N. Veraksa et al., 2021). Hope among educators has been high that pedagogical strategies using active/interactive screen media technology introduced with the advent of Web 2.0 would stimulate higher brain functions and increase meaningful learning (Agostinho et al., 2016; Bus et al., 2020; Mayer, 2017; Slutsky et al., 2021; Sweller et al., 2011, 2019).

However, research findings that support the cognitive load theory (Sweller, 2016; Sweller et al., 2019) have revealed that many active screen media applications developed for education are ineffective because they contain elements that overload the working memory with extraneous content unrelated to learning objectives (Mayer, 2017; Mayer & Fiorella, 2014; Mayer & Moreno, 2003; Rhodes et al., 2020). Many active screen media educational applications have failed to produce the desired learning (Carson et al., 2017; B. Y. Hu et al., 2020; Mayer, 2017; Parong & Mayer, 2018; Peebles et al., 2018; San Martin Soares et al., 2021; Sweller et al., 2011, 2019; N. Veraksa et al., 2021; Z. Zhang, Wiebe et al., 2022). The literature review in this chapter offers insight on reasons for the failure.

For learning to occur, educators must follow effective practices, no matter what tools they use (Sweller et al., 2011, 2019). Montessori education has been effective for over a hundred years because its practices, developed initially for persons with developmental disabilities and adapted for young children, involve intentionally removing distractions around the learning content (Montessori 1939/1966). Montessori educational practices maintained ideal cognitive load even before the construct of working memory executive function was formulated or cognitive load theory developed (Baddeley & Hitch, 1974; Courtier et al., 2019; Denervaud et al., 2019; Lillard, 2017; Montessori, 1939/1966; Sweller, 1988).

The purpose of this quantitative study was to examine the working memory function of preschoolers, in Montessori and non-Montessori learning environments, who engaged in varying amounts of parent-controlled passive, active, and total screen time for any relationship between preschoolers' working memory function (DV), Montessori preschool program exposure (IV), and amount of parent-controlled passive (IV), active (IV), and/or total screen time (IV). I gathered data on the working memory function of young children involved in 11 learning conditions. The conditions were (a) Montessori preschool, (b) non-Montessori preschool, (c) a weekly amount of parent-controlled passive screen media, (d) a weekly amount of parent-controlled active screen media, (e) a total weekly amount of parent-controlled screen media (f) Montessori preschool combined with parent-controlled total screen time, (g) Montessori preschool combined with parent-controlled passive screen time, (h) Montessori preschool combined with parent-controlled active screen time, (i) non-Montessori preschool combined with parent-controlled total screen time, (j) non-Montessori preschool combined with parent-controlled passive screen time, and (k) non-Montessori preschool combined with parent-controlled active screen time. Outcome data on working memory function of children learning in these 11 settings emanated from the RQ that underpinned this study. Study results provide insight on the links between the variables Montessori preschool exposure, non-Montessori preschool exposure, parent-controlled passive screen time, parent-controlled active screen time, parent-controlled total screen time, and working memory function in all combinations.

Chapter 2 includes the following sections: Literature Search Strategy, Theoretical Foundation, Literature Review Related to Key Variables and/or Conclusions, and Summary and Conclusions. In the Theoretical Foundation section, I describe executive function (Lezak, 1982) and working memory (Baddeley & Hitch, 1974) constructs and cognitive load theory (Sweller, 1988, 2016; Sweller et al., 2011, 2019). The literature review includes discussion of Montessori pedagogy and cognitive load effects on working memory (Montessori, 1909/1964, 1914/1965) and the effects of cognitive load on working memory with screen media applications (Mayer, 2017; Sweller, 2011, 2019).

Literature Search Strategy

The focus of the literature review for this study was young children's use of screen media; their participation in Montessori and non-Montessori preschool programs; and their executive brain function, especially cognitive load and working memory. I performed a preliminary Boolean keyword search for peer-reviewed articles in Walden University Library's Subject Research: Education section using EBSCO Discovery Service. I searched Walden University's Thoreau Multi-Database Search tool, which provided access to these databases: Academic Search Complete, ACM Digital Library, Annual Reviews, APA PsycArticles, CINAHL Plus with Full Text, Cochran Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Cochrane Methodology Register, Communications and Mass Media Complete, Computers & Applied Sciences Complete, CQ Researcher, Database of Abstracts of Reviews and Effects, EBSCOhost, EBSCO ebooks, Education Research Starters, Education Source, ERIC, Gale Academic OneFile, HathiTrust, Health and Psychosocial Instruments, MEDLINE with Full Text, Mental Measurements Yearbook with Tests in Print, Ovid Nursing Books, Ovid Nursing Journals Full Text, Oxford Education Bibliographies, Project Muse, ProQuest Ebook Central, PsycARTICLES, PsycBOOKS, PsycCRITIQUES, PsycEXTRA, PsycINFO, PsycTESTS, PsychiatryOnline, Psychological Experiments Online, Psychotherapy.net, SAGE Journals, SAGE Knowledge, SAGE Research Methods Online, ScholarWorks (Walden journals &

dissertations), Social Work Abstracts, SocINDEX with Full Text, Springer e-books, Taylor and Francis Online, Teacher Reference Center, and Walden Library Books. I also searched the websites of the Annie E. Casey Foundation, Child Care & Early Education Research Connections, Child Stats, Children's Defense Fund, Education Commission of the States, F1000 Research, Kids Count Data Center, Learn TechLib—The Learning and Technology Library, MERLOT (Multimedia Educational Resource for Learning and Online Teaching), National Academies Press, NCES Publications, OECD iLibrary, ProQuest Central, Teacher Reference Center, UNESCO, UNICEF, and U.S. Department of Health and Human Services. By mining the reference lists of research articles that I found using this search strategy, I was able to identify additional sources that clarified the context for this study. I also used Google Scholar, in particular its cited by feature, to search for relevant peer-reviewed references.

Keywords for the literature search included the following: *screen time*, *screen*, *screen time*, *screen*, *app*, *application*, *screen media application*, *touchscreen*, *touchpad*, *tablet*, *iPad*, *device*, *smartphone*, *iPhone*, *handheld device*, *mobile device*, *computer screens*, *internet addiction*, *early childhood*, *young children*, *children*, *preschool*, *preschool-aged, Head Start*, *Montessori*, *prekindergarten*, *executive function(s)*, *cognitive load*, *cognitive load effects*, *short-term memory*, *long-term memory*, and *working memory*. An ongoing EBSCOhost Alert Email Notification populated with these keywords ensured that the most current studies published right up until the time this dissertation was published were included in the literature review. Current peer-reviewed research reports published within the last 5 years gave context to this study, which will fill a gap in the research. Books with a theoretical focus and pivotal research studies by seminal theorists older than 5 years were also included in the literature review. The search included resources published between 1827 and 2022, with the oldest seminal source included in the literature review published in 1859 and the newest peer-reviewed research report published in 2022.

Theoretical Foundation

The two theoretical bases for this study were the cognitive load theory (Sweller et al., 2011) and the construct of executive function (Lezak, 1982), particularly working memory. In the 21st century information age, most people, including young children, engage in interaction with the world mediated by electronic screen media, so their construction of meaning is directly affected by screen time. The cognitive load theory (Sweller et al., 2011, 2019) has offered insight on supporting working memory capacity and therefore supporting learning by providing an ideal amount of new information to the learner. According to the cognitive load theory (Sweller et al., 2011, 2019), when too much new information bombards a learner at once, the overload causes all learning to shut down. This theory is relevant in Montessori education which encompasses carefully developed methods and materials that reduce a young child's cognitive load (Courtier et al., 2019; Denervaud et al., 2019; Fabri & Fortuna, 2020; Gilder, 2012; Ginns et al., 2016; P. A. Kirschner et al., 2011; Paas & Sweller, 2012; Sweller et al., 2011, 2019; van Merriënboer & Sweller, 2005). Cognitive load theory has also been relevant in determining the effects of different passive and active screen media applications on the learning of young children (de Jong, 2010; Lillard et al., 2015; Mayer, 2017; McMath et al., 2022; Rhodes et al., 2020; Squire, 2011; Z. Zhang, Adamo et al., 2020). Cognitive load theory and working memory executive function are constructs providing a guiding framework for this study about how combined Montessori preschool exposure and parent-controlled screen-time-and-type influenced pre-school-aged children's working memory function.

Executive Function

The term *executive function* refers to a construct linking together a group of higher-level cognitive abilities that come to play during goal directed behavior (Ackerman & Friedman-Krauss, 2017; Jusienė et al., 2020; Lezak, 1982). According to Lezak's (1982) conceptual model, executive functions include the mental abilities to (a) maintain attentional focus (attention), (b) inhibit impulses (self-control), (c) switch flexibly between two or more concepts (flexible thinking), and (d) mentally manipulate ideas (working memory) (Marulis & Nelson, 2021). Researchers in the early childhood education field have recognized the important role played by executive function skills in successful cognitive, academic, and developmental outcomes for young children (Diamond & Ling, 2016; Friedman & Miyake, 2017; hceconomics, 2017; Kilger & Blomberg, 2020; Rothlisberger et al., 2013). Executive function has been strongly associated with academic and lifelong success (Bull et all., 2008; Diamond & Lee, 2011; Friedman & Miyake, 2017; Huizinga et al., 2018), and the preschool years between 3 and 6 years old are the time of greatest change in these core executive function components (Diamond, 2013; Simms/Mann Institute, 2016; Simpson & Riggs, 2010; Spencer, 2020). Also, seminal research shows that intervention by a preschool program can improve working memory function (Diamond et al., 2007; Phillips-Silver, 2018; Solomon et al., 2018; Zelazo et al., 2008, 2018). Therefore, research studies such as the current study that have revealed factors affecting the development of executive functions during the critical preschool years support teacher and parent interventions that create a lifelong impact on children (GarrisonInstitute, 2011a, 2011b; Lillard et al., 2015). Although all executive functions work hand in hand, the one that is critical to and affects all others is working memory (Ahmed, et al., 2019, 2022; Blakey & Carroll, 2015; McKenna et al., 2017; Rothlisberger et al., 2013). In the current study, I examined working memory executive function in a pre-school-aged population.

Working Memory

According to seminal working memory theorist, G. A. Miller (1956), working memory is the part of human consciousness that a person is aware of at any given time. Working memory stores immediate experiences and retrieves information from the long-term memory as needed. The working memory processes the experience, knowledge, and memories a person can hold at that moment in their consciousness and leverages them to support the completion of a current goal. Working memory is a limited-capacity executive function used for immediately storing, integrating, and manipulating information (G. A. Miller, 1956). Working memory functions to maintain information that is relevant to the task at hand and resist against information that could interfere with task performance. Higher levels of working memory have been associated with greater mathematics performance (K. Lee & Bull, 2016; Peng et al., 2016), early reading acquisition (Peng et al., 2018), consistent daily goal mastery (Blume et al., 2022), and higher levels of academic achievement (Vandenbroucke et al., 2017).

Researchers Baddeley and Hitch (1974) created a model of working memory, called the human information processing model. Information from the outside environment first briefly enters a sensory memory and is stored in the visual-spatial scratch pad or the phonological loop. Baddeley and Hitch assumed the phonological loop to be responsible for the manipulation of speech-based information and the visuospatial sketchpad to be responsible for manipulating visual images (Baddeley, 1986, 2020; Chemerisova & Martynova, 2019). If a person pays selective attention to incoming sensory information, between four and seven pieces of data may move into the working memory. There, information is encoded or identified; organized; and interpreted, with the help of information retrieved from long-term memory which moves into the working memory to aid encoding of the new information. The encoded schema or newly learned information is then permanently stored in the long-term memory. The model suggests that every component of working memory has a limited capacity and that the components are relatively independent of each other.

According to Baddeley and Hitch (1974), the human brain is plastic. Exposure to experience in life is not just passively processed by the working memory and other executive functions as is information in a computer. Learning creates a permanent change to the brain as myelin sheaths form around dendrites and grow thicker and more permanent through repetitive practice and thought processing (Z. Zhang, Adamo et al., 2022). A young child’s learning activity, which is basically all activity engaged in by a young child, can have a lasting effect on brain function, including working memory function (Baddeley, 2020). Activities of young children such as watching or interacting with screen media or learning in preschool programs can have lasting effects on both retained learning and executive brain functions including working memory.

In the early years after conception of the construct of working memory, theorists postulated that the short-term memory component of working memory could hold between four and ten pieces of information, or an average of seven items, at one time (Baddeley & Hitch, 1974; G. A. Miller, 1956). Research has revealed that the number of separate pieces of information that the working memory can hold at once is closer to four (Cowan, 2001). The small capacity of the short-term memory component of working memory to hold information in mind acts as a valve to the mind. The short-term memory can only attend to and hold a few pieces of information at one time. The working memory is a combination of processes that focus attention on items of information and process sensory input through phonological loop and visual-spatial scratch pad before letting important learning through to the long-term memory, which has unlimited learning storage capacity (Baddeley & Hitch, 1974; Chemerisova & Martynova, 2019). All learning and goal directed actions are controlled by limited working memory capacity (Blume et al., 2022), be they reading for comprehension (Foroughi et al., 2016; Peng et al., 2018), learning American Sign Language (Macnamara & Conway, 2016) or navigating driving hazards (Wood et al., 2016).

A limited working memory has always been part of Montessori pedagogy as well, even before seminal theories about working memory function were formed. Reflecting the views of his close associate Maria Montessori, E. M. Standing (n.d./2022) wrote that because the child's "store of mental energy is so limited we must be careful not to expect it to work beyond its strength" (p. 258). Standing then gave an explanation about how this "precious streamlet" (p. 259) or limited working memory was supported during presentation of math problems to young children using the concrete golden bead math materials created by Montessori. This learning material decreased the load on working memory and allowed young children to learn "higher forms of order" (Standing, n.d./2022, p. 259) in mathematics. Cognitive load theory explains how supporting working memory, in the way described by Standing and other ways, increases intentional learning.

Cognitive Load Theory

In the analysis and conclusion of his seminal 1988 report of research on problem solving, Sweller put forward the theory that the design of instruction could lower the amount of working memory resources a learner used and make learning more efficient. Sweller called the used working memory resources *cognitive load* and divided cognitive load into three types: intrinsic, extraneous, and germane. Intrinsic cognitive load describes the work associated with learning a specific topic or skill; extraneous cognitive load refers to the instructional design or way tasks and information are presented to a learner, particularly if it includes distracting content irrelevant to the learning objective; and germane cognitive load labels the work required to create a schema for permanent storage of knowledge in a learner's brain. Capacity and duration of working memory is limited (Sweller, 2015). However, all information must be paid attention to and processed in the working memory before it can be permanently stored in the long-term memory. If the presentation of new learning creates too heavy a cognitive load, learning is slowed down or stopped, and tasks go unfinished. Instruction designed to take into account the role and limits of working memory strengthens the quality, permanence, and strength of the learning (Sweller, 2016, 2017; Sweller et al., 2019).

Categories of Knowledge

Biologically Primary Knowledge. Like standing upright and the development of opposable thumbs, human minds have also evolved. Cognitive abilities such as recognition of faces, general problem-solving strategies, speech, and engagement in basic social relations via spoken language are learned by human beings but do not need to be intentionally taught. Curricula and instruction are not required for humans to develop biologically primary knowledge (also called generic-cognitive knowledge or domain-general knowledge) and may even be futile, according to Sweller et. al. (2011, 2019). Humans can easily comprehend low element interactivity, biologically primary information such as the spoken exchange in a conversation with a friend or the storyline in a movie since these do not impose a heavy intrinsic load on the working memory. Acquiring biologically primary knowledge, even if complex like learning a primary language, does not create any discernable cognitive load burden for the learner (Sweller et al., 2011, 2019).

Biologically Secondary Knowledge. Instructional content developed to teach biologically secondary, academic material with high element interactivity can only be effective if it does not impose too high a cognitive load (Sweller et al., 2011, 2019).

Biologically secondary human knowledge is not spontaneously acquired but requires specific training or enculturation. Biologically secondary knowledge or domain-specific knowledge such as reading, writing, and means-end problem solving has more recently been required by the cultures of human societies, and a secondary mental processing engine evolved to handle its wide range of categories of information (Sweller, 2016). Learning to write, for example, requires more than just living in a society with other writers; it requires a conscious effort and can be difficult. Most deliberate instruction of human beings imparts biologically secondary knowledge, which is learnable and teachable. Without societal procedures and learning institutions, biologically secondary knowledge would not be acquired by most members of human society (Sweller & Sweller, 2006).

Renner et al. (2016) found the acquisition of biologically secondary knowledge to be a trait human beings and orangutans shared. Renner at al. found that both human children and adult orangutans had the ability to learn to organize meaningful and arbitrary items by size, color, or number, but only after training, not spontaneously. Humans (and other primates) can acquire knowledge that is specific to survival within a certain environment and pass it down for generations (Renner et al., 2016). In fact, the efficiency with which biologically secondary knowledge is transferred to new learners determines how well the learners survive and thrive (P. A. Kirschner et al., 2018). Based on decades of research, Sweller's (1988) cognitive load theory delineates how human cognitive architecture, particularly working memory function, affects the gathering of biologically secondary knowledge with clear implications for teaching and learning.

Human Cognitive Architecture

Evolutionary Psychology. Biologically primary and biologically secondary knowledge enter the human mind through two different cognitive systems (Geary & Berch, 2016; Sweller et al., 2011, 2019). Biologically primary knowledge is acquired by human beings automatically without deliberate teaching. Biologically secondary knowledge, on the other hand, becomes part of the human schema through the natural information processing systems that have evolved to manage the complexity and variety of information bombarding all organisms (Sweller & Sweller, 2006). Cognitive load theory details that biologically secondary knowledge acquisition parallels another well-known natural information processing system -- biological evolution (Geary & Berch, 2016; Sweller & Sweller, 2006). Seminal researchers Darwin (1859, 1871), Campbell (1960), Dawkins (1976) and Popper (1979) all articulated an analogy between the development of human knowledge and biological evolution by natural selection, suggesting that they share a common underlying base (Sweller & Sweller, 2006). The principles of biologically secondary knowledge acquisition and biological evolution equate in these five ways: (a) human long-term memory ≈ a genome, (b) learning from other people ≈ biological reproduction, (c) random generation of potential solutions to problems ≈ random mutation, (d) working memory's processing of new information ≈ the epigenetic system's management of environmental information, and (e) working memory's drawing upon information in the long-term memory ≈ the epigenetic system's management of information in the genome. Cognitive load theorists' equating of the principles of biologically secondary knowledge acquisition or evolutionary psychology with more commonly understood principles of evolutionary biology serves as a framework that can guide the creation of pedagogy and support teaching and learning (Sweller, 2017).

Amassing Information: The Information Store Principle. Natural information processing systems have each evolved to manage the variable and complex information inherent in every natural environment (Sweller et al., 2011, 2019). One purpose of a natural information processing system is to respond to variability by ignoring what is irrelevant to its functioning and responding to what is relevant. In human cognition, the working memory responds to an onslaught of fluctuating information by acting as a valve, processing only about four pieces of new information at a time (Cowan, 2001). A corresponding example from evolutionary biology is a species' handing of genetic changes. A few genetic mutations can be safely incorporated into a species genome having little effect or perhaps benefitting its chances of survival (Darwin, 1859, 1871). According to Sweller and Sweller (2006), too many changes at once, however, cannot be accommodated because they would radically change the functioning and coordination of the organism's biological processes. The species does not just cease getting benefits from genetic changes when it experiences too many of them. It dies. This is also true for learning. Limiting the number of new items processed at once allows working memory to weed out irrelevant and respond to relevant information. Creators of pedagogy that understand how and why the working memory processes limited information at one time have the potential to create products that provide an ideal amount of cognitive load for learning, rather than killing the hoped-for learning (Sweller et al, 2019).

Another purpose of natural information processing systems is to handle large amounts of complex information and unexpected changes in situation by creating large information stores (Sweller et al., 2011, 2019). Information that is deemed relevant during initial processing by the working memory is organized into schemas (also called schemata) in the mind. Schemas are stored in an essentially limitless long-term memory that holds innumerable schemata. Working memory buffers information entering the mind from outside through the senses. At the same time, working memory facilitates the connection of incoming information with previously learned knowledge stored in schemata in the long-term memory (Ericsson & Kintsch, 1995; Sweller & Sweller, 2006). The schemata stored in long-term memory influence or even determine perceptions about which new information is relevant. The greater the number of domain specific, permanent schemas that are acquired by deliberate teaching and learning, the better. More schemas allow relevant sensory experiences to be recognized, processed, and then assimilated and accommodated into the mind more quickly. The interactions occurring in the working memory between (a) outside information entering through the senses and (b) schemata stored in the long-term memory are key to acquiring biologically secondary knowledge. Supporting working memory function and thereby supporting teaching and learning is the foundation of the cognitive load theory.

Acquiring Information: The Borrowing and Reorganizing Principle, and The Randomness as Genesis Principle. According to evolutionary psychology as applied in the cognitive load theory, acquiring information by learning from other human beings is equivalent to biological reproduction in evolutionary biology (Sweller et al., 2011, 2019).

The most important purpose of instruction is to employ effective procedures for transferring the knowledge from one person to another that will be stored in the learner's long-term memory. Cognitive load theory clarifies how information is communicated and created in natural systems in line with the borrowing and reorganizing principle and the randomness as genesis principle.

The Borrowing and Reorganizing Principle. Like genes are shared in asexual and sexual reproduction, ideas from others are taken into the mind, stored, and/or transformed, and used to create more ideas (Sweller et al., 2011, 2019). When a learner borrows ideas from a teacher during instruction, they will usually listen to what the instructor says, read what they write, or study diagrams or multimedia materials the teacher has created. By this procedure, information is borrowed from the teacher's long-term memory and assimilated into the learner's long-term memory. Although ideas are initially shared and learned through imitation or borrowing of the ideas, reorganization occurs and results in changes to the new information that are parallel to changes in genome occurring during sexual reproduction. If changes to the borrowed ideas support effective adaptation as novel situations arise, the learning session has been successful. The borrowing and reorganizing principle is central to cognitive load theory and reveals the major procedure by which human beings acquire knowledge: borrowing it from other human beings. The borrowing and reorganizing principle clearly implies that teachers should provide learners with as much information as possible rather than relying on methods that withhold information such as constructivist, discovery, or problem-based approaches.

The Randomness as Genesis Principle. According to evolutionary biology, all genetic variety between organisms can be traced back to a succession of random mutations (Darwin, 1859, 1871). Genetic mutations that test as effective by improving a species' survival and reproduction are retained in its natural information store or genome. Most mutations, however, do not contribute to successful survival or reproduction and are not stored but instead eliminated from the genome. The random generate and test process also aptly illuminates human cognition during problem-solving (Sweller et al., 2011, 2019). When solution seekers arrive at a dead end, at least one in a previous sequence of moves were made at random to find out if it could lead to a problem solution. The larger the amount of stored knowledge about a problem, or domain-specific knowledge, the less randomly generated moves are used to solve it. Greater domain-specific knowledge results in fewer dead ends and provides the cognitive resources that increase human creativity in interactions with the external environment.

Interacting with the External Environment: The Narrow Limits of Change Principle and the Environmental Organizing and Linking Principle. The purpose of information gathered in the long-term memory is to enable people to interact with the external environment (Sweller et al., 2011, 2019). Natural information systems must both (a) gather information from the environment and (b) perform effectively in the environment. The narrow limits of change principle puts-forward characteristics needed by a natural system to obtain information from the environment. Characteristics needed to perform appropriately within the environment are described by the environmental organizing and linking principle. The narrow limits of change principle and the environmental organizing and linking principle shed light on the reasons human cognition and working memory function the way they do (Sweller & Sweller, 2006). These two principles predict effects of instructional strategies on working memory load and therefore learning.

The Narrow Limits of Change Principle. The narrow limits of change principle describes how permutations, or the number of ways unorganized elements can be combined, limit the number of randomly generated and unorganized elements a natural information processing system can handle at one time (Sweller et al., 2011, 2019). For example, the possible permutations of three elements are only six, mathematically expressed as 3! = 6. On the other hand, 10 elements produce 10! = 3,628,800 permutations. A natural information processing system must be structured to account for the exponential increase in possible combinations of elements with the addition of each new randomly generated element. In the biologically evolved epigenetic system, limited mutations occur to the genome in reaction to environmental stressors (Allis & Jenuwein, 2017). In human cognition, a working memory with a limited capacity of only two or three items and a limited duration of 10-15 seconds deals with novel, incoming information. (Goldstein, 2010).

The Environmental Organizing and Linking Principle. The environmental organizing and linking principle indicates that in response to its environment, a natural information processing system can draw upon a large information store if informational elements are organized into groups that can be accessed as single units. In evolutionary biology, the epigenetic system responds to environmental changes by accessing relevant genes from the large information store of a DNA strand and creates proteins which build an adapted phenotype (Sweller & Sweller, 2006). In human cognition, knowledge is organized into schemas, and a single cue from the environment can trigger the working memory to quickly link to huge amounts of knowledge stored as organized schemas in the long-term memory. The environmental organizing and linking principle indicates how the use of information stored in long-term memory is accessed and used by a human being responding to their natural environment.

Scientific findings about human cognitive architecture support educator use of explicit instruction when presenting biologically secondary or domain-specific educational content and provide the foundation of the cognitive load theory (Sweller et al., 2006). Explicit instruction is compatible with human cognitive architecture:

1. Human beings have evolved to learn directly from other people using the borrowing and reorganizing principle (Sweller et al., 2019).
2. The narrow limits of change principle indicates that instruction needs to be organized in a way that reduces load on the working memory (Sweller et al., 2019).
3. Receiving information directly from other people using the borrowing and reorganizing principle produces a much lower load on human working memory than when a person generates novel information all alone using the randomness as genesis principle (Sweller et al., 2019).
4. Once learned information has been organized and stored via schemas in the long-term memory, it can be quickly transferred to the working memory at

any time using the information store principle and the environmental organizing and linking principle. Instruction that is designed to take into account the principles of human cognitive architecture enhances learning according to cognitive load theory and the research findings that have supported it (O. Chen et al., 2016a, 2016b, 2018; Korbach et al., 2020; Leahy & Sweller, 2016, 2020; Moran, 2016; Nugteren et al., 2018; Sala & Gobet, 2017; Sithole et al., 2017; Szulewski et al., 2019).

Categories of Cognitive Load: Intrinsic, Extraneous, and Germane

One goal of educational design is to decrease extraneous cognitive load, according to cognitive load theory (Sweller et al., 2019). When extraneous cognitive load is reduced, a larger portion of working memory resources can be devoted to elements that are pertinent or germane to the learning content instead of irrelevant or extraneous to it. Detractors that steal working memory resources from germane learning content include (a) physical discomforts such as fatigue, heat or cold, hunger, or ill health; (b) emotional distractions such as anxiety, sadness, low self-esteem, or boredom; (c) cognitive distractions such as noise, chaos, missing tools, or faulty learning equipment; or (d) distractions built into the instructional design such as irrelevant information, too little or too much information, or busy multimedia with too many pictures, colors, or sounds. The term cognitive load effects refers to a list of extensively-researched instructional design strategies and the effects of these designs on learner cognitive load and knowledge acquisition.

Intrinsic cognitive load refers to the complexity of new learning, or more specifically, how many interacting elements are inherent in the learning content (Sweller et al., 2011, 2019). Most of the time, the intrinsic cognitive load of specific learning content is germane or necessary to the learning of that content. Learning content with an intrinsic cognitive load having low element interactivity requires fewer working memory resources than learning content with high element interactivity. Learning content with high element interactivity is more difficult to learn than content with lower element interactivity because understanding is only possible when all elements of the learning can be readily processed in the working memory. If learning material can be learned one concept at a time, it has low element interactivity and low intrinsic cognitive load. A consideration of the intrinsic cognitive load or number of interacting elements inherent in learning material aids a teacher in designing instruction that does not overload the working memory. Designing pedagogical materials to take into account the cognitive load intrinsic in specific learning content supports teaching and learning according to cognitive load theory.

Cognitive Load Effects

Cognitive load effects are predicted by the theoretical construct of human cognitive architecture, which includes a working memory with limited space and an unlimited long-term memory (Puma & Tricot, 2020; Sweller et al., 2011). The percentage of the cognitive load generated by a pedagogical procedure that is germane to learning rather than an extraneous detraction directly affects the success of that instructional technique (Kalyuga, & Singh, 2016). Schemas of knowledge already available in a learner’s long-term memory also affect the ease of new knowledge acquisition. If the same learning content is presented to randomly selected groups of learners using a different instructional procedure with each group, some procedures may be more effective than others in transferring knowledge to learners. Each cognitive load effect was discovered when instructional procedures were tested for effectiveness in randomized, controlled experiments. If research results showed the superiority of one pedagogic procedure over another, an either negative or positive cognitive load effect was discovered (Sweller et al., 2019). So far 17 cognitive load effects have emerged through research that examined cognitive load during instruction and learning (Plass, Moreno, & Brünken, 2010; Sweller et al., 2011, 2019; Tindall-Ford et al., 2020). Cognitive load effects that occur when transferring knowledge to learners in early childhood are defined in this section.

The Worked Example Effect. A worked example provides learners with a problem statement and a studiable, step-by-step procedure for solving the problem (O. Chen et al., 2019, 2020; Sweller et al., 2011, 2019). Worked examples reduce cognitive load for novice learners because they provide problem-solving schemas that can be stored in long-term memory, in line with human cognitive architecture and the information store principle. Worked examples have even been shown through research to effectively replace classroom lectures (Clark & Mayer, 2016; Renkl, 2017). For novices, learning material element interactivity is higher than for learners who have more experience with particular learning material. So as a learner creates and secures a schema of the problem-solving strategy in their long-term memory, they do not need to study additional, redundant worked examples, and worked examples then add to extraneous cognitive load and make learning less efficient (Ashman et al., 2020; O. Chen et al., 2015, 2020).

Providing a worked example as a teaching strategy stands in contrast to providing just the problem alone, which prompts the student to use a means-end problem solving strategy that taxes working memory (Sweller et al., 2011, 2019). Proponents of a constructivist approach to learning and teaching have voiced a concern that learning with worked examples deprives students of active learning and problem-solving experience. However, abundant research supports the learning that occurs when students use worked examples (Sweller et al., 2011). As pointed out by cognitive load researchers P. Kirschner et al. (2006) “the use of discovery learning and problem-solving during learning have a very weak research and theoretical base in contrast to the use of worked examples…It is the cognitive consequences of the activity that matters” (Sweller et al., 2011, p. 107). Discovery learning, a currently popular approach to early childhood education, produces extraneous cognitive load on the working memory and reduces learning outcomes according to research (Ashman et al., 2020; O. Chen et al., 2015, 2020). Montessori education, on the other hand, uses direct instruction via (a) the three-period lesson followed by (b) worked examples with hands-on materials which are approaches found through research to support working memory function and increase learning outcomes (O. Chen et al., 2019; 2020; Sweller et al., 2011, 2019).

There are specific worked example-related cognitive load effects. During research of the worked example effect, related cognitive load effects on learning have been discovered. Cognitive load effects that are related to the worked example effect uncovered thus far include problem completion, split-attention, redundancy, modality, expertise reversal, guidance fading, variability, and generation.

The Problem Completion Effect. A completion problem is a partially worked example that requires the student to complete some important steps (Sweller et al., 2011, 2019). This strategy in teaching and learning serves to focus a learner's attention on the schema put forward by the worked example. A completion problem includes an element of problem solving that motivates learners to attend to key information as they think more deeply about the problem. However, the learner's working memory is not encumbered with having to solve the full problem. Research supports the problem completion effect in teaching and learning (Matthews et al., 2017).

The Split Attention Effect. Cognitive load researchers have discovered that some formats of worked examples are more effective than others (Sweller et al., 2011, 2019). The split attention effect occurs when the format of the worked example forces a learner to split their attention between two or more sources of information separated by either space or time. For example, if the labels to a diagram are listed below the diagram rather than embedded on the diagram itself, a learner must hold in mind the label names as they look back and forth between diagram and labels. The diagram and its labels are separated by space. Likewise, presenting corresponding words and pictures successively forces a student to hold partial information in mind for a time and mentally integrate it later. The matching words and pictures are separated by time. These formats create a heavy extraneous cognitive load. The key to optimizing teaching and learning by taking the split-attention effect into account is to reduce the search for referents and the need to temporarily store information in working memory by placing, for example, all necessary text information in close proximity to its illustration on a diagram. Students also learn more easily when words and pictures are integrated temporally, viewed simultaneously rather than successively (Ayers & Sweller, 2014; Mayer & Fiorella, 2014). Electronic screen media applications can use a pop-up source of information within a diagram where explanations are hidden until a student clicks a hyperlink and reveals the information. Pop-ups reduce the split attention effect. Physically and temporally integrating pertinent information, so it does not split a student's attention between two places or times, reduces extraneous cognitive load and supports learning (N. L. Schroeder & Cenkci, 2018).

The Seductive Details Effect. The split-attention effect occurs when all pieces of information are necessary to the learning at hand, but their spatial or temporal separation from each other creates extraneous cognitive load. The seductive details cognitive load effect occurs when interesting, attractive materials provide additional information that is not necessary to accomplish the learning objectives of a lesson (Park, Flowerday, & Brünken, 2015).

The Modality Effect. The modality effect on learning occurs when both the visual and auditory information channels are engaged in the working memory (Sweller et al., 2011, 2019). When a diagram and written words are used to present information to a learner, only their visual channel is engaged. But when a diagram and spoken words are used in a pedagogical presentation, both auditory and visual channels are employed. Reading is a biologically secondary skill, so integrating written words and images uses working memory resources, which creates cognitive load and is partially responsible for the split-attention effect. Presenting learning material that employs both visual and auditory channels at once, however, takes advantage of a human biologically primary ability to learn while simultaneously listening to speech and looking at objects (Baddeley & Hitch, 1974). For the use of combined auditory and visual input to positively effect learning, however, each modality must contribute information that is vital for comprehending the learning material. If, for example, the spoken text only re-describes what is shown visually, no special modality effect on learning occurs, according to research. The modality effect on cognitive load and learning is relevant in electronic multimedia presentations that combine auditory and visual elements and Montessori preschool education that taps into five or more sensory pathways during its pedagogical presentations (Castro-Alonso & Sweller, 2019; Clark & Mayer, 2016; Montessori, 1914/1965). Meta-analyses on variables strongly associated with student achievement supported the modality effect (M. Schneider & Preckel, 2017). Clarity in presentation of learning material was strengthened when spoken words, rather than text, accompanied visual illustration, and learners could focus all their visual attention on the figure while listening to the explanation (M. Schneider & Preckel, 2017).

However, continuing research has discovered that when verbal text is lengthy, the transient information effect and the reverse modality effect occur (Sweller et al., 2011, 2019). Lengthy verbal explanations can overload the working memory, either alone or in combination with visual illustrations. A verbal explanation is transient since it “disappears” (Sweller et al., 2011, p. 220) after it has been spoken, forcing a learner to tax working memory to remember the important information. In cases of wordy verbal explanation, a reverse modality effect occurs as students learn more efficiently when provided with written text that they can refer back to, either alone or combined with pictures and diagrams (Leahy & Sweller, 2016).

The Redundancy Effect. Like the split-attention effect and the modality effect, the redundancy effect on cognitive load can occur when instructional information is presented in any combination of spoken words, written material, diagrams, pictures, or animations (Sweller et al., 2011, 2019). However, the redundancy effect occurs for a different reason than either the split-attention or modality effects. The redundancy effect on cognitive load occurs when many sources of the same pedagogical information can each be fully understood without referring to the any of the others. For example, if written or spoken text simply re-describe a diagram that can be fully understood without text, a student may focus their attention on unnecessary information and try to integrate it with necessary information. The redundant presentation of text and diagram causes extraneous cognitive load on a learner's working memory. Research affirms the redundancy effect as students learn less when provided with unnecessary information at the same time as essential information (Kalyuga et al., 2004; Mirza et al., 2020).

The Expertise Reversal Effect. The expertise reversal effect is a type of redundancy effect (Sweller et al., 2011, 2019). The expertise reversal effect occurs when information in a pedagogical presentation is helpful to a new learner but becomes redundant to a more knowledgeable student experiencing the same educational presentation. The expertise reversal effect takes place, for example, when detailed written explanations embedded in a diagram are essential to a novice learner's comprehension of learning material but redundant for one who has already mastered the material, creating extraneous cognitive load for them. As a learner moves along the continuum from novice to expert, information and activities initially essential to learning become redundant and ineffective. The goal of teaching and learning is for all students to move to a higher and deeper level of learning, be they novices or experts. To be effective, instruction designed to help a novice move to the next level of mastery must be structured differently than instruction for students who have more expertise in particular subject matter, and vice versa. Research on cognition and expertise has indicated that prior knowledge is the most important learner trait that influences learning processes (Kalyuga, 2009). Direct instruction of small segments of knowledge reduces cognitive load for a novice learner while a knowledgeable learner benefits from using the knowledge stored in their own long-term memory interactively with information presented during instruction (Blayney et al., 2016; O. Chen et al., 2017). Learners at an intermediate level of expertise benefit from a combination of direct instruction for new pieces of information and drawing upon their own knowledge base to deal with familiar elements. The cognitive load theory, and particularly research findings on the expertise reversal effect, provide a paradigm for investigating the causes of more or less success when using certain instructional strategies with learners at different levels of expertise.

The expertise reversal effect occurs in multimedia and hypermedia representations. Johnson et al. (2015) conducted research on supporting multimedia learning and discovered students with low prior knowledge that had posttest scores comparable to the posttest scores of students with high prior knowledge. Johnson et al.'s results occurred when students learned with (a) visual signaling and (b) an image of an animated pedagogical agent. Students with high prior knowledge and no visual signaling or animated pedagogical agent scored better on posttests than others with high prior knowledge whose multimedia learning included the visual signaling and animated pedagogical agent. With high prior knowledge, students learning performance was hampered when multimedia learning materials included extraneous visual signaling and animated pedagogical agents. Johnson et al.'s (2015) findings support the expertise reversal cognitive load effect.

The Isolated Elements Effect. According to the isolated elements effect, if a teacher presents complex information as a series of isolated elements and at first does not discuss the interactive relations between the elements, the teacher avoids placing excessive intrinsic cognitive load on the working memories of low-knowledge learners (Sweller et al., 2011, 2019). Isolating and separately teaching elements of complex learning material before teaching how the elements relate to one another reduces element interactivity. Designing curriculum that takes into account the isolated elements effect on cognitive load supports a novice learner's ability to incorporate complex new knowledge into long-term memory. Reducing element interactivity to the point that the intrinsic cognitive load created by the learning material is not too high to be processed in the working memory supports learning for low-knowledge learners. A scaffolded progression from simple to complex components of a learning task is a teaching and learning strategy that supports manageable working memory load and successful learning, according to research supporting the isolated elements effect (Blayney et al., 2016; F.-T. Hu et al., 2015; Zimmermann et al., 2016).

The Variability Effect. The variability effect was initially discovered when cognitive load researchers were investigating how the configuration of worked examples either promoted or inhibited a student's transfer of knowledge and skills in varied contexts (Clark et al., 2006; Sweller et al., 2011). The variability effect occurs when a collection of worked examples or tasks that are highly varied result in better transfer of learning performance than worked examples or tasks that are similar to each other (Likourezos et al., 2019). Varying worked examples increases intrinsic cognitive load (Sweller et al., 2011, 2019). Intrinsic cognitive load that exceeds working memory capacity impedes learning and most commonly occurs with novice learners. But, unlike extraneous cognitive load which should always be reduced, if possible, increased intrinsic cognitive load that does not exceed working memory capacity supports and increases learning. Researchers have theorized that a learner benefits from varied worked examples by gaining an increased ability to distinguish between the relevant and irrelevant elements in the worked examples (van Merriënboer & Sweller, 2005).

The Guidance Fading Effect. For learners benefitting from instruction where worked examples are used, research has revealed an interaction between the worked example effect and the expertise reversal effect called the guidance fading effect according to Sweller et al. (2011, 2019). Worked examples are effective instructional tools for novice learners since they provide relevant and specific problem-solving steps that minimize the learner's use of the randomness as genesis principle while maximizing the use of the borrowing and reorganizing principle. Worked examples help a new learner readily transfer new knowledge to their long-term memory. However, more experienced learners may find integrating worked examples into long-term memory stores containing similar, already-existing knowledge slows down further learning. An experienced learner benefits from problem-solving practice without worked examples, which create extraneous cognitive load for the experienced learner. A student transitioning from novice to experienced learner can benefit from a completion task or faded worked example that takes into account the guidance fading effect. A completion task/faded worked example provides a problem statement with a partly worked solution, so worked example and problem solving are both included. Gradually decreasing levels of instructional guidance as student expertise increases has been shown to support learning, revealing the guidance fading effect (Foster et al., 2018; Nückles et al., 2020). Although, due to the ever-shifting level of a learner's expertise, more research including rapid student evaluation at several points during implementation of a teaching strategy is warranted (Kern & Crippen, 2017) to ensure "knowledge-dependent dynamic provision of guidance" (Sweller et al., 2011, p. 174).

The Imagination Effect. For experienced learners, imagining the steps to a problem's solution can be more effective than studying a worked example or faded worked example of the problem solution steps (Sweller et al., 2011, 2019). The results of a long history of research studies, even predating the development of the cognitive load theory, demonstrate the imagination effect (Clark, 1960; Corbin, 1967; Egstrom,1964; Perry, 1939; Sackett, 1964). For novice learners, the borrowing and reorganizing principle of human cognitive architecture makes directly studying worked examples the best way to construct initial schemas in the long-term memory. However, once a more experienced learner has schemas for a concept in place in the long-term memory, the environmental organizing and linking principle allows a large amount of environmental information relating to the acquired schemas to be quickly processed in the working memory. Imagining problem solving procedures supports learning for a student with more experience by employing working memory to process interacting elements that are germane to learning and freeing that student from processing redundant worked examples that create extraneous cognitive load (Kappes & Morewedge, 2016; Leopold & Mayer, 2015; Leopold et al., 2019; L. Lin et al., 2017).

The Self-Explanation Effect. Both the imagination effect and the self-explanation effect call for nurture of effective mental processes that create ideal cognitive load for learning. The self-explanation effect was not conceptualized and initially researched within the paradigm of cognitive load theory but is related to the imagination effect (Sweller et al., 2011, 2019). During self-explanations, a student imagines a concept, skill, or problem-solving process while trying to relate the imagined procedure to principles already stored in the long-term memory. The self-explanation effect occurs when an experienced learner has a mental dialogue while studying a worked example that helps them better understand, learn, and build a schema in their long-term memory about the concept in the worked example (Clark et al., 2006). Self-explanations help learners with some expertise create connections between the interacting elements of a worked example and relate them to previous knowledge. Explaining and providing justifications for problem-solving steps in a worked example creates deeper learning of subject matter as revealed on student assessments (Bisra et al., 2018; Chi et al., 1989; Larsen et al., 2013; L. Lin et al., 2016).

The Element Interactivity Effect. The level of complexity, or in other words the interaction between fundamental components of new knowledge in a learning activity, determines the intrinsic cognitive load imposed by that learning material (Sweller et al., 2011, 2019). Initial experiments by Sweller and Chandler (1994) and Chandler and Sweller (1996) estimated the degree of element interactivity by actually counting the number of elements that learners with specific levels of expertise had to consider in order to learn a certain procedure. Element interactivity is in fact the key determiner of the learning material's cognitive load on working memory (Leahy & Sweller, 2020). If element interactivity is low, then extraneous cognitive load caused by worked example, split attention, modality, redundancy, expertise reversal, generation, imagination, and other cognitive load effects is not as likely to interfere with learning (O. Chen et al., 2015, 2017, 2018b, 2020; Wong et al., 2020). If the element interactivity in the subject matter to be learned is high, extraneous cognitive load from any source is more likely to derail learning (Leahy & Sweller, 2020; Sweller et al., 2011, 2019).

The element interactivity effect refers to the fact that many different kinds of cognitive load effects are only obtained when high element interactivity in learning material creates high intrinsic cognitive load (Sweller et al., 2011, 2019). The expertise reversal effect, for example, constitutes a specific example of the element interactivity effect (O. Chen et al., 2017). The element interactivity effect occurs because of changes in the complexity of material being learned. The expertise reversal effect also occurs with changes in level of element interactivity (interaction of new pieces of knowledge), but the element interactivity is reduced specifically by increases in learner expertise. For example, a very young child learning to read the word *flower* must process each mark in each letter as a separate interacting element while a slightly older child can quickly recognize a letter and its sound already stored in long-term memory (Leahy & Sweller, 2020). An adult, on the other hand, may see the word *flower* and in a split second retrieve an image of a flower from long term memory, processing the entire word as a single element rather than several interacting sounds or connected marks on the page of text. Just as manifestation of the expertise reversal effect is determined by element interactivity, so are most other cognitive load effects explained by the cognitive load theory and substantiated through research (Sweller et al., 2011, 2019).

When the intrinsic cognitive load of a learning task exceeds a student's working memory resources due to having too many complex interacting elements for the learner's level of expertise, the learning task can be altered to reduce cognitive load (Sweller et al., 2011, 2019). Some ways of reducing intrinsic cognitive load include (a) pretraining, (b) focusing on subgoals, (c) presenting declarative and procedural information separately, and (d) reducing intrinsic load in worked example solutions by using a modular approach versus a molar one. The first strategy, pretraining, is simply teaching students one of the concepts or learning elements alone before introducing a second interacting element. With foundational, pretrained information stored in long-term memory, relationships between pretrained and new elements process more quickly and easily in working memory which allows new learning because of the environmental organizing and linking principle of human cognitive architecture. The second strategy of focusing on subgoals cues a student to the fact that certain steps of a problem-solving process belong together and encourages the student to self-explain the purpose of the steps. Processing a smaller number of problem-solving steps at once can also reduce element interactivity to a level that can be handled by the working memory. A learner can more readily integrate the small sections of new learning with knowledge already stored in long-term memory.

Presenting declarative and procedural information separately is a third way to reduce intrinsic cognitive load (Sweller et al., 2011, 2019). Declarative information is related to reasoning about the cause and solution to a problem while procedural information pertains to the action steps that need to be physically taken to solve the problem. Declarative information has higher element interactivity than procedural information. Research has indicated that if a teacher waits to introduce just-in-time practice of procedural steps until schemas in long-term memory have been created for new declarative information, appropriate cognitive load supports learning (Mayer, 2017; van Merriënboer & Kirschner, 2018). Finally, intrinsic cognitive load inherent in the problem-solution steps of a worked example can be reduced. Problem-solving using a generalized formula (a molar approach) forces a novice learner to mentally process many interacting elements at one time, creating a high intrinsic cognitive load. Breaking down a problem-solution into a smaller set of related components and/or considering each component separately from the other elements of the formula (a modular approach) reduces the element interactivity and intrinsic cognitive load of a worked example (Hushman & Marley, 2015; van Merriënboer & Kirschner, 2018).

The Transient Information Effect. One generator of extraneous cognitive load is particularly tied to technology-driven instructional systems: transient information (Leahy & Sweller, 2016; Sweller et al., 2011, 2019; Wong et al., 2020). The transient information effect occurs if learning is thwarted because information disappears before a learner has time to process and link it with already acquired knowledge. Oral speech, by nature, is transient. In fact, humankind invented writing as a way to make transient, spoken information more permanent. Spoken-only instruction has the potential to hinder learning because it requires a learner to hold sentence after sentence in working memory while each sentence is integrated with the last. Spoken instruction creates a heavy cognitive load unless information is shared in manageable amounts and/or made more permanent through learner notetaking or instructor-provided reference text (Biard et al., 2018; Singh et al., 2017).

Modern screen media technology can easily transform written into spoken words and static drawings into animated, moving, and transient images (Ayres et al., 2020; Wong et al., 2020). Therefore, technology-driven instructional systems, especially animations, are vulnerable to creating extraneous cognitive load by changing permanent information into transient information and inadvertently hampering learning (Boucheix et al., 2017; Castro-Alonso et al., 2018). People raised during the digital revolution that began with the invention of the metal oxide semiconductor (Atalla, 1961; Kahng, 1963) have grown accustomed to a continuous flood of digital innovations, invented to solve human problems. However, learning does not improve simply because a teacher adopts new technology (Hegarty, 2004).

Pedagogical animations in particular can generate extraneous cognitive load due to transient information that operates in combination with split-attention, modality, and redundancy cognitive load effects (Ayers et al., 2014; Sweller et al., 2011, 2019). Precautions that designers of educational animation can take to mitigate negative cognitive load effects include the following (Sweller et al., 2011, 2019):

1. Cueing and signaling can help a learner draw out the relevant information from a pedagogical animation (Xie et al., 2017, Zimmermann et al., 2015).
2. Giving the learner control of the animation so they can slow down, pause, rewind, or restart the flow of information can mitigate a negative transient information effect.
3. Segmenting educational animations into shorter, simpler sections lowers element interactivity and reduces cognitive load from all sources.
4. A learner’s possession of prior knowledge before engaging with a pedagogical animation helps a student more easily chunk information in working memory and reduces the learner-perceived complexity of the material. Learners already experienced with particular instructional content may be able to benefit educationally from technology-driven instructional media that presents transient information.

The Human Movement Effect. One use of educational animations has been shown through research to be especially effective (Sweller et al., 2019). Teaching of human movement or motor skills is accomplished more efficiently through instructional animation than static diagrams (Ayres et al., 2020; Mavilidi et al., 2020). Cognitive load theorists surmise that animated demonstrations of hand and body movements are easily processed by the working memory because imitating motor movements is a biologically primary ability, necessary for human survival (Ginns & Kydd, 2020; Lajevardi et al., 2017; Park et al., 2020; Sepp et al., 2020). In fact, research with brain-imaging techniques has revealed mirror neurons that activate in the human brain during both participation and observation of motor activity. Mirror neurons enable some learning of motor skill through simply watching motor skill performance (Thanikkal, 2019). Use of animations to teach motor skills therefore produces low cognitive load since it taps into a biologically primary learning system (Sweller et al., 2011, 2019).

The Grounded or Embodied Cognition Effect. The embodied cognition effect, also called the grounded cognition effect, is obtained when, during learning, students make fine motor physical movements such as gesturing and tracing, or gross motor patterns of movement such as those learned during participation in sports (Ginns & Kydd, 2020; Mavildi et al., 2020; Park et al., 2020; Sepp et al., 2020). Physical movement of the body is a biologically primary human skill, executed unconsciously and therefore not taxing on working memory resources (Geary & Berch, 2016). The embodied cognition effect is different from the previously described human movement effect, which occurs while simply watching the movements of others lowers a student's cognitive load and supports learning of the specific movement being observed (Sweller et al., 2019). The embodied cognition effect occurs when the performance of movement, gesturing, and tracing during learning activities unrelated to the gestures nevertheless increases student learning (Du & Zhang, 2019; Mavilidi et al., 2020).

Seminal researchers such as Barsalou (2008) and Piaget (1970) have established that a strong connection exists between bodily movements, sensory processes, and cognition. Embodied cognition or learning through movement and sensory interaction with the environment was observed by Montessori (1909/1964, 1914/1965, 1949/1989) early in her work with young children and used as a foundation in the educational methods she developed. In fact, since the Montessori method's inception, pointing and tracing with the finger have been incorporated into all Montessori pedagogical lessons for young children, in line with current research on embodied cognition (Agostinho et al., 2015; F.-T. Hu et al., 2014, 2015; Korbach et al., 2020; Macken & Ginns, 2014; Montessori, 1909/1964; Park et al., 2020). Likewise, cognitive load theory has undergone an "evolutionary upgrade" to reflect how "the human motor system and collaboration… support the learning of complex cognitive tasks" (Paas & Sweller, 2012, p. 27). Mavildi et al. (2020) pointed out that tangible examples bolster the internalization of abstract concepts and enrich mental representations of the concepts in long-term memory. Targeted current research has revealed embodied cognition effects on young children's learning of numeracy skills, foreign language, science, and geography when infusing physical activity into the early childhood classroom (Mavilidi et al., 2015, 2016, 2017; Mavilidi, Okely et al., 2018; Mavildi, Ruiter et al., 2018; Toumpaniari et al., 2015). Embodied interaction has also been shown to enhance engagement and learning in mixed reality computer simulations (Lindgren et al., 2016).

Somewhat related to embodied cognition is cognitive offloading. Risko and Gilbert (2016) identify cognitive offloading as a strategy that humans use to reduce working memory load by storing memories or memory triggers in the physical environment. When a person ties a string around their finger to remind them to complete a task or relies on a smartphone or search engine to store and retrieve information, they are reducing cognitive load through cognitive offloading.

The Collective Working Memory Effect. According to the evolving collaborative cognitive load theory, the collective working memory effect occurs when a learner achieves higher learning outcomes while working in a collaborative group than when learning alone (Sweller et al., 2011, 2019; Zambrano et al., 2020). The borrowing and reorganizing principle allows human beings to learn more efficiently from knowledgeable instructors or even other students than alone, forced to use the random generate and test principle. In fact, collaboration itself is a biologically primary skill, acquired effortlessly by human beings, as are skills that support collaboration such as hearing, listening, joint attention, planning, generalizing, and speaking in a primary language (Zambrano et al., 2020). Two or more learners sharing the effort needed to achieve a mutual learning goal has been shown through research to stimulate engagement in learning and use of metacognitive skills (J. Jung et al., 2019; P. A. Kirschner et al., 2018; Zambrano et al., 2020). This cognitive load effect can be seen in Montessori classrooms, which include children within a 3-year age span. Older students spontaneously teach younger students, and collaboration occurs between children of all ages and abilities during 3-hour work cycles of student-led work (Montessori, 1909/1964, 1948/1973, 1949/1974). However, other research has revealed “social loafing” (Sweller et al., 2011, p. 230) when collaborating learners rely on the work of other group members, disengage from group cooperation, and learn little. Also, sharing and coordinating information, or transaction costs, can increase the extraneous cognitive load of learning in a collaborative group (F. Kirschner et al., 2009). However, if transaction costs are kept low, collaborative groups allow students to divide the interacting elements of a learning task between several people thereby reducing the cognitive load for each learner and supporting deep transfer of learning, especially for complex problem-solving tasks (P. A. Kirschner et al., 2018; Sweller et al., 2019).

Cognitive offloading, described in the previous section, also occurs in collaborative groups or transactive memory systems. Cognitive offloading in collaborative groups happens when knowledge is distributed across a group of individuals so that the collective group knows more than any one individual. Cognitive offloading is a mechanism by which a collaborative group might reduce cognitive load and demonstrate the collective working memory effect.

The Generation Effect. When instructional materials have high levels of element interactivity, the worked example effect is demonstrated (O. Chen et al., 2015, 2016b). Learners exhibit better test performance when they practice with worked examples that provide problem solutions. However, when the element interactivity in learning materials is low, an opposite, generation effect appears. The generation effect occurs when learners provide answers to problems without any guidance and score higher on performance tests than those who practiced with materials that provided guidance and answers (O. Chen et al., 2018b). Worked examples can produce extraneous cognitive load for problems with low element interactivity, which are easier to solve without extra direction.

The Testing Effect. The testing effect, supported by research dating back a century, occurs when a learner retains more information from having a test on learned information than restudying the learned information (Gates, 1917; Leahy & Sweller, 2020). Similar to the generation effect, however, the testing effect is more likely to occur when element interactivity is low (Hanham et al., 2017). When element interactivity is high, reviewing the step-by-step solutions provided by worked examples can produce more successful learning outcomes, creating a reverse testing effect (Hanham et al., 2017).

The Self-Management or Self-Regulation Effect. The self-management of cognitive load effect, also labeled self-regulated learning, happens when students apply the principles of the cognitive load theory to themselves and manage their own cognitive load as they learn (Plass, Kalyuga, & Leutner, 2010; Sweller et al., 2019). Under ideal conditions, all student learning would be supported with high quality pedagogic materials created to consider cognitive load. However, the free exchange of information, as facilitated by the internet for example, increases the chances that learners will encounter low quality learning materials. A student's selection of study activities, be they too easy or too difficult, affect cognitive load and therefore learning outcome (Foster et al., 2018; Nugteren et al., 2018). Students who are taught to apply cognitive load principles to their own learning can glean more knowledge from poorly designed learning material than students who have only been exposed to materials with high quality instructional design

(Sweller et al., 2019). Plass, Moreno, and Brünken. (2010), citing several research studies, warn however that for learners inexperienced in self-regulation of learning strategies, the metacognitive activity of monitoring, control, and self-refection can initially increase extraneous cognitive load and lower learning performance. As with all learned skills, self-management of cognitive load must be processed through the working memory before storage in the long-term memory makes it instantaneously available to the learner. Designers of curricula and teachers can support a student's self-management of cognitive load by providing a scaffold of suggested strategies, steps to take, and goals in the metacognitive process of reducing extraneous cognitive load (Plass, Kalyuga, & Leutner, 2010).

The Working Memory Resource Depletion Effect and The Spacing Effect. According to recent research by O. Chen et al. (2018a), working memory resources become depleted after prolonged mental effort resulting in decreased learning outcomes compared to learning performance after tasks requiring less mental exertion. This depletion effect does not occur, however, when learning episodes requiring high mental effort are spaced with time between each episode. The effect on working memory function of temporally spacing learning activities is more pronounced when the learning tasks have similar "cognitive components" (O. Chen et al., 2018a, p. 484). According to O. Chen et al.'s (2018a) research with primary-aged children learning mathematics, information processed over longer periods with temporal gaps between learning episodes produced higher learning outcomes on post-tests than when learning was massed or presented consecutively with no breaks. This spacing effect occurred even though the amount of information presented to the children and the total time they were given to process the information were identical in both spaced and massed presentations.

The Effect of Emotions, Stress, and Uncertainty. Characteristics of the physical learning environment affect cognitive load and can determine instructional effectiveness (H.-H. Choi et al., 2014). Specifically, effects of the physical environment include affective effects such as emotions, physiological effects such as stress, and cognitive effects such as uncertainty and use valuable working memory resources, reducing working memory capacity needed for learning tasks (Plass & Kalyuga, 2019; Sweller et al., 2019). Plass and Kaplan (2016) proposed the theory that emotion operates in a cognitive processing channel separate from the phonological and visual-spatial channels prominently considered in classic working memory theory (Baddeley & Hitch, 1974) and can affect learning in several different ways. Emotions, stress, and uncertainty might be inherent in a learning task making them an integral or intrinsic part of the learning. For example, medical professionals learn in situations where patient illness and suffering evoke uncertainty and strong emotion, and members of armed forces learn under the stress of threat of violence. When emotions, stress, and uncertainty cause extraneous cognitive load that interferes with learning, a learning environment should be created that mitigates them. When emotion, stress, and uncertainty are an intrinsic part of the learning task, instruction should include interventions such as mental practice or collaboration that support a student's ability to learn, even in these unavoidable environmental conditions.

The Goal Free Effect. According to research, less cognitive load on the working memory is created when a learner is instructed to find as many answers to a problem or question as they can rather than just one right answer. This is called the goal-free effect in cognitive load theory (Sweller et al., 1998, 2011, 2019). A human being looking for one right answer to problem usually uses a means-end strategy to work backwards from the goal to the problem's given conditions and constraints. Means-end analysis puts a heavy load on working memory because the learner must hold in mind (a) the problem, (b) the goal, (c) the difference or relationship between the problem and the goal, (d) any problem-solving operators, and (e) any sub-goals. When presented with a goal-free problem, a learner cannot wheedle out the differences between the current problem and the goal because there is no goal. So, they will consider each problem and find any problem-solving operator that can be applied. When this two-step procedure generates a new problem, the learner repeats the process. Reducing problem-solving to a low pressure, two-step procedure that is (a) completed while holding fewer items in mind and (b) allows many right answers reduces both intrinsic and extraneous cognitive load.

However, study results on the goal-free effect have been mixed. Some research disputes the goal-free effect such as Nebel et al.'s (2017) finding that having specific goals lowered extraneous and intrinsic cognitive load for educational game players. However, other abundant research has borne out that goal-free problem solving provides a combination of low cognitive load and focus on solutions that supports the construction of knowledge (Sweller, 1988; Sweller et al., 2019).

Literature Review Related to Key Variables and Concepts

Working memory function is at the foundation of all other executive function skills, and its development is most pronounced from ages 3 to 4 years (Blakey & Carroll, 2015; McKenna, 2017; Rothlisberger et al., 2013). Educator support of working memory function through cultivation of ideal cognitive load in mindfully chosen learning environments could produce positive social change by improving learning and attainment of life skills by pre-school-aged children (Ackerman & Friedman-Krauss, 2017; Sweller et al., 2011, 2019). Because of working memory's importance to human learning, researchers have examined ways to improve working memory. Techniques for improving working memory function range from administration of pedagogic working memory training (Diamond & Ling, 2016; Ninaus et al., 2015) to modulation of neurophysiological brain oscillations with frequency-tuned electromagnetic fields (Albouy et al., 2018). Studies have shown that working memory in young children declines without learning environment components such as emotionally calm and secure relationships with caregivers (de Wilde et al., 2016) or supportive pedagogy (Brock et al., 2018; Conway, 2019; Gade et al., 2017; Passalunghi & Costa, 2016; Peng & Fuchs, 2017; Thiery et al., 2016). Findings in several studies showed that relationships existed between the cognitive load inherent in the activities of children, such as use of screen media or participation in authentic Montessori programs, and the development of optimally functioning working memory (Blakey & Carroll, 2015; Lillard, 2012; Lillard, & Heise, 2016; Lillard et al., 2015, 2017; Nathanson et al., 2014).

Montessori Pedagogy and Cognitive Load Effects on Working Memory

Although Montessori education (Montessori, 1909/1964) is well over 100 years old, research on its effectiveness is not prolific. Scholars such as Marshall (2017) have therefore chosen to review studies that "do not explicitly evaluate Montessori but which evaluate the key elements" (p. 1) of the method. Marshall's strategy shall be used in this section to identify the cognitive load effects of some Montessori didactic practices by citing working memory measurements of students in learning environments with key elements closely matching Montessori practices (Sweller et al., 2011, 2019).

The Montessori education framework for teaching and learning, which parallels research supported practices that create ideal intrinsic cognitive load on the working memory (Denervaud et al., 2019; Sweller et al., 2011), acts as working memory training in early childhood. Diamond and Ling (2016) listed Montessori education and tools of the mind (Bodrova & Leong, 2007; 2017; Fabri & Fortuna, 2020) as methods of education supportive of executive functions, including working memory. Research has shown that cognitive training programs can improve executive function (Pietto et al., 2018). Support of learning through support of appropriate cognitive load on the working memory is at the foundation of Montessori pedagogic activity and is accomplished in several ways in a Montessori classroom.

Respect for the Child and the Work of Childhood

Montessori teachers are required to speak to and interact with children in non-manipulative, non-condescending but respectful ways. This treatment of the child stems from Montessori philosophy that the child is doing the important work of creating the adult they will become (Montessori, 1909/1964, 1949/1972, 1949/1989; Standing, 1962). According to Montessori philosophy, the child instinctually knows what they need to be doing to develop the coordination, concentration, order, and independence characteristic of a physically and mentally healthy adult (Lillard, 2021). By respecting young children's expertise in the creation of themselves and therefore allowing young children the freedom to choose activities, the Montessori method and its teachers support healthy executive function, including working memory function (Diamond, 2012). Children treated with respect and dignity and allowed to follow their own passions are free from the stress accompanying disrespectful treatment (Montessori, 1909/1965). Stress created by disrespectful treatment inhibits working memory function and specifically learning by creating extraneous cognitive load on the working memory (Plass & Kalyuga, 2019).

Following the Child

Montessori (1909/1964) education supports executive function, including working memory, by avoiding emotional manipulation and abuse of a pre-school-aged child (Plass & Kalyuga, 2019). A Montessori teacher does not try to get the child to fall in line with a predetermined set of accomplishments for the day (Montessori,1949/1974; Standing, 1962). Rather, the Montessori teacher follows the child or in other words, observes the child as they choose classroom activities that they are interested in for clues on how to share the knowledge the child is interested in at that moment (Lillard, 2020). Within the prepared learning environment of the Montessori classroom, a child has freedom within limits to choose from materials carefully placed there to lead to specific learning outcomes (Montessori, 1914/1965, 1949/1974). The child is free to learn in an environment alongside adults who are observing and supporting their learning choices and interests. The child feels free but is also directly instructed by both the contents of the learning environment and the teacher (Lillard, 2021). The positive emotion generated when a student follows their own interests supports learning by (a) reducing extraneous cognitive load created by negative emotion and (b) protecting intrinsic motivation (Plass & Kalyuga, 2019). Diamond and Ling (2016) cited loneliness as a condition that lowers executive function. In Montessori learning environments, attentive observation of each student by the teacher allows the teacher to step in with just-in-time support of learning and other needs (Montessori, 1948/1967). Even if a child is working on something independently, the presence of an available teacher can keep them from feeling alone (Montessori, 1914/1965).

Normalization of a Child's Coordination, Concentration, Order, and Independence

The Montessori method has a worldwide, century-deep goal of supporting the normalization (a term coined by Montessori) of a young child (Montessori, 1909/1964, 1914/1965). Order, concentration, coordination, and independence are the four qualities that Maria Montessori believed were the direct aim of young children's development (Standing, 1962). Normalization can be observed when a child's movements and observable intentions exhibit coordination, concentration, order, and independence (Montessori, 1909/1964, 1948/1967, 1949/1972).

The emphasis of Montessori pedagogy on protecting a child's concentration and reinforcing order in environment and pedagogical tasks supports learning, according to the cognitive load theory (Sweller, 2016; Sweller et al., 2011, 2019). Multitasking places increased cognitive load on working memory. Focus on one task at a time reduces element interactivity and contributes to an organized schema of ideas in long-term memory as evidenced by the research backed isolated elements effect of the cognitive load theory (Örün & Akbulut, 2019; Osborne et al., 2016; Pollard & Courage, 2017).

Montessori approaches teach students to (a) manage multitasking by ignoring irrelevant interruptions that are unrelated to the main goal or task and thereby (b) mitigate a negative split-attention cognitive load effect (Montessori, 1948/1967; Sweller et al., 2011, 2019; Szumowska & Kossowska, 2017). In Montessori pedagogy, each new, simple concept builds intentionally on a previously learned concept (Leahy & Sweller, 2020; Montessori, 1914/1965, 1948/1967). Montessori instructional strategy follows Sweller et al.'s (2011) guidelines to reduce "working memory load by converting multiple lower-level schemas into a smaller number of higher-level schemas or even a single higher-level schema that can be treated as a single entity" (p. 58) in the working memory.

Reading, a biologically secondary skill, requires the integration of brain networks adapted for language, visual imagery, and executive functions such as attention and working memory (López-Barroso et al., 2020). Early childhood is the time when neuroplasticity is greatest and potential for encouraging reading through deliberate and consistent actions such as dialogic reading between adult and child or Montessori language activities is at its peak (Hutton et al., 2017). Dialogic reading techniques and Montessori methods prepare preschoolers for reading by familiarizing them with top-down, left-to-right reading conventions; page-turning; and matching symbols with spoken words. Early familiarization with these basic reading conventions secures them in the child's long-term memory where they can be retrieved as a child is learning more advanced reading skills, reducing cognitive load on the child's working memory per the isolated elements effect (Sweller, 2016). The support Montessori pedagogy provides for executive functions emanating from the prefrontal cortex of the brain was also demonstrated by research results with dementia patients who experienced improved cognitive function while using Montessori classroom materials (Sheppard et al., 2017).

Diamond and Lee (2011) pointed out that before the creation of the construct of executive function, Maria Montessori recognized the presence of brain functions for goal directed behavior and developed her educational methods to support them. Diamond (2012) listed 10 specific characteristics of Montessori school curricula, which have been empirically shown to improve children's executive functions (see also Lillard & Else-Quest, 2006; TEDx Talks, 2014). Montessori schools (a) support children's practice of executive functions at higher and higher levels through challenging but interesting activities, (b) deliberately reduce stress in the classroom, (c) avoid embarrassing or publicly humiliating a child because teachers are given explicit philosophical and didactic standards that help the teachers avoid disrespectful treatment of children, (d) intentionally cultivate students' sense of wonder, pride, and self-confidence, (e) provide hands-on, active learning activity, (f) easily accommodate each child learning at a different pace, (g) emphasize both character and academic development, (h) cultivate oral language, (i) support children's teaching of each other, and (j) cultivate social skills and bonding (Ultanir, 2012).

Although called by different names in Montessori pedagogy and the construct of executive function, evidence of a pre-school-aged child's normalization, as delineated and specifically supported in Montessori classrooms, is also evidence of executive brain function (Ackerman & Friedman-Krauss, 2017; Diamond, 2012; Howell et al., 2013;

Jusienė et al., 2020; Lezak, 1982; Montessori, 1948/1967). Maintaining attentional focus is equivalent to sustaining concentration in Montessori pedagogy. Inhibition of impulses or self-control is equivalent to Montessori's idea of order in a child's movement and thinking. Switching flexibly between two or more concepts or flexible thinking is equivalent to Montessori's idea of independence in thought and action. The executive functions (a) inhibitory control of impulses or self-control, (b) organization, and (c) self-monitoring are equivalent to Montessori's idea of a child's thoughts being self-guided by internalized order that manifests in orderly actions. The executive abilities to (a) plan, (b) switch flexibly between tasks and thoughts, and (c) initiate tasks coincide with Montessori's idea of the young child's independence enabling them to take initiative and make real choices without overt coercion by adults. Mental manipulation of ideas or *working memory*, through support of appropriate cognitive load, is at the foundation of Montessori pedagogic activity and is accomplished in several ways in a Montessori classroom. Finally, prolific research has determined associations exist between the physical fitness gained by pre-school-aged children through practicing and mastering physical coordination skills and brain function, including the executive functions of both (a) inhibitory control and (b) working memory (Carson et al., 2017; de Bruijn et al., 2018; Mavilidi, Ruiter et al., 2018; McMath et al., 2021, 2022; Mora-Gonzalez et al., 2019; A.Veraksa et al., 2021).

The Prepared Learning Environment

The Montessori educational approach relies on a carefully prepared environment. Each piece of learning material has a specific, permanent home on the shelves of the classroom which is accessible to every child. A calm, muted color scheme, aesthetically attractive natural materials, and display of materials with visual space between each activity contribute to a reduction in visual and sensory clutter and prevent potential extraneous cognitive load caused by a chaotic environment (Montessori, 1948/1967, 1949/1972; Standing, 1962). The care of the environment, including cleaning and restoring order to it, are carried out by the young children in the learning environment as part of Montessori pedagogy. The children's ownership of responsibility for maintaining this environmental order is reflected in the traditional labeling of Montessori schools as *children's houses* (Montessori, 1909/1964). According to research conducted by flow theorists Rathunde & Czikszentmihalyi (2005, 2014), Montessori school environments (a) elevated intrinsic motivation, (b) promoted flow experience, and (c) increased undivided attention. These calm, peaceful learning conditions are a hallmark of Montessori education and set it apart from other educational programs.

In fact, the qualities of the physical learning environment effect cognitive load and can interact with learner and learning task characteristics to support ideal cognitive load on the working memory or create extraneous cognitive load (H.-H. Choi et al., 2014; Örün & Akbulut, 2019). Örün and Akbulut's (2019) research showed an increase in perceived mental effort and lowered working memory function when students worked in a chaotic, noisy environment versus one that was quieter and more distraction free. Research has indicated that high pressure environments compromise working memory and lower cognitive functioning (Sattizahn et al., 2016). Furthermore, Sattizahn et al. (2016) found that those with higher working memory capacity were more susceptible to pressure-induced cognitive deficits. A learning environment that is not designed to mitigate the effects of high pressure and stress on learners imposes extra extrinsic cognitive load that decreases the ability of students to learn.

H.-H. Choi et al. (2014) identified three types of effects that the physical learning environment can have on cognitive load: (a) cognitive effects such as uncertainty, (b) physiological effects such as stress, and (c) affective effects such as emotions (Sweller et al., 2019). Uncertainty, stress, and emotions can compete with learning-task-relevant cognitive processes and thereby hinder both initial learning and learning transfer (Moran, 2016; Sweller et al., 2019). In reference to abundant research findings supporting the learning environment's effects on cognitive load, Sweller et al. (2019) concluded "that learning is best supported by preventing states that might negatively affect learning" (p. 285). Maintenance of a learning environment rich in predictability, freedom from stress that distracts from learning, and enabling of self-confidence is a hallmark of the Montessori method built on supporting a learner's experience of order, concentration, coordination, and independence (Montessori, 1914/1965, 1929/1970, 1936/1966).

Montessori learning environments feature learning materials that support convergent thinking, where playing or working with a material leads a student to one right answer. Unlike in Montessori programs, traditional preschool programs often use the discovery method of learning (Edwards et al., 2012). Montessori early childhood didactic practices have been criticized because students are given direct instruction at the beginning of learning activities rather than being introduced to new concepts through discovery learning (Lillard, 2017, 2018, 2019, 2020, 2021; Marshall, 2017). However, Sweller (1988) suggested that problem solving as a learning device is ineffective because the cognitive processes required by learning and problem solving do not overlap very much. Because the means□ends analysis inherent to problem solving requires such a large amount of cognitive processing capacity, cognitive resources are not available for schema creation (Sweller, 1988; Sweller et al., 1998, 2019). According to Sweller et al. (2011, 2019) the discovery method of learning places a heavy cognitive load on the working memory. However, evidence detailed below indicates that Montessori practices reduce rather than increase the extraneous cognitive load on working memory and thereby support learning.

Freedom Within Limits

Children in Montessori preschool programs reap the benefits of free choice in the activities they choose to do within the classroom (Montessori, 1909/1964). At the moment a child is attracted to and motivated to try an activity, they may choose and participate in the activity (Montessori, 1914/1965, 1936/1966, 1948/1967). This practice supports feelings of self-efficacy, self-esteem, and curiosity (Lillian et al., 2017; Rathunde & Csikszentmihalyi, 2005, 2014). Positive and calm feelings do not create extraneous cognitive load on the working memory, so they are supportive of learning (Sattizahn et al., 2016; Vallée-Tourangeau et al., 2016). Also, children are free to move away from an activity, leaving it intact on a table or floor mat, and return to it later. This freedom to leave and return to learning activities later supports learning, according to the cognitive load theory, since working memory resources can become depleted after prolonged cognitive work according to O. Chen et. al (2018a; see also Rathunde, 2009, 2014, 2015). However, when learners have temporal space between learning activities requiring similar cognitive resources, they absorb and retain the new learning better according to the cognitive load spacing effect (O. Chen et al., 2018a). In a Montessori classroom, learners of all ages have the freedom to act on internal cues that working memory resources are becoming depleted and halting learning by taking natural breaks in an activity as needed (O. Chen et al., 2018a; Montessori, 1914/1965, 1948/1967). Learning is supported by Montessori classroom procedures that allow leaving and returning to learning materials that will remain undisturbed by teacher or classmates.

Organization in the environment, classroom procedures, and teacher-kept records provide structure that keeps calm order in the classroom environment (Montessori, 1936/1966). Careful organization of classroom materials and training of the children in procedures that promote respectful interactions and mindful movement through the learning environment help students learn independently in the Montessori mixed-age classroom (Montessori, 1914/1965, 1936/1966; Standing, 1962). Since materials are stored in their permanent places on open shelves, cognitive load is not wasted by the child in worry or confusion about where to find a desired learning material. The classroom organization and clear boundaries that are part of Montessori pedagogy contribute to a child's ability to concentrate without distraction and also reduce extraneous cognitive load (Sweller, 2016).

Learning Through Movement

A new term has arisen for learning through physical activity – embodied cognition (Mavilidi et al., 2019; Sepp et al., 2019). In harmony with Montessori's concept of the absorbent mind, the theoretical framework of grounded or embodied cognition puts forward that action and perception are inextricably bound and bi-directionally influence each other, with all cognitive processes being grounded in the physical environment (Barsalou, 2008; Montessori, 1949/1989; Rathunde, 2009, 2014, 2015). Montessori (1948/1967) philosophy and pedagogy recognize a young child's need for "movement connected with the mental activity going on" (p. 142) and support it with procedures that protect a child's free movement through the learning environment during the entire learning period. Current research supports Montessori education's emphasis on learning reinforced through movement and manipulation of learning materials as supportive of working memory through reduced cognitive load (Agostinho et al., 2015, 2016; Novak & Schwan, 2021; Sepp et al., 2019; Vallée-Tourangeau et al., 2016). Montessori (1914/1965, 1936/1966) perceived use of the hand to be key to both human brain evolution and human learning, based on theories available in her lifetime (Ginns & Kydd, 2020; Gregory, 1928; Standing, 1957/1998; F. R. Wilson, 1999). Pointing and tracing, hand movements embedded into all initial hands-on three-period lessons in a Montessori classroom, have abundant, recent research supporting their positive effects on learning (Agostinho et al., 2016; Ginns & Kidd, 2020; Ginns et al., 2016, 2020; F.-T. Hu et al., 2015; Mavilidi et al., 2020; Park et al., 2020; Risko & Gilbert, 2016; Sepp et al., 2020; Sweller et al., 2019). Vallée-Tourangeau et al. (2016) found that interactive movement and use of manipulatives during learning reduces learner anxiety, which also decreases extraneous cognitive load (Plass & Kalyuga, 2019; Sweller et al., 2019). Korbach et al. (2020) built on findings of embodied cognition using Montessori geometry materials and methods for young children (F.-T. Hu et al., 2014, 2015) to study use of hands in pointing and tracing with an active screen media application. Results indicated a beneficial effect of pointing and tracing gestures on learning performance including an observed shift in visual attention, and deeper processing of information, even though study participants did not perceive reduced load on subjective ratings (Du & Zhang, 2019).

Montessori learning materials are intentionally designed to attract children's practice of gross and fine motor skills during all learning (Montessori, 1909/1964). According to classroom procedures, for example, all learning activities are carried out on mats or rugs that the children take from a central location and place on any high or low table or section of the floor that they choose. Also, learning materials are designed to invite many different kinds of movement, with goals for the child's practice of those kinds of movement built into the teacher's lesson plans. For example, using visual, tactile, haptic, and stereognostic senses to learn concepts of dimension, a child also practices their princer grasp while working with the classic Montessori preschool material, the knobbed cylinders (Montessori, 1909/1964, 1914/1965). Likewise, a child learns through gross motor movement using vestibular and proprioceptive senses during Montessori's walking on the line learning activities (Montessori, 1909/1964). Montessori pedagogical design which welcomes and facilitates a young child's purposeful and task-related full-body movements in the classroom also supports working memory function and learning (Mavilidi et al., 2014, 2020; Mavilidi, Ruiter et al., 2018). According to recent research, full-body movement that is related versus unrelated to the learning task supports working memory through both (a) the embodied cognition cognitive load effect and (b) the reduction of the extraneous cognitive load created during the “effort to stay seated” that “could not be dedicated to learning” (Mavilidi et al., 2020, p. 115; see also Mavilidi et al., 2015, 2016, 2017, 2020; Mavilidi, Okely et al., 2018; Mavildi, Ruiter et al., 2018; Toumpaniari et al., 2015).

Learning Through the Senses with Concrete Materials in Meaningful Contexts

Montessori educational philosophy and practices incorporate hands-on materials intended to provide learning through multiple senses. Human senses include sight (vision); hearing (audition); touch (tactition, haptic, stereognosis); taste (gustation); smell (olfaction, chemoreception); balance (vestibular, equilibrioception); position and movement in space (proprioception); muscle tension sensation; stretch receptors in lungs, bladder, stomach, and gastrointestinal tract; grasping or contact with surfaces during movement through space (haptic perception); time (circadian rhythm); magnetic force sensitivity (magnetoception); heat (thermoception); hunger (famenception); thirst (prodipsia); and even pain (nociception) (Feez, 2019; Hiskey, 2010; Lillard, 2011; Montessori, 1909/1964,1948/1967; Standing, 1962). Information enters the working memory through every human sensory receptor, but most biologically secondary knowledge is received through visual, auditory, and embodied channels and processed through the (a) visuospatial sketchpad, (b) phonological loop, and (c) embodied foci within working memory (Mayer, 2014; Sepp et al., 2019; Sweller et al., 2019). Montessori pedagogy capitalizes on the modality cognitive load effect and embodied cognition in learning by taking advantage of the biologically primary human ability to listen to speech while they look at objects (Sweller et al., 2011), and also while they taste, smell, move, and feel sensations emanating from without and within their bodies (Ginns & Kydd, 2020; Mivilidi et al., 2020; Park et al., 2020; Sepp et al., 2019, 2020). Since biologically primary learning occurs without creating additional cognitive load in the working memory, Montessori education's intentional use of all sensory modalities in its pedagogical practices (Montessori, 1909/1964, 1914/1965, 1936/1966) supports young children's acquisition of biologically secondary knowledge, such as reading and mathematics concepts, without creating extraneous cognitive load (F.-T. Hu et al., 2015; Novak & Schwan, 2021). According to Mavildi et al. (2020), mental schemas that consist of multi-modal representations of learning material are "closely intertwined with sensorimotor functions" (p. 106) and are therefore higher-quality cognitive schemas. In schemas where information from different sensory modalities is chunked together, the working memory can process more information at one time "but through different sub-systems" (Mavilidi et al., 2020, p. 115; see also Risko & Gilbert, 2016). Information received through multiple, coordinating sensory modalities is more "durable" (Park, Flowerday, & Brünken, 2015, p. 268).

The materials and activities in a Montessori classroom provide rich, semantically meaningful experiences that allow children to effortlessly absorb sensory information in natural contexts (Montessori, 1949/1989). Zimmerman et al. (2016) found that young children learned less from video than in-person presentations, but meaningful contexts enhanced the learning of young children. Montessori learning environments intentionally capitalize on the biologically primary abilities of learners to gather information about the real world through all senses by including sensorial learning materials and activities (Montessori, 1909/1964; Lillard & Taggart, 2019). Indeed, about a quarter of the learning materials in a Montessori early childhood environment are identified as “the sensorial material” (Montessori, 1914/1965, p. 65) and are stored together on shelves in the sensorial area of the classroom. Some of these classic Montessori materials include (a) pink tower, (b) knobbed cylinders, (c) broad stair, (d) red rods, (e) knobless cylinders, (f) geometric solids, (g) geometric cabinet, (h) constructive triangles, (i) binomial and trinomial cubes, (j) rough and smooth boards, (k) the mystery bag, (l) fabric matching, (m) thermic tablets, (n) thermic bottles, (o) baric tablets, (p) sound cylinders, and (q) bells (Montessori, 1909/1964, 1914/1965, 1949/1974; Nienhuis, 2019).

In-person presentations include back-and-forth communication and just-in-time feedback between teacher and student that enhance learning (Zimmerman et al., 2016). Social engagement supports learning transfer (Hipp et al., 2017; Zimmerman et al., 2017). Montessori pedagogy for young children also includes pervasive, intentional teacher and hands-on material led instruction on the qualities of objects, such as color, form, and texture. As contrasts between objects are made obvious to the child, the child becomes curious to explore, discriminate between, and classify them (Ahlquist & Gynther, 2019; Montessori, 1949/1989). This use of variation, invariance, and isolation of qualities in Montessori pedagogy gives young children finite classification categories for an infinite number of objects and ideas, facilitating the schema formation described in cognitive load theory (Ahlquist & Gynther, 2019; Sweller et al., 2019). As Maria

Montessori (1948/1967) put it, “to teach details is to bring confusion; to establish the relationship between things is to bring knowledge (p. 58).”

A focus in Montessori learning environments on young students learning through experience with the real world rather than fantasy materials has been criticized (Lillard & Taggart, 2019). However, providing children with the steps and time to engage in or help with activities such as cooking, building, and other real work boosts both skills and positive feelings of self-worth in young children (Lillard & Taggart, 2019; Montessori, 1914/1965, 1949/1974). Lillard (2018) referred to “a human drive for virtuosity” (p. 397) underlying young children’s developmentally guided choices. Children are strongly attracted to real activities and often say out loud, I want to do it by myself. Certainly, Montessori pedagogy for young children where a quarter of the learning environment is devoted to step-by-step instruction and materials for practice of practical life skills aligns well with the borrowing and reorganizing principle of human cognitive architecture (Montessori, 1914/1965, 1948/1967; Sweller & Sweller, 2006).

In line with the borrowing and reorganizing principle of human cognitive architecture, each Montessori pedagogical material is intentionally designed to be self-correcting (Montessori, 1914/1965, 1948/1967). For example, in the seriation and dimension learning material called the knobbed cylinders, the cylinders will fit into their cylinder block only one way, and that one way reinforces the correct dimension-based seriation for the learning activity (Montessori, 1909/1964, 1948/1967). Montessori materials support user-controlled and asynchronous learning with feedback “juxtaposed with instructional content at the process level” (Zeglen & Rosendale, 2018, p. 23) or provided when learners are actively learning rather than in formal assessment outside of the learning activity. Also, Montessori pedagogy supports learner control of the pace of learning; children can take as much time as they need with any learning activity (Montessori, 1914/1965, 1949/1974). Learner control of pacing reduces cognitive load (Sweller, 2011). According to cognitive load researchers, de Bruin and van Merriënboer (2018), learning environments like Montessori that are filled with such self-cueing learning methods and materials lead to better self-regulation of learning activity, more efficient learning, and higher learning outcomes (Montessori, 1909/1964).

Learning in a Montessori environment is notably aided by Montessori's series of pedagogical materials in each subject area. Hands-on, concrete learning tools heavily support a student at the beginning of the learning process (Montessori, 1914/1965, 1948/1967). But as the learner internalizes concepts into their long-term memory, the concrete support provided by materials becomes increasingly abstract also. In Montessori education, a learner moves from three-dimensional learning tools to two-dimensional drawings and written words, and finally to freedom from concrete support. Because abstract learning begins with concrete materials, Montessori students acquire complex knowledge one graspable concept at a time. This learning routine that starts with concrete materials and moves to abstraction is the same for all Montessori students, whether in preschool or high school. The Montessori pedagogical patterns described guard against the expertise reversal effect and demonstrate the guidance fading effect on cognitive load (Sweller et al., 2011, 2019). Montessori education provides hands-on, direct instruction to introduce new concepts and supports a learner's access of their own long-term memory as they become increasingly expert in a branch of learning, in harmony with cognitive load theory (Montessori, 1914/1965; Sweller et al., 2011, 2019).

Van Merriënboer and Kirschner's (2018) four-component instructional design (4C/ID) was specifically created by these cognitive load researchers to follow a pattern of managing extraneous cognitive load by gradually decreasing guidance at each level of complexity. This pedagogical pattern is right in line with century-old Montessori practices. Younger Montessori students use gained knowledge to care for their own classroom and older children in Montessori schools use their knowledge in real-life work by running farms and small businesses (Montessori, 1948/1973). The 4C/ID model also indicates a preference for activity based on real-life tasks to reinforce both novel and recurrent fundamental skills (Sweller et al., 2019; van Merriënboer & Kirschner, 2018). Montessori pedagogy has some parallels to the 4C/ID model, which was specifically developed using the model of human cognitive architecture at the foundation the cognitive load theory (Montessori, 1909/1964, 1949/1972; Sweller et al., 2019; van Merriënboer & Kirschner, 2018).

The Three-Period Lesson

In contrast to other early childhood pedagogies that use minimal guidance during instruction, Montessori education uses the three-period lesson when introducing the use of each learning material (Montessori, 1909/1964, 1914/1965, 1948/1967; Standing, 1962). Although children have freedom to choose what materials they will work with during any given work session, an observant Montessori teacher joins the child as they choose something new and gives an intentionally clear and simply worded lesson to the child tying the material to the concept it is designed to teach. Purposefully short verbal explanations are a key component of Montessori's three-period lesson. This combination using hands-on learning materials and very concise verbiage while presenting young children with new concepts creates ideal cognitive load for learning in line with both the modality and redundancy effects in cognitive load theory (Mayer, 2017; Sweller et al., 2011, 2019). In fact, cognitive load researchers have discovered that a reverse modality effect occurs when lengthy verbal text accompanies a visual presentation; students learn most effectively when short verbal explanations accompany visual presentations (Liu et al., 2021; Renkl & Scheiter, 2017). Also, Montessori early education's introduction of short written narration or labels into a learning activity with diagrams reduces cognitive load and increases learning in line with reverse modality and transient information cognitive load effects (Mayer, 2017; Mayer & Johnson, 2008).

This element of direct instruction in Montessori early childhood programs contrasts with the constructivist, discovery, problem-based, experiential, and inquiry-based teaching methods of traditional preschool programs (P. Kirschner et al., 2006). However, mirror neuron system research has indicated that when a teacher models actions for a child, as in a Montessori three-period lesson, the demonstration causes a child's mirror neurons to discharge in brain areas controlling the observed muscle movements, even when the child is still (Burzi et al., 2016; Hétu et al., 2016). Imitation is a powerful tool for acquiring biologically secondary knowledge (Sweller & Sweller, 2006). Also, according to P. Kirschner et al. (2006), Montessori practices incorporate imitation of adult-demonstrated use of Montessori materials to reduce extraneous cognitive load whereas traditional, discovery-based early childhood pedagogical practices create extraneous cognitive load due to the narrow limits of change principle described by cognitive load theory. Sweller et al. (2011, 2019) described a flawed philosophical foundation, popularized in the 1990s, upon which the discovery-based learning movement rested. Proponents of discovery learning assumed that since most of learning outside of schools was acquired effortlessly, without direct instruction, the best way to improve teaching and learning was to eliminate explicit instruction for young children (Sweller et al., 2011). Montessori practices are in line with cognitive load theory's clarifications about biologically primary and biologically secondary knowledge and the very different processes by which each vital kind of learning are acquired (Geary & Berch, 2016; Sweller et al., 2011, 2019).

Mixed-Age Groups

Montessori educational environments encompass a three-year age span within the same classroom (Montessori, 1909/1964, 1936/1966). The fact that learners of different ages and ability levels are working in the same space at the same time necessitates a pedagogical structure that can accommodate simultaneous engagement by students in diverse learning activities. The same set of hands-on materials can often be effectively used by students with different levels of expertise. For example, the Trinomial Cube (Montessori, 1909/1964, 1948/1967) that is first introduced to Montessori children at about 3 years old as a sensorial (and fun) three-dimensional puzzle also shows middle school algebra students how to factor the trinomial formula $(a + b + c)^3$. Montessori education's deep, thorough plan and hands-on materials for teaching and learning systematically help learners build a foundation of schemas for specific, complex academic concepts to be fleshed-out years into the future, in line with human cognitive architecture (Sweller at al., 2011, 2019). The building of solid schemas of knowledge yields a sturdy scaffold that supports new learning with lower cognitive load on the working memory.

Another strong advantage of a Montessori mixed-age classroom is the peer-to-peer teaching and learning that happens there (Montessori, 1909/1964, 1936/1966; Standing, 1962). Ready help and collaboration with more experienced students is beneficial to younger learners and generates a collective working memory effect on learning consistent with the emerging collaborative cognitive load theory (Sweller et al., 2019; Zambrano et al., 2020). However, all students experience worry-free "arousal" (Hoogerheide et al., 2019, p. 45), increased perceived germane cognitive load, and better performance on transfer problems by teaching worked examples to other students than by studying them on their own, even if the student-teacher is also a novice with the learning material. Montessori includes and supports natural and child-initiated opportunities for peer-to-peer teaching as part of its pedagogy (Montessori, 1936/1966), in line with practices for supporting learning found to be effective by cognitive load research (Hoogerheide et al., 2019; Sweller et al., 2019; Zambrano et al., 2020).

Montessori Education and Technological Innovation

Squire (2011) made a connection between Montessori education and effective video games for learning. Although Squire did not reference cognitive load theory (Sweller et al., 2011, 2019), Montessori practices (1909/1964) that produce successful learning due to support of working memory also produce successful learning when applied to screen media (Mayer, 2017). A certified former Montessori teacher, Squire drew parallels between the kind of participatory, focused learning found in Montessori classrooms and what he termed, high quality video games. Squire also listed a variety of famous and successful individuals who were educated in Montessori schools. Squire's list of Montessori graduates included *The Sims* creator Will Wright who told the Wall Street Journal that "SimCity comes right out of Montessori" (Sims, 2011, para 9) and both Google co-founders Larry Page and Sergey Brin, who credited Montessori education as the key to their success in an interview with Barbara Walters (2004). Other former Montessori students not mentioned by Squire who became successful technology entrepreneurs include Jimmy Wales, founder of Wikipedia, and Mark Zuckerberg, founder of Facebook (British Bulgarian Business Association [BBBA], 2017; Gaylord, 2012; McAfee, 2011; Sims, 2011). Inventor/scientists Thomas Edison (1893) and Alexander Graham Bell (1876) each founded and funded a Montessori schools (BBBA, 2017). And, technology entrepreneur and founder of Amazon, Jeff Bezos, not only attended a Montessori school as a child (Sims, 2011) but has also founded and currently funds a "Montessori-inspired tuition-free preschool system" called Bezos Academy (Delouya, 2022, para 1; see also Hartmans, 2022). Technology groundbreakers who attribute their successful journey to a Montessori education provide anecdotal evidence that Montessori pedagogy effectively provides a foundation for innovation, creative problem solving, and lifelong learning.

Cognitive Load Effects With Screen Media Applications

Screen media applications that are used by young children come in several varieties. The screen media present in most family households over the past eight decades has been television; therefore, much research has been conducted on the effects of television viewing in many areas of human development with mixed results (Takeuchi et al., 2015). Some recent studies have found a dearth of negative effects. For example, studies conducted over decades that linked television viewing with entry into the criminal justice system have been called into question with recent evidence that takes genetically informed models into account (Schwartz & Beaver, 2016). Even when screen time exceeded the limits set by the American Association of Pediatricians (AAP; 2016), it was not associated with delinquency, risky behavior, reduced grades, mental health problems, or lowered working memory function (Ferguson, 2017; McHarg et al., 2020a; San Martin Soares et al., 2021; Toh et al., 2021; A. Veraksa et al., 2021). Although, Twenge and Campbell (2018) found moderate to high screen time of over four hours per day was associated with lower psychological well-being for adolescents. Other studies have also found detrimental effects on working memory function when screen time was higher than AAP recommendations (De Lucena Martins, 2020; Dong & Potenza, 2017; McHarg et al., 2020a; N. Veraksa et al., 2021; Vohr et al., 2021; Z. Zhang, Wiebe et al., 2022). Research results on the effect of screen time on human development are mixed.

Cognitive Theory of Multimedia Learning

A theory spawned by research and developed by Mayer (2014, 2017) called the cognitive theory of multimedia learning details specifically how a combination of pictures and words affects cognitive load and learning. The cognitive theory of multimedia learning incorporates cognitive load effects discovered through research using the lens of seminal cognitive load theory (Anmarkrud et al., 2019; Sweller, 1988) with learning through multimedia, largely with electronic, screen media devices and applications (Mutlu-Bayraktar et al., 2019). O. Chen et al. (2017) indicated that the cognitive load theory, built on a foundation of human cognitive architecture and evolutionary educational psychology, provides instructional design principles for all modes of computer-based learning. For example, an expertise reversal cognitive load effect in multimedia and hypermedia representations was found by Johnson et al. (2015). Johnson et al.'s research showed that students with low prior knowledge had higher posttest scores that were comparable to the posttest scores of students with high prior knowledge when learning with visual signaling and an image of an animated pedagogical agent. Students with high prior knowledge and no visual signaling or animated pedagogical agent scored better on posttests than others with high prior knowledge whose multimedia learning included the visual signaling and animated pedagogical agent. With high prior knowledge, students' learning performance was hampered when multimedia learning materials included extraneous visual signaling and animated pedagogical agents, supporting the expertise reversal cognitive load effect. The expertise reversal effect is just one example of 17+ cognitive load effects directly tied to multimedia learning. An app-creator's awareness and understanding of cognitive load effects on learning are the key to their crafting of effective learning content with multimedia applications (Mayer, 2014, 2017; Sweller et al., 2011, 2019).

Screen Media at Home

At home, parent-controlled activities affect the development of young children's executive functions, including experiences with multimedia. For example, Twait et al. (2019) found that dialogic reading in the home between parent and child made a significant difference in the executive function of at-risk preschoolers. Also, Florit et al.'s (2022) research found significant correlation between working memory and reading comprehension, and first grade study participants performed better on comprehension post-tests when reading from a screen versus paper. Logically then, handheld screen media applications designed to be interactive also affect children when used at home. Research studies have revealed some of the factors that influence the amount and type of screen time young children engage in at home. The amount and type of screen time young children engage in depends on the priorities of their parents – the family culture (Asplund et al., 2015; Howe et al., 2017). Howe et al. (2017) found that parenting style and family type rather than child temperament, were associated with 2-year-olds' television viewing. Montessori (1936/1966, 1949/1989) philosophy and culture of elevating in importance the sensory, hands-on activity of young children may also have an effect of diminishing young children's screen time in families who have familiarized themselves with early childhood philosophies and chosen to enroll their children in a Montessori preschool. The presence of screen media in homes places decisions about a child's exposure to screen media learning environments largely into the hands of parents worldwide (Asplund et al., 2015). Parents are the gatekeepers of their child's exposure to a nearly infinite amount of exponentially increasing content and delivery portals.

Screen Media for Early Childhood Education

When educators choose electronic media as a teaching and learning medium for young children, the brain development of the child must be included in the planning, development, and use of the electronic learning tools. Most understanding of young children's brain function is still evolving. For example, Lillard and Peterson (2011) discovered that fast-paced educational television programs significantly reduced children's learning outcomes compared to slow-paced programs, a surprising finding that supported changes in educational television for young children. Research on effects of the interactions between young children's minds and screen media applications is in the early stages of development (Elkind, 2016; McHarg et al., 2020a, 2020b; Slutsky & DeShetler, 2017; Slutsky et al., 2014, 2021; A. Veraksa et al., 2021; Zhang et al., 2022; Zhao et al., 2022). Research is especially needed on the effects of small and convenient devices such as smart phones and tablet computers which have only been in young children's hands for eight to twelve years (Jusienė et al., 2020). Also, numerous aspects of the screen media could affect a developing brain. Variant light emissions (H.-C. Jung et al., 2017; Mander, 2002; Sourman et al., 2018; Zhu et al., 2019), fantasy content (Lillard et al., 2015), adult content (Carson et al., 2015), seductive details unrelated to the learning objectives of an educational media application (Park, Flowerday, & Brünken, 2015; Pink & Newton, 2020), and other video or audio elements of a screen media application can contribute to extraneous rather than germane cognitive load and reduce learning (Squire, 2011; Sweller, 2011, 2019).

Technical Issues Reduce Screen Media Effectiveness as Learning Tools

Sometimes an idea seems good when an innovator imagines it but breaks down when they attempt to carry it out in real life. Use of electronic screen media as a teaching tool for young children is one such idea. In the movie *Napoleon Dynamite* (Hess, 2004), Napoleon and Pedro intended to build a sweet bike ramp. But when they built the ramp and Napoleon was testing it out, the ramp cracked, and Napoleon and his bike crashed. Those results showed Napoleon, Pedro, and the movie audience that more understanding of the physics of ramps and bicycles was needed to create a ramp that would function the way Napoleon imagined it.

Unintended consequences usually mediate the effects of new technologies. Heikkila (2017) pointed out that the current generation should be the happiest people who have ever lived. So many of our persistent humanity related problems have been solved by technology devices that are only becoming more prolific with time (Heikkila, 2017). Why are people not happy then? Because devices do not work as creators imagine and intend. Technology is glitchy. A killer of happiness is expecting something to work and then it has annoying, frustrating problems. No matter the genius of the invention, it is still subject to the foibles of being made with earthly materials and subject to numerous effects on its electronic performance including the weather, building structures that block signals, and wear and tear on device components. Developing didactic learning material that takes into consideration technical issues and educational principles to effectively make use of multimedia technology requires extensive planning (te Pas et al., 2016). But during the development and adaptation of new and exciting technology, a quick pace is not necessarily equal to careful planning.

Screen Media Interactivity

Still, the reality persists that preschool children use some type of screen media an average of 2 to 3 hours per day (McNeill et al., 2019) with most viewing time devoted to television (Jusienė et al., 2017; Kostyrka-Allchome et al., 2017), and use of mobile screen media devices among young children are on a steep rise (Kabali et al., 2015; Kostyrka-Allchome et al., 2017; Paudel et al., 2017; Radesky et al., 2014, 2016). Mobile screen media devices can be used in many situations and locations. Also, "the interactivity of content enables children to engage in digital realities as if they were part of those realities" (Jusienė et al., 2020, p. 1). In line with ongoing research of the National Association for the Education of Young Children, & Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College (2012), interactive content that is created based on sound learning science principles such as cognitive load theory can help young children gain skills and knowledge (see also Schindler et al., 2017). However, young children learn through all their senses (Montessori, 1909/1964, 1949/1989) and acquire higher order cognitive skills through social and problem-solving interactions in activities such as dramatic play (C. D. Lee et al., 2020). With curricula-creator effort focused on bridging the gap between multisensory, real-world activity and attempts to make the virtual world multisensory, research is needed on how time with passive and active screen media affects a young child's working memory and therefore the children's learning capacity (Mayer, 2014, 2017; Sweller et al., 2011, 2019).

Passive and Active Screen Media Effects on Brain Development and Learning

Research has shown positive correlations between the number of different touch screen tablet apps and the frequency of their parent-controlled use; and preschool children’s numeracy and print awareness, print knowledge, and phonemic sound knowledge (Beschorner & Hutchison, 2013; Neumann, 2016; Wang, 2022). On the other hand, increasing screen time has been significantly statistically linked to inattention problems, with children who engaged in more than 2 hours of screen time per day having a 7.7-fold increased risk for meeting the criteria for ADHD (Tamana et al., 2019). Recent research supports older findings that passive television viewing is either detrimental to or shows no positive effect to executive and other cognitive functions. For example, Carson et al. (2017) found a significant correlation between television screen time and lower vocabulary scores on the Peabody Picture Vocabulary Test but no correlation for active video game/computer game use. Takeuchi et al.’s (2015) longitudinal study of 290 children between 5 and 18 years old found that regardless of sex, age, or socioeconomic status, the more hours of television a child watched, the bulkier the hypothalamus, septum, sensorimotor area, visual cortex, and frontopolar cortex of their brain became. This altered brain affected emotional responses, arousal, aggression, vision, and language-based reasoning ability. Verbal IQ scores lowered proportionally with the number of hours of television viewing per day. Working memory and another executive function, response inhibition, were not correlated with screen time, either passive television viewing or active play of video games (Carson et al., 2017). However, Hutton, Dudley et al. (2020), found negative associations between screen-based media use and brain white matter integrity in pre-school-aged children as screen time increased beyond AAP recommendations (see also Welsh,1991).

Although the cognitive load theory was created in the late 1980s (Sweller, 1988), research on how cognitive load affects learning has gone up exponentially in the last decade with the largest number of new studies occurring in the last 5 years (Skulmowksi & Xu, 2022). Interest may be growing because screen media devices have become new tools waiting for a project, with educators of students at all ages anxious to use the seemingly limitless potential of these readily available, motivational (even addictive), and adaptable potential tools for learning (Ribner et al., 2021). Between 1988 and 1999, 7520 published studies listed in Google Scholar had the term *cognitive load* in the title. In the next decade, 2000 to 2010, the number of studies on cognitive load in Google Scholar jumped to 35,100. In just the half-decade between 2016-2021, though, 29,600 studies of cognitive load were conducted and listed in Google Scholar, with 16,100 of those specifically examining cognitive load on the working memory of students while using screen media applications.

Researchers have explored the possibility that screen media could be used as a more effective teaching tool if it incorporated strategies to make it active, namely enhancing narratives with turn-taking prompts using a questioning character (Krcmar & Cingel, 2017; Piotrowski, 2014; Strouse et al., 2013), providing responsive feedback (Roseberry et al., 2014; Strouse et al., 2013), or giving the child agency or control of the device via computer mouse or touch screen (Hirsh-Pasek et al., 2015; E. L. Schroeder & Kirkorian, 2016). However, recent studies examining the effects when all three interactive strategies were employed found that interactivity was no better than passive viewing for near transfer tasks and worse than viewing for far transfer tasks (Alade et al., 2016; McEwen & Dubé, 2015; E. L. Schroeder & Kirkorian, 2016). An exception is when pointing and gesturing movements are incorporated into educational applications that use screen media, which does promote positive learning outcomes (Agostinho et al., 2020). Lui et al. (2021) found a positive association between a cognitive executive function score including working memory and amount of touchscreen exposure in 10-month-old infants. However, E. L. Schroeder and Kirkorian (2017) suggest that young children's cognitive resources may be overtaxed by the task of interacting with the screen, which leaves little room in the working memory for educational content. Anderson and Davidson (2019) attributed the observed differences in learning during passive versus active screen media use to the activation of completely different brain networks during the two types of media interaction. Viewing of television and other passive media activated the default mode network (DMN) of the brain and spurred temporal and spatial learning while use of interactive screen media deactivated the DMN and enhanced stimulus-response-goal-associative learning (Anderson & Davidson, 2019). Debue and van de Leemput (2014) found through analysis of eye-tracking data that information retention was impacted by the presence of animations and pictures in multimedia content, since higher numbers of fixations on these animations showed a user's attention was attracted to them. Interacting with the screen may create extraneous cognitive load on limited working memory resources.

Also, Peebles et al. (2018) obtained mixed results when using a video to teach social/emotional skills to young children that was increasingly more interactive as they added turn-taking with a questioning character, responsive feedback, and child agency with control of the device. McEwen and Dubé (2015) found highly interactive tablet computer applications challenged the cognitive load of children. Possibly, either cognitive load increased as interactivity increased or the researchers had attempted to teach biologically primary social/emotional perceptions that the 3- to 5-year-olds in the study were not brain-developmentally ready to control, learn, understand, or perceive (Peebles et al., 2018). Parong and Mayer (2018) conducted a study to compare the instructional effectiveness of immersive virtual reality, which is the most active screen media format currently available, versus a self-directed slideshow on a desktop computer. Results revealed that although students self-described greater enjoyment and motivation from participation in an immersive virtual reality science lesson, they performed significantly better on post-tests after learning with a self-directed PowerPoint slideshow designed using the cognitive theory of multimedia learning (Parong & Mayer, 2018). The cognitive theory of multimedia learning incorporates research revealed cognitive load effects into its instructional design principles (Mayer, 2014, 2017; Mayer & Fiorella, 2014; Mayer & Moreno, 2003). Parong and Mayer's results provide further evidence that the interactivity in active screen media applications can easily increase element interactivity and cause overwhelming intrinsic or extraneous cognitive load on a student's working memory. So even if a student feels strongly motivated to use an active educational screen media application, such as a video game, they will only learn from the application if app-created cognitive load is not too high.

Carson et al. (2017) called for more empirical evidence to support or deny a difference between passive and active screen media in their effects on development of cognitive functions including working memory. Troseth et al. (2016) pointed out that research needs to spark principles for media use with children that guide people who teach and care for young children in choosing the type of media use that will support children’s learning. Research results have also been inconclusive or mixed about how active participation with screen media affects young children’s cognitive load and working memory, although learning outcomes are key to determining if cognitive load is ideal (de Jong, 2010; Elkind, 2016; Lillard et al., 2015; Mayer, 2017; McHarg et al., 2020; Rhodes et al., 2020; Slutsky & DeShetler, 2017; Slutsky et al., 2021; N. Veraksa et al., 2021; Z. Zhang, Adamo et al., 2022; Zhao et al., 2022).

Summary and Conclusions

Exposure to screen media has changed the way pre-school-aged children explore their surroundings (Bus et al., 2020; Elkind, 2016; Leppänen et al., 2020; Slutsky et al., 2014). The combination of multisensory, first-hand experience and screen media generated experience has transformed early childhood learning environments (Beatty & Egan, 2020; Beschorner & Hutchison, 2013; Csibi et al., 2021; McManis & Gunnewig, 2012; Neumann, 2016; Wang, 2022). Electronic data delivered through screen media devices are attractive to curious pre-school-aged children and have gained widespread use by them, especially at home, with 97% of worldwide households possessing at least a cell phone (IGI Global, 2021a, 2021b; Ribner et al., 2021; Sharkins et al., 2016; Swartz, 2017). Extensive research has shown that cognitive load (Sweller et al., 2011, 2019) created by a screen media application either supports or encumbers working memory function and affects the usefulness of the application as a learning tool (Huber et al., 2018; Lillard et al., 2015; L.-Y. Lin et al., 2015; McHarg et al., 2020a, 2020b; Slutsky et al., 2021, N. Veraksa et al., 2021; Zhang et al., 2022; Zhao et al., 2022).

Some pedagogical practices typical of Montessori (1914/1965) learning environments have been found through research to produce ideal cognitive load and improve working memory function (Denervaud et al., 2019; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard & Heise, 2016). These educational practices include reduction of outside distractions, incorporation of multisensory and tactile experiences, and focus of attention on one new concept at a time (Blakey & Carroll, 2015; Ginns et al., 2020; Paas & van Merriënboer, 2020; Sepp et al., 2019; Sweller et al., 2011, 2019). A gap in the literature has existed because no study before the current one tested working memory of preschoolers exposed to both (a) varying amounts of parent-controlled passive, active, and/or total screen time, and (b) Montessori education. Results of the current study filled this gap and could contribute to pedagogical protocols that align use of screen media technology and early childhood pedagogy with ideal cognitive load to support the working memory function of pre-school-aged children (Matheson & Hutchinson, 2014; Rhodes et al., 2020; Sharkins et al., 2016).

To address the gap in the literature, I used the following methodology in the current research study. Survey questionnaires with Likert-type items and open-ended questions were used to gather data on the relationship between young children's working memory function, Montessori preschool exposure, and parent-controlled passive, active and/or total screen time. Working memory function was measured by parent responses on the BRIEF-P (Gioia et al., 2003b). Data on the preschoolers' amounts of (a) parent-controlled passive, active, and total screen time, and (b) Montessori preschool exposure were gathered via the Screen Time Questionnaire, which I created. Identification by the current study of associations between exposure to Montessori or non-Montessori education; parent-controlled passive, active, and total screen time; and working memory function could promote social change by informing educational protocols that support cognitive load germane to learning as a contributor to healthy working memory function (Ahmed et al., 2019, 2022; Huber et al., 2018).

Chapter 3: Research Method

The problem that inspired this research study was that working memory function is declining in pre-school-aged children and can be impaired by the extraneous cognitive load to working memory imposed during screen time and/or preschool programs (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015; Zhao et al., 2022). The purpose of this quantitative study was to examine the working memory function of preschoolers, in Montessori and non-Montessori learning environments, who engaged in varying amounts of parent-controlled passive, active, and total screen time for any relationship between preschoolers' working memory function, Montessori preschool program exposure, and amount of parent-controlled passive, active, and/or total screen time. In Chapter 3, I provide an overview of the methodology for the study. Key topics include the research design and rationale, methodology, and threats to validity. The Research Design and Rationale section includes information on the study variables. In the Methodology section, I describe the study population; sampling and sampling procedures; procedures for recruitment, participation, and data collection; and instrumentation and operationalization of constructs. The Threats to Validity section includes discussion of the ethical procedures that I followed.

Research Design and Rationale

I sought to answer the following RQ in this study: Is there a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time; and working memory function in pre-school-aged children (DV)? The IV and DV in this study were observed rather than randomized or manipulated with researcher interventions, so I gathered no pretested values of (a) working memory or (b) passive, active, or total weekly screen time. I also collected information on age, gender, and school using the Screen Time Questionnaire.

Research Design

I conducted a quantitative survey investigation. As reflected in the RQ, I gathered data on amount of Montessori preschool program exposure (IV), amounts of parent-controlled passive, active, and total screen time (IVs), and working memory function (DV) of pre-school-aged children. Data were gathered from a convenience sample of parents of Montessori and non-Montessori preschool children. The parents completed questionnaires on behalf of their children.

Procedures

The procedures for gathering study data involved administration of a cross-sectional survey, which was comprised of two questionnaires. The first was the Screen Time Questionnaire, which included open-ended questions and some Likert-type items to collect data from parents on the amount and type of parent-controlled total, passive, and/or active screen time engaged in by their children. The Screen Time Questionnaire also collected data on a child’s sex, age, and school. The second questionnaire was the BRIEF-P (Gioia et al., 2003). The BRIEF-P, completed by parents, enabled assessment of the working memory function of children.

The Screen Time Questionnaire and the BRIEF-P were each available for completion with either online or paper protocols. The online Screen Time Questionnaire was accessed by participants using a web address or QR code listed on paper and emailed invitation flyers. Use of web address or QR code took a participant to the study web page where they agreed to conditions on the informed consent form and were automatically offered links to the study questionnaires in English or Spanish. The online BRIEF-P protocol was accessed through the PARiConnect (2021) website. Participants also submitted their complete BRIEF-P's through PARiConnect where I retrieved them for analysis. I opted to use the BRIEF-P electronic protocol scoring service provided by PARiConnect to calculate the working memory *T*-score for each participating child. Participants completed the online Screen Time Questionnaire at SurveyMonkey (2022). A participant could return again and again to the Screen Time Questionnaire and record their child's screen time each day for 1 week and then submit the questionnaire. I retrieved completed Screen Time Questionnaires from SurveyMonkey (2022; see Appendices B, C, D, and E for BRIEF-P sample questions and Screen Time Questionnaire in English and Spanish).

If participants had problems accessing an online questionnaire, they could request a paper copy through the email address provided on the informed consent form. If a participating parent requested a paper questionnaire, I dropped it off to their child's school office in a sealed envelope, with the parent's email address as identifying information. School office staff identified the parent using school records that included parent email addresses and sent the envelope home in the child's book bag. When the completed questionnaire was returned to school in a sealed envelope I had provided, a school official called me, emailed me, text-messaged me, or put the envelope in my school mailbox; and I picked up the envelope in the school office. During the course of the study, I collected 12 BRIEF-P and 14 Screen Time Questionnaire paper protocols from participants who requested, received, and returned them by following the procedures just described. Participants completed 46 BRIEF-P and 39 Screen Time Questionnaire protocols online. Altogether, I received 111 completed questionnaires, 58 BRIEF-P's, and 53 Screen Time Questionnaires (see Tables 7 and 8 to view raw data for this study).

Participants

The study participants were parents of pre-school-aged children, half of whom attended a public Montessori preschool program and the other half a public non-Montessori program located in a medium-sized, midwestern U.S. city. I asked all participants to complete the two-part questionnaire containing the Screen Time Questionnaire and the BRIEF-P. If a participant completed only one questionnaire, their data were still included in the study. Factors that might impact young children's working memory function were analyzed for any relationship between working memory function; Montessori preschool program exposure; and amount of parent-controlled passive, active, and total screen time; I used SPSS-28 to perform the multiple regression analysis. The findings address a gap in the literature on the influence of both parent-controlled screen time and exposure to Montessori education on working memory function of pre-school-aged children (Ginns et al., 2016; Huber et al., 2018; Lillard et al., 2015; Sharkins et al., 2016).

Constraints Affecting the Design Choice

Cognitive load can be assessed by indirect or direct measures (Paas et al., 2010). Sweller et al. (2011) described five indirect measures of cognitive load used by researchers. A questionnaire administered immediately after a learning activity requesting a participant's own estimate of mental expenditure during the activity is an indirect, subjective measure of cognitive load. A second indirect measure of a learner's cognitive load is performance during acquisition of learning. If two teaching approaches are compared, the one which (a) requires greater instructional time before student mastery of learning material and/or (b) elicits the most student errors during learning imposes the greater cognitive load. A third indirect measure is Paas and van Merriënboer's (1993) efficiency measure, which combines mental effort and task performance scores. In a fourth indirect method of assessing cognitive load, dual-task methodology, students perform a simple secondary task during the primary learning activity, such as responding to a sound (Cragg & Nation, 2007; McClelland, 2021). If the primary learning task imposes a heavy cognitive load, performance on the secondary task declines. A fifth indirect measure of cognitive load requires creation of a computational model. A computational model reveals the number and complexity of problem-solving steps in a learning strategy or pedagogical approach and tests their effects on cognitive load through computer simulated experiments. The greater the steps and complexity, the greater the cognitive load imposed by the learning material.

The first four indirect measures of cognitive load—(a) subjective measure, (b) performance during acquisition, (c) efficiency measure, and (d) dual-task methodology—require direct researcher access to participants for questioning and/or assessment during the learning process or immediately after it. However, Walden University's IRB prohibited me from having direct contact with children during the current study. Also, subjective and efficiency measures require metacognition and self-reflective answers on a questionnaire that are too cognitively advanced for pre-school-aged children. Creating a computational model, the fifth indirect measure of cognitive load, requires expertise in mathematics, and computer science and computer resources capable of running thousands of computerized experiments. As sole researcher for this study, I did not have the expertise or computer resources to create a computational model. The indirect measures of cognitive load described by theorists Sweller et al. (2011) were not available for use in this study due to Walden University IRB and resource constraints.

Obtaining a direct measure of cognitive load involves gathering physiological data from participants during a learning activity that signals increased memory load (Sweller et al., 2011; Vanneste et al., 2021). Examples include (a) spectral analysis of heart rate; (b) eye tracking to measure pupil dilation and microaccade movements during fixed eye gaze (Duchowski, 2018; Kaluarachchi et al., 2021; Korbach et al., 2017, 2020; Krejtz et al., 2018; Krzysztof et al., 2018; Szulewski et al., 2019); (c) functional magnetic resonance imaging (fMRI) to measure cerebral blood flow indicating neural activity; and (d) electroencephalography (EEG) to capture alpha, beta, and theta brain wave rhythms (Antonenko & Keil, 2018; Vanneste et al., 2021). Another direct measure is analysis of speech complexity during learning, which undergoes a reduction in lexical density with an increase in cognitive load (F. Chen et al., 2016). Direct measures have advantages over subjective measures of cognitive load because they can be completed during learning without disrupting the learning task. However, no direct or physiological measures of cognitive load were used in this study because they required direct researcher access to child participants and/or were prohibitively expensive, with specialized equipment operated by certified technicians producing data that would need to be interpreted by medical doctors.

I ruled out direct and indirect measures of cognitive load for use in this study due to Walden University IRB, cost, equipment-availability, and researcher certification constraints. Instead, working memory function was measured using an assessment instrument designed to be completed by a young child’s parent, the BRIEF-P (Gioia et al., 2003b). Ideal cognitive load is always equivalent to a learner’s working memory capacity (Sweller et al., 2011). Therefore, in this study, working memory function was measured using the BRIEF-P. *T*-scores were compared among children enrolled in Montessori and non-Montessori preschool programs who engaged in a range of passive and active screen-time-at-home conditions. Results imply the level of support to working memory function of cognitive load imposed by exposure to each preschool and parent-controlled-screen-media-use pedagogical condition.

Suitability of the Design Choice to the Advancement of Learning, Instruction, and Innovation for Young Children

In this quantitative study design, participants were volunteer rather than assigned to groups randomly selected from the preschool population and provided with pretest or a treatment of specific amounts of parent-controlled passive, active, and total screen time. This study design did not allow a conclusion about what type of preschool program (Montessori or non-Montessori) or amount of parent-controlled passive, active, or total screen time *caused* higher or lower working memory function. However, results of the study as it was designed were able to show any statistically significant relationships or *links* between exposure to a Montessori preschool program, amount of passive, active, or total screen time controlled by parents, and working memory function. Also, interactions had the potential to be revealed between (a) parent-controlled passive, active, and total screen time amount and type and Montessori preschool program exposure, (b) Montessori exposure and working memory, and/or (c) parent-controlled passive, active, and total screen time and working memory. The design of the study about the innovated early learning environment created when combining Montessori preschool exposure with parent-controlled screen time added to the field of learning, instruction, and innovation. First, the design acknowledged the variable of parent-controlled screen time as a learning environment where young children are spending increasingly more time (Beatty & Egan, 2020; Beschorner & Hutchison, 2013; Bus et al., 2020; Csibi et al., 2021: Herodotou, 2018; IGI Global, 2021a, 2021b; Leppänen et al., 2020; McManis & Gunnewig, 2012; Neumann, 2016). Second, the design facilitates study of the mitigating effects on working memory function of an “innovation in learning,” parent-controlled total, passive, and/or active screen time combined with Montessori preschool exposure. This innovated learning environment has occurred through the natural assimilation of technology developed for another purpose “in order to harness and scale ‘it’ for better, more efficient learning results” (Redding et al., 2013, p. 5; see also Walden University, 2021). Third, exploration of the effects on working memory of combining a new learning environment, parent-controlled passive, active, and/or screen time, and a learning environment already known to produce innovative thinkers, Montessori preschool exposure (Sims, 2011; Walters, 2004), produced data that could expose pedagogy supportive of innovators and producers of new knowledge and “encourage growth for the entire economy” (Biasi et al., 2022, p. 3). This study fits within the field of learning, instruction, and innovation with young children, and results have added knowledge to that field.

When designing this research study, with data collected using BRIEF-P and Screen Time Questionnaire survey instruments completed by children’s parents, I took into account pre-school-aged children’s vulnerability. Early childhood is a unique time of life where learning occurs at exponentially faster rates than at any other time (Birdsong & Vanhove, 2016; Chomsky, 1975; Kim & Park, 2020; Kulic et al., 2019; Montessori, 1914/1965; Slutsky et al., 2021; Vygotsky, 1934/1962). Therefore, research on the effects of educational treatments meant to support young children’s learning is important (Diamond & Lee, 2011; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard, 2017; Lillard & Else-Quest, 2006; Lillard & Heise, 2016). However, young children are vulnerable because of their small size, inexperience, and dependence on adult caretakers for their safety and growth. The early learning experiences that lay a foundation for the quality of future life can be either beneficial or detrimental to a child's wellbeing (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Dodge et al., 2016; Gade et al., 2017; Gormley et al., 2017; Montessori, 1949/1989; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Thompson, 2018; Volckaert & Noël, 2015; Zhao et al., 2022). So, while research on the early childhood population is vital, so is protecting young children from potential negative effects that might occur during participation in a study (Harger & Quintela, 2017; Rose, 2017). For these reasons, Walden University's IRB prohibited direct contact between a researcher and a child, and Walden University is not alone. All IRB-sanctioned, peer-reviewed research conducted with young children carries strict safeguards (Harger & Quintela, 2017; Rose, 2017).

Because this study design did not include interview or direct observation of children by the researcher, it was in line with safer-for-children research designs needed to advance knowledge about learners in all fields that study early childhood education. Researchers have frequently used parent report measures such as questionnaires, surveys with Likert-type items and open-ended questions, and time-use diaries to gather data on a pre-school-aged child's screen time (K. Choi et al., 2018; Hinkley et al., 2018; Huber et al., 2018; Madigan et al., 2019; San Diego et al., 2022; H. Schneider et al., 2020; Sherman & Brooks, 2010; Taylor et al., 2018). Because young children rely on their parents for media access, parents are the most effective data gatherers of their child's screen time (Domoff et al., 2019b; J. L. Miller et al., 2017; Rideout, 2017). The design for this study that dictated collecting data on children's screen time from parents is not only the safest data gathering method for young children, as reviewed in the previous paragraph, but also provided the most accurate data. Also, this data collection method was in line with the educational discipline of learning, instruction, and innovation which advocates seeking for and trying new, innovative approaches to teaching and assessing learners that use new research-based knowledge and potential pedagogical tools as they become available (Walden University, 2021).

Methodology

The following methodology was used in this research study. I used existing research tools, a questionnaire and survey with some Likert-type items, to gather data on a new phenomenon about which no previous research had been published: the ties to working memory function of a learning environment created by combining exposure to Montessori preschool and parent-controlled passive, active, and total screen time. I measured working memory function by administering and analyzing parent responses on the BRIEF-P (Gioia et al., 2003b). I also gathered data on amounts of Montessori preschool exposure and parent-controlled passive, active, and total screen time using the Screen Time Questionnaire. Identification of correlations between Montessori preschool exposure; parent-controlled passive, active, and total screen time; and working memory function could promote positive social change by informing didactic protocols that support ideal cognitive load as a contributor to healthy working memory function (Diamond & Lee, 2011; Fabri & Fortuna, 2020; Ginns et al., 2016; Huber et al., 2018; Lillard, 2017; Lillard & Else-Quest, 2006; Lillard & Heise, 2016).

Population

The target population was children between 3 and 6 years of age who were enrolled in one of two types of preschool programs. The first was a public, magnet Montessori preschool program drawing students from urban, suburban, and rural areas in the largest school district in its U.S. midwestern state. The second was a public, magnet non-Montessori preschool program drawing students from urban, suburban, and rural areas, also in the largest school district in the same U.S. mid-western state.

U.S. News & World Report (2022) reported on the diversity of this school district's 2021-2022 enrollment. Of the students enrolled, 39% were White, 25% Black or African American, 20% Hispanic/Latino, 10% two or more races, and 6% Asian or Asian Pacific Islander. Of the enrolled students, 48% qualified for free or reduced-price lunch, and 19% were learning English (see Table 1). From this racially, culturally, and economically diverse applicant pool, children were chosen for attendance in each magnet program during a publicly held, equally weighted, random lottery drawing held once a year at the school district administration building (Baum, 2015). Both schools were populated with students from the same demographic of diverse, randomly selected applicants. Table 1 summarizes diversity demographics of students in the school district from which the study population was drawn and compares them to children's diversity demographics in the United States.

Table 1

Demographics: Partner School District Student Population Versus Nationwide U.S. Child Population

Population	Study Sample (%)	United States (%)
White	39	50
Black	25	14
Hispanic	20	26
Asian	6	5
Multiracial	10	5
Qualify for Free Lunch	48	52
Learning English	19	10

Note. Demographic data for the convenience sample are from U.S. News & World Report (2022). Racial demographic data for the United States are from AAP Research (2021). Free and reduced lunch and learning English as a second language data for the United States are from the National Center for Education Statistics (2022a, 2022b).

Estimate of Target Population with G*Power

The target for study participation was to gather data from 100 respondents or 50 students from each school. An initial G*Power (Buchner et al., 2020) analysis indicated that with 74 total respondents or 37 per school, the study would have less than a 5% chance ($p \leq .05$) of mistakenly rejecting the H_0 (see also Faul et al., 2007, 2009; Mayr et al., 2007). With 74 participating parents, the study could reveal any relationship between Montessori preschool exposure; amount of parent-controlled passive, active, and total screen time; and working memory function with 95% accuracy. Although 74 participants, 37 per school, signed up for the study, only 60 total respondents, 30 per school, completed at least one of the two study questionnaires. A second G*Power analysis indicated that with 30 participants per school for a total of 60 parent participants, the study would have less than a 7% chance ($p \leq .07$) of mistakenly rejecting the H_0. With 60 participating parents, the study revealed any links between Montessori preschool exposure, amount of parent-controlled passive, active, and total screen time, and working memory function with 93% accuracy, according to G*Power. The chosen alpha level for this study with four IVs was $p \leq .07$ for a sample size of 60 total participants a priori a power analysis using G*Power. G*Power input values can be viewed in Table 2 and output values in Table 3. Linear multiple regression *t*-test values calculated in G*Power are illustrated on Figure 1.

Table 2

*Input: A Priori Computational Power Analysis Via G*Power*

Run	Tail(s)	Effect Size f^2	α Err Prob	Power (1- β Err Prob)	Number of Predictors
1	One	0.15	0.05	0.95	4
2	One	0.15	0.07	0.93	4

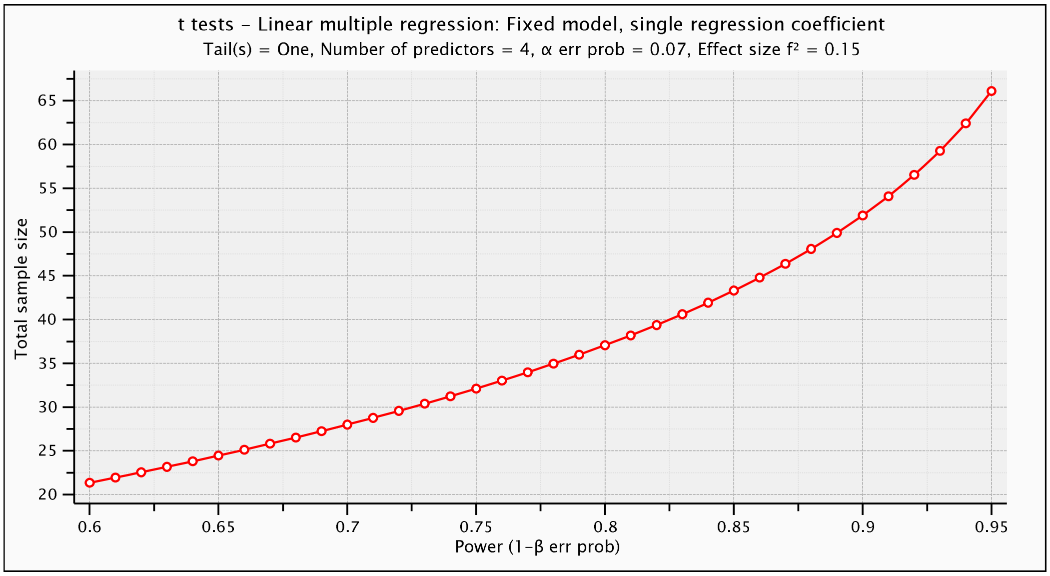
Table 3

*Output: A Priori Computational Power Analysis Via G*Power*

Run	Non-centrality Parameter δ	Critical *t*	*Df*	Total Sample Size	Actual Power
1	3.3316662	1.6672385	69	74	0.95092350
2	3.0000000	1.4974254	55	60	0.93244177

Figure 1

Linear Multiple Regression t*-tests for Power Analysis Via G*Power*



Note. Reprinted from G*Power with no permission required (Buchner et al., 2020).

Sampling and Sampling Procedures

When creating the sampling strategy, I took into consideration two things: proximity of schools to one another and diversity of families enrolled in these schools. This convenience sample was selected from two public early childhood programs that agreed to participate and were geographically located within 20 miles of each other. The participating Montessori and non-Montessori preschools were both magnet programs in the same school district that were housed in urban neighborhoods but drew students from all areas of the city. I solicited volunteer participants in the same manner at both programs through emailed and paper fliers, distributed through school offices to parents. Each volunteer parent claimed an incentive $40 Amazon gift card upon submitting both completed questionnaires.

The sample included all children whose parents volunteered based on solicitations by the emailed and paper invitation fliers at the magnet Montessori and magnet non-Montessori programs participating in the study. Children who were between 3 and 6 years old and enrolled in one of two participating programs were included in the study. I only distributed invitation fliers to parent participants with a child enrolled in one of these two schools. All enrollees were invited to participate through contact with their parents, but only 60 parents chose to both sign up and participate in the study.

Procedures for Recruitment, Participation, and Data Collection

Recruitment

I asked participants to voluntarily join the study through an invitation included in the weekly school newsletters of the participating programs. Both school principals also emailed stand-alone copies of the invitation flier to each child's household and sent paper copies home from school with children which were put in their book bags under adult supervision. The invitation included a financial incentive to families who fully participated by completing and returning both questionnaires. As each participant's questionnaires were collected, I emailed the participating parent an internet link to an online Amazon gift card for $40.

Since I gathered data from schools located within relatively close proximity to each other, I intended to enact a recruitment strategy of extending in-person invitations to parents to participate in the study. However, COVID-19 pandemic protocols at both schools prohibited in-person contact between myself and parents that was not necessary for the students' education. Regular Parent Teacher Association (PTA) meetings were suspended, and I was not allowed to distribute invitation fliers alongside car lines. Perhaps more participants would have been attracted to the study if I had been able to extend personal invitations as initially planned. In adaptation to conditions of the COVID-19 pandemic, I extended invitations to participate through only four points of contact: (a) paper school newsletters, (b) emailed school newsletters, (c) stand-alone emailed and/or paper fliers sent home in each student's book bag, and (d) a post on the PTA Facebook page of each participating school that included an introduction to myself and an invitation flier with QR code and weblink to the study.

Informed Consent. Each participant was provided with an informed consent form when accessing study information using the QR code or weblink that were displayed on all paper and emailed recruitment flyers. If interested in joining the study, the participant signed the informed consent form with an electronic signature and returned it to the researcher through the study webpage. The informed consent form (a) delineated any inherent risks of study participation and (b) explained procedures for keeping participant identity confidential and child information private. The informed consent form provided an option for a parent to receive copies from the researcher of (a) the BRIEF-P test results for their child (to be emailed to the parent by the researcher) and (b) the overall findings of the study by clicking an internet link. If choosing to receive test results for their individual child, the parent would of necessity have had to agree to waive confidentiality.

Participation

I provided all participating parents with the two questionnaires, which were accessed by clicking virtual buttons on the study webpage labeled with the name of each questionnaire. Through the study webpage, I provided links to the questionnaires to each participant after their agreement to all conditions delineated on the informed consent form. The parent filled out both the Screen Time Questionnaire and the BRIEF-P for their child. Parents then submitted completed questionnaires through the weblinks provided at the end of each form. Although I asked each participant to complete both questionnaires, if for some reason they only completed one questionnaire, I still included the data from that questionnaire in the study.

Data Collection and Analysis

I tallied scores from both the BRIEF-P, a standardized survey instrument, and the survey of parent-controlled passive, active, and total screen time, the Screen Time Questionnaire. Parents were allowed to record responses on the Screen Time Questionnaire in any unit (e.g., minutes, parts of hours, hours), but I later converted responses to all minutes. Through the Screen Time Questionnaire, I requested information on age, gender, and school. Then, I conducted a multiple regression analysis using SPSS-28 to discover any links between (a) parent-controlled passive, active, and total screen time and working memory, (b) Montessori preschool program exposure and working memory, and (c) parent-controlled passive, active, and total screen time and Montessori preschool program exposure.

Exit Strategy. As each participant submitted both questionnaires, I emailed them a link to an incentive Amazon gift card for $40. I thanked participants by email for their contribution to knowledge about (a) preschoolers' working memory function in their current learning environments and (b) ways teachers and designers of pedagogy could improve learning environments for pre-school-aged children in both formal preschool programs and in the parent-controlled screen media applications young children use. Debriefing procedures would have included my communicating the date when an analysis of their child's BRIEF-P results would be sent to families who requested them, but no parent requested these results. I provided an internet link to the results of this dissertation study in the informed consent form. Because this study involved a one-time administration of the BRIEF-P and the Screen Time Questionnaire, no follow-up interviews or treatments were required of parents.

Instrumentation and Operationalization of Constructs

Behavior Rating Inventory of Executive Function-Preschool Version

I purchased BRIEF-P (Gioia et al., 2003b) online and paper protocols from PAR. Appendix A provides documentation of permission to use this instrument from the publisher.

Appropriateness of BRIEF-P to the Current Study. The BRIEF-P measures five subscales of executive function: Working Memory, Inhibit, Shift, Emotional Control, and Plan/Organize. Likert-type test items targeting each of these areas of executive function are interspersed through the BRIEF-P, so I collected data for rating students on all subscales. However, I only included the subscale *T*-scores for Working Memory in the current study. Seventeen BRIEF-P test items targeted working memory function (Greene, 2019; Isquith et al., 2005). Test-retest reliability for the Working Memory subscale is High (.80 to .89) for both parent and teacher ratings (Sherman & Brookes, 2010). Evaluation of BRIEF-P's validity also revealed modest correlation between BRIEF-P Working Memory and IQ as measured by the Differential Abilities Scale (Sherman & Brookes, 2010; Slick et al., 2006) and high correlation between BRIEF-P Working Memory and Attention Problems, Withdrawn, and Emotionally Reactive scales on the Child Behavior Checklist (Achenbach & Rescorla, 2000; Sherman & Brookes, 2010).

Published Reliability and Validity Values for the BRIEF-P. The vendor of the BRIEF-P, PAR, gathered and published the following reliability and validity data. (Greene et al., 2019; Isquith et al., 2004, 2005; Sherman & Brooks, 2010):

- Normative data are based on child ratings from 460 parents and 302 teachers from urban, suburban, and rural areas, reflecting 1999 U.S. Census estimates for race/ethnicity, gender, socioeconomic status, and age.
- Clinical samples included children with ADHD, prematurity, language disorders, and autism spectrum disorders, as well as a mixed clinical group.
- Demonstrates high internal consistency reliability (.80-.95 for the parent sample and .90-.97 for the teacher sample) and moderate test-retest reliability (.78-.90 for the parent sample and .64-.94 for the teacher sample).
- Demonstrates convergent and discriminant validity with other measures of inattention, hyperactivity-impulsivity, depression, atypicality, anxiety, and somatic complaints.

Populations With Whom BRIEF-P Was Previously Used. Other researchers have opted to use the BRIEF-P to gather data on executive function including working memory in their current studies with various populations of pre-school-aged children. Researchers using the BRIEF-P have gathered executive function data on children with MindUp training (Crooks et al., 2020), bilingualism (Garcia et al., 2018), stuttering (Ntourou et al., 2018), pre-reading skills (Figuccio et al., 2019), varying levels of motor performance (Houwen et al., 2017), attention deficit hyperactivity disorder (Çak et al., 2017; H. Schneider et al., 2020; H.-F. Zhang, 2018), autism spectrum disorders (Carotenuto et al., 2019; Precenzano et al., 2017), Smith-Magenis syndrome (Wilde & Oliver, 2017), Down syndrome (Joyce et al., 2020; Loveall et al., 2017; Wilde & Oliver, 2017), global developmental delay (Smirni et al., 2018), epilepsy (Maiman, 2018), sleep disordered breathing (Hill et al., 2017; Joyce et al., 2020), hearing loss (Hill et al., 2017), maltreatment experience (Fay-Stammbach & Hawes, 2019), different levels of nutrition and physical activity (McMath et al., 2021), preterm birth (Zvara et al., 2019), and pre- and post-natal exposure to various toxins (Braun et al., 2017; de Water et al., 2019; England-Mason et al., 2020; Etzel et al., 2018; Gowachirapant et al., 2017; Herreras, 2019; San Diego et al., 2022). Research designs in these studies have included data gathering on executive function using the BRIEF-P at least in part because it was completed by caregivers such as parents and teachers who have already established relationships of trust with the pre-school-aged subjects. But the research data gathered by a parent or teacher only furthers knowledge in the field if the instrument used has acceptable internal and external validity. Published research, including each study cited above, has established the BRIEF-P's reliability and validity (Skogan et al., 2016).

Screen Time Questionnaire

I gathered data on children's screen time at home indirectly from parents through the Screen Time Questionnaire, which I created. Parents first answered questions about their child's age, gender, and school. Then, they provided data for 1 week about their preschooler's time spent with passive and/or active screen time during seven daily time periods. A parent could record their child's screen time in hours, hours and minutes, or minutes as they chose. Then, each participating parent transferred the screen time for the whole week, including passive, active, and total combined hours of screen time, to a 6-point scale with Likert-type items called the Screen Time Summary. Three questions with Likert-type items helped parents categorize each child's weekly passive, active, and total screen time into one of six classifications: (a) 7 or less hours, (b) 8-14 hours, (c) 15-28 hours, (d) 29-35 hours, (e) 36-49 hours, and (f) more than 49 hours.

However, for the study statistical analysis, I did not use the data grouped into these six classifications. Instead, I opted to analyze tallied total minutes of each child's parent-controlled passive, active, and total screen time. My use of total minutes for each of the three types of parent-controlled screen time yielded finer detail about differences in screen time between participants than did the broadly grouped data. The Screen Time Questionnaire in English and Spanish can be viewed in Appendices D and E. Individual raw data totals are available in Tables 7 and 8 in Chapter 4.

Basis for Development. Parent report measures such as questionnaires, surveys with Likert-type items, and time-use diaries are frequently used to gather data on a pre-school-aged child's screen time (K. Choi et al., 2018; Herreras, 2019; Hinkley et al., 2018; Huber et al., 2018; Madigan et al., 2019; San Diego et al., 2022; H. Schneider et al., 2020; Taylor et al., 2018). Young children are usually reliant on their parents for media access, unlike adolescents or adults (Domoff et al., 2019b; J. L. Miller et al., 2017; Rideout, 2017). This fact naturally makes parents the most effective data gatherers of their child's screen time. The design for this study that dictated collecting data on children's screen time from parents was not only safe for young children as determined by Walden University IRB standards, but it provided the most accurate data.

Evidence of Reliability and Validity. The study design included no pretest of working memory function, or piloting of the Screen Time Questionnaire. I administered the survey questionnaires only once. By not piloting the instrument I reduced demonstrated reliability of the study but increased study validity because familiarity with the test itself did not affect test scores. Verification of reliability was provided by an expert reviewer, the Walden University quantitative methodologist serving on the committee for this dissertation research study, who also vetted the study design for meaningfulness and clarity (see the Screen Time Questionnaire in English and Spanish in Appendices D and E).

Sufficiency of Instrumentation to Answer Research Question

To answer the RQ, I collected data on (a) working memory executive function, (b) type of preschool exposure, Montessori or non-Montessori, (c) number of days absent from school to determine total days of preschool program exposure, (d) child’s age, and (e) weekly hours of parent-controlled passive, active, and total screen time. I collected data on working memory executive function using the BRIEF-P, a reliable, valid, standardized instrument (San Deigo et al., 2022; Sherman et al., 2010). I determined the children’s enrollment in either a Montessori or non-Montessori preschool program from a demographic question at the beginning of the Screen Time Questionnaire: What is the name of your child’s school? I collected information on a child’s age with a question on the Screen Time Questionnaire. And, since the BRIEF-P was standardized using both age and gender, I also collected data on each child’s gender. I provided places on the Screen Time Questionnaire for parents to record, tally, and summarize weekly hours of parent-controlled passive, active, and total screen time. I converted screen time totals for all three screen time variables to minutes and analyzed the data with multiple regression using SPSS-28. The BRIEF-P and Screen Time Questionnaire were sufficient to collect all data needed to answer the RQ for this study (see Appendices B, C, D, and E to view the Screen Time Questionnaire and sample questions from the BRIEF-P in English and Spanish).

Data Analysis Plan

I used SPSS-28 for data analysis. In using the program, I incorporated data screening procedures to inform the usability, reliability, and validity of study data for determining any relationships between Montessori preschool program exposure, amount of parent-controlled passive, active, and total screen time, and working memory function. The procedures were as follows:

1. I discovered the amount of missing data from unanswered questions on the BRIEF-P and researcher created survey of passive, active, and total screen time by running an analysis of the frequencies of missing data in SPSS-28 descriptive statistics. If more than 10% of responses on a particular variable had been missing, the median replacement method to replace missing values with somewhat neutral mean values that were less meaningful in Likert-type data would have allowed analysis and would have had a somewhat neutral impact on the study results. However, very few responses were missing, far less than 10% of responses on any particular variable.
2. I created a boxplot in SPSS-28 to reveal any univariate outliers and determine whether they were causing the mean to be pulled misleadingly away from the median data value of a variable. Outliers that surfaced in the data collected by either the BRIEF-P or Screen Time Questionnaire were not removed before data analysis, however, because an SPSS-28 analysis of the Cook's distance showed that no outlier had a value > 1. Tables 7 and 8 in Chapter 4 include a display of the Cook's distance values for all sets of individual participant data.
3. I generated Kolmogorov-Smirnov and Shapiro-Wilk statistics in SPSS-28, and a normal quantile-quantile plot graph revealed whether study data were distributed on a normal curve for each variable. Also, observation revealed whether data were negatively skewed to the left or more positively skewed to the right. The distribution of data on a normal quantile-quantile plot graph also visually showed the presence of outliers. The Kolmogorov-Smirnov and

Shapiro-Wilk statistics for each study variable can be found in Tables 12, 13, 14, 15, and 16 in Chapter 4. Normal quantile-quantile plot graphs for each variable can viewed in Figures 2, 3, 4, 5, and 6 in Chapter 4.

4. I ran the linearity test available in SPSS-28 which showed whether linearity or consistent slopes existed in the relationships between IVs (Montessori exposure, passive screen time, active screen time, and total screen time) and DV (working memory function). These linearity data are displayed in Tables 17, 18, 19, and 20 in Chapter 4.
5. I created a scatter plot in SPSS-28 with the DV to test for homoscedasticity or whether residual error of the DV was consistent across different values of the variable. The variable was on the y-axis and the residual error values of the variable on the x-axis. Find this scatterplot in Figure 7 in Chapter 4.
6. Calculation of a correlation coefficient for predictor variables (a) weekly amount of passive screen time, (b) weekly amount of active screen time, (c) weekly amount of total screen time, and (d) Montessori preschool exposure revealed multicollinearity, which was present if the correlation coefficient was close to +1 or -1. I displayed coefficients for the current study in Table 21 in Chapter 4.

Restatement of Research Question and Hypotheses

The RQ and hypotheses read as follows:

RQ: Is there a relationship between weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), weekly amount of parent-controlled total screen time (IV), and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV)?

H_0: There is no relationship between weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), weekly amount of parent-controlled total screen time (IV), and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).

H_a: There is a relationship between weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), weekly amount of parent-controlled total screen time, and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).

The RQ led to the null hypothesis (H_0); using SPSS-28, I performed a multiple regression analysis to test H_0.

Inclusion of Potential Confounding Variables

In this study, I examined relationships between the DV and IVs and not causes or correlations. No confounding variables were related by correlation or cause to the IVs or DV. Information was collected on each child's (a) age, (b) gender, (c) school name, (d) number of days of Montessori preschool program exposure (IV) (calculated from days absent), (e) weekly hours of parent-controlled total screen time (IV), (f) weekly hours of parent-controlled passive screen time (IV), (g) weekly hours of parent-controlled active screen time, and (h) working memory function as measured by the BRIEF-P (DV). The child's age was collected to confirm if it was within the 3- to 6-year-old parameters of the study. The child's gender was needed because the BRIEF-P was standardized using gender. The name of the school indicated whether a participant was enrolled in the Montessori or non-Montessori program. Questions on the BRIEF-P gathered data about five executive functions, but only data on working memory were included in this study.

Means of Interpreting the Results

I made key parameter estimates about the working memory function of the entire population of Montessori and non-Montessori preschool enrollees using varying amounts of passive, active, and total parent-controlled screen time by taking the point estimate (μ) of scores on the BRIEF-P of the current study sample. The sample included 30 Montessori preschool volunteer participants and 30 non-Montessori preschool volunteer participants with all their amounts of parent-controlled passive, active, and total screen time as recorded on the Screen Time Questionnaire. Confidence intervals were 93%, with $p \leq .07$. These confidence intervals represent the level of certainty that the results of this study were not attributable to chance based on the actual number of 60 participants completing the study (see Tables 2 and 3, and Figure 1 for sample power statistics).

Threats to Validity

Threats to External Validity

For this study, I used a convenience sample rather than a random selection design, which was an inherent threat to external validity in every instance. However, the study design controlled for and potentially eliminated the threat to external validity of testing reactivity since parents completed both the BRIEF-P and Screen Time Questionnaire while observing the behavior of their own preschool children in natural settings. There should have been no external validity reducing reaction by the children due to oddness of the testing setting.

Threats to Internal Validity

Threats to the internal validity of a research study can be posed by outside events that occur during the duration of the study or unintended consequences caused by the study design. These threats include history, maturation, testing, instrumentation, statistical regression, experimental mortality, and selection-maturation interaction (Bhandari, 2022; Warner, 2013). I gathered data from questionnaires administered at only one point in time. Therefore, history, maturation, and experimental mortality did not affect its internal validity since these threats referred to (a) events taking place, (b) maturation of individual participants, and (c) participants dropping out of the study between a first and second administration of questionnaires. By giving only one administration of the Screen Time Questionnaire and BRIEF-P to participants, I removed the threat of statistical regression to the mean that often occurs when the participants take a test for the second time. As I administered no pretest in this study design, the design posed no threat to internal validity due to testing or instrumentation. No opportunity existed in the study design for participants to become familiar with the questionnaires and thereby create a testing threat to internal validity. The no-pretest design of this study also eliminated the instrumentation threat to internal validity as it left no chance for a pretest/posttest incongruency.

Ethical Procedures

I requested permission to invite parents of preschool aged children to complete the BRIEF-P and Screen Time Questionnaire, and administrative officials of two early childhood programs granted permission. The Montessori and non-Montessori programs were magnet early childhood centers with Pre-K and kindergarten programs in the same public school district. I met with the school district's COE by phone, due to COVID-19 restrictions at the time of the meeting and explained the purpose and procedures for data collection in this study. I asked for permission to solicit parent participation from the district's two early childhood centers, one Montessori and one non-Montessori. The COE asked me to submit a request in writing explaining the study and providing copies of the two questionnaires to be distributed. I submitted copies of the dissertation proposal draft, BRIEF-P, and Screen Time Questionnaire. The COE officially granted permission by email for me to conduct the study as described in the dissertation proposal and returned all submitted materials back to me. A copy of the email with names removed can be found in Appendix F. Once COE permission was granted, I asked the principals of the two early childhood centers for permission to conduct the study with parents in their schools. I emailed the principal of the Montessori early childhood program with details, and they granted permission during a phone conversation. The COE contacted the principal of the non-Montessori program, who approached me with questions. The non-Montessori program principal granted permission to conduct this study in the school they oversaw during a face-to-face conversation.

Treatment of Participants

Institutional Permissions. Permission from the Walden University IRB was granted on January 7, 2022, before any contact with participants or data collection began (approval no. 01-07-22-0120393). Permission from the public school district partner site to contact participants and collect data for this study can be viewed in Appendix F.

Recruitment Processes. I distributed flyers in both Spanish and English through the administrators of each of the two partner schools that described the purpose of the study and solicited parent participation. Each partner school administrator emailed the flier directly to all households in the school and also sent a paper copy home with each child in their home folder or bookbag. I had intended to invite families in person to participate in the study by distributing flyers during PTA meetings and in school car lines, but it was not possible because of COVID-19 in-person-contact restrictions.

Treatment of Data

Participants entered the study by clicking a QR code linked to a secure webpage to access the BRIEF-P and the Screen Time Questionnaire. The completed BRIEF-P was then submitted directly back to the PARiConnect system for scoring. PARiConnect (2021) was guaranteed to be secure and protective of confidentiality. I administered the Screen Time Questionnaire using SurveyMonkey (2022), which also guaranteed privacy and security of data collected using their product to a level satisfactory to Walden University IRB. When both questionnaires were submitted by each participant, I emailed them a link to an online $40 Amazon virtual gift card. Neither I nor any school official needed to personally contact or be contacted by a participant for them to access the incentive virtual gift card. However, any participant requesting a BRIEF-P score analysis by email would have needed to waive confidentiality as explained in their signed informed consent document.

Other Ethical Issues

Three elements of this study could have potentially caused ethical issues. First was my past and present affiliations with the schools participating in the study. One of the public preschools allowing recruitment of participants for this study was a school where I worked as a school assistant for two years. Another participating public preschool was the program that three of my own children attended between 6 and 15 years ago, so I have a connection with that program as a former parent. However, before requesting participation from these two schools, I consulted with the Research Ethics Support Specialist at the Walden University IRB office. They told me that a researcher could ethically conduct research in a school where they were currently or previously employed as long as they did not recruit students from the classroom in which they were currently working. A potential ethical issue was also my status as a certified Montessori teacher. I was not working in a Montessori classroom at the time of the study but had in past years. The third potential ethical issue was offering of incentives to participants. The Screen Time Questionnaire required every participant to track and record all their child's screen time for a week which was slightly labor-intensive. The modest incentive of a $40 Amazon gift card may have motivated more families to participate, securing sufficient participation for valid study results.

Summary

In summary, the methodology I used for this research study involved distribution of questionnaires to gather data on working memory function in a learning environment created by combining Montessori or non-Montessori preschool exposure and time spent at home with parent-controlled passive, and active screen media technology. I measured working memory function using parent responses on the BRIEF-P (Gioia et al., 2003b). I gathered data on age, gender, days of Montessori preschool program exposure, and weekly amounts of preschoolers' parent-controlled passive, active, and total screen time via the Screen Time Questionnaire. Identification of relationships between Montessori education; parent-controlled passive, active, and total screen time; and working memory function could promote social change by informing didactic protocols that support germane cognitive load and reduce extraneous cognitive load during learning activity as contributors to a healthy working memory (Huber et al., 2018). In Chapter 4, the purpose, research question, and hypotheses of this study are reviewed as an introduction to the analysis of data I collected for the study, which is also detailed in that chapter.

Chapter 4: Results

The purpose of this quantitative study was to examine the working memory function of preschoolers in Montessori and non-Montessori learning environments who engaged in varying amounts of parent-controlled passive, active, and total screen time for any relationship between preschoolers' working memory function, Montessori preschool program exposure; and amount of parent-controlled passive, active, and total screen time. To accomplish this purpose, I used two questionnaires to collect data from parents on their 3- to 6-year-old children. The combined instrument included questions on (a) total days spent in a Montessori early childhood program, (b) passive, active, and total screen time in minutes for 1 week; and (c) working memory function as measured by BRIEF-P *T* scores. Then, I ran a multiple regression analysis of these data using SPSS-28 to determine any relationships between Montessori preschool program exposure and/or parent-controlled screen time and working memory function. In addition, I examined a *t*-test conducted through SPSS-28 to discover any significant differences in screen time between Montessori and non-Montessori students.

The RQ that underpinned this study was as follows:

> RQ: Is there a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time; and working memory function in pre-school-aged children (DV)?

The IVs and DV in this study were observed rather than randomized or manipulated with researcher interventions, so I gathered no pretested values of (a) working memory, or (b) passive, active, and total weekly screen time. I also collected information on age, gender, and school using the Screen Time Questionnaire. Hypotheses were as follows:

H_0: There is no relationship between Montessori preschool program exposure, weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time (IV); and working memory function in pre-school-aged children (DV).

H_a: There is a relationship between Montessori preschool program exposure (IV), weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time (IV), and/or weekly amount of parent-controlled total screen time (IV); and working memory function in pre-school-aged children (DV).

In this chapter, I present the results of this quantitative survey investigation. Before presenting the results, I discuss the data collection process. I provide details on the time frame and response rates; discrepancies in data collection from the plan presented in the research method chapter of the dissertation proposal; external validity, including a description of how representative the sample was of the population of interest and how proportional it is to the larger population, given the use of convenience sampling; and results of basic univariate analyses. The Results section includes exact statistics and probability values, confidence intervals around statistics, effect sizes, post-hoc analyses of statistical tests, and statistical tests of hypotheses that emerged from the analysis of main hypotheses. Tables and figures are provided to illustrate the results. The chapter concludes with a summary of key points and a transition to Chapter 5.

Data Collection

Time Frame and Response Rates

Participant recruitment for this study began on February 4 and continued through May 19, 2022. Every other week through the recruitment period (seven distributions), school personnel disbursed virtual and paper flyers inviting families to participate in the study. The flyers were simultaneously disseminated through (a) an emailed newsletter sent to parents by a school principal and (b) the physical placement of a paper flyer in each student's take-home folder or book bag under supervision of their classroom teacher. Participant recruitment and data collection for the non-Montessori early childhood program took place between February 4, 2022, and April 30, 2022. The principal of the Montessori program requested a February 17, 2022, start date for flyer distribution, and the last data were collected from that school on May 19, 2022.

Recruitment flyers communicated that I sought 100 total participants for this study, 50 participants each from the Montessori and non-Montessori programs. During seven rounds of recruitment flyer disbursement, 74 total participants signed up for the study (37 Montessori and 37 non-Montessori), agreeing to the conditions in the waiver and gaining access to the link to study questionnaires. However, only 60 of the 74 who signed up completed questionnaires, representing 30 Montessori and 30 non-Montessori participants. The fact that an exactly equal number of parents signed up (37 and 37) and participated (30 and 30) from each school was coincidental. Of the children whose parents completed questionnaires, one was 3 years old, 15 were 4 years old, 39 were 5 years old, and five were 6 years old. Nineteen boys and 11 girls were enrolled in the Montessori program. Of the Montessori parents, 23 completed both questionnaires while seven completed only one questionnaire. Of 30 children whose parents completed questionnaires in the non-Montessori program, 14 were male and 16 were female, with 27 completing both questionnaires and three completing just one questionnaire. Tables 4, 5, and 6 summarize distribution of child participants based on age, gender, and type of early childhood program.

Table 4

Distribution of Child Participants by Age and Type of Early Childhood Program

Student Age	Montessori (number)	Montessori (%)	Non-Montessori (number)	Non-Montessori (%)	Total (number)	Total (%)
3 Years	0	0	1	4	1	2
4 Years	10	33	6	20	16	26
5 Years	15	50	19	63	34	57
6 Years	5	17	4	13	9	15
Total	30	100	30	100	60	100

Table 5

Distribution of Child Participants by Gender and Type of Early Childhood Program

Student Gender	Montessori (number)	Montessori (%)	Non-Montessori (number)	Non-Montessori (%)	Total (number)	Total (%)
Female	11	37	16	53	27	45
Male	19	63	14	47	33	55
Total	30	100	30	100	60	100

Table 6

Distribution of Child Participants by Age and Gender

Student Age	Female (number)	Female (%)	Male (number)	Male (%)	Total (number)	Total (%)
3 Years	0	0	1	3	1	1
4 Years	7	26	9	27	16	27
5 Years	14	52	20	61	34	57
6 Years	6	22	3	9	9	15
Total	27	100	33	100	60	100

Coincidentally, an equal number of parents completed the study at each participating school. Regarding the children who were represented in the study, 45% were female and 55%, male. As indicated on the recruitment flyer, parents with children between the ages of 3 and 6 were invited to participate in the study. At 57% of total participants, 5-year-old children were the majority. Then, 4-year-old children were the second highest percentage of study participants at 27%, for a combined percentage of 4-

and 5-year-olds of 84% of total participants. These distribution statistics are not surprising for two reasons. First the schools in the study were both public schools that accepted only children who had reached the age of eligibility, either 3 or 4 years old, by August 1st. Because the study was conducted during the last 4 months of the school year, many 4-year-old prekindergarten children in the non-Montessori program would have already turned 5 years old. Also, many children entering the Montessori program at 3 years old would have turned 4 years old before or during data collection for the study. Second, because participants who had already turned 6 years old were not solicited for this study, very few parents of children who were 6 years old signed up. The integrity of the study, however, was not compromised by having its core participant group comprised of 4- and 5-year-old children. These age groups fit well within the age parameters specified for the standardized BRIEF-P (Gioia et al., 2003a). Tables 7 and 8 list raw, numerical data totals.

Table 7

Non-Montessori Individual Collected Data Totals and Cook's Distance Values

Participant ID	Montessori Exposure in Days	Passive Screen Time in Minutes	Active Screen Time in Minutes	Total Screen Time in Minutes	Working Memory *T*-Score	Cook's Distance Value
1	0	540	420	960	50	.00177
2	0	300	0	300	60	.00262
3	0	420	420	840	65	.00715
4	0	660	60	720	71	.01913
5	0	720	180	900	44	.00653
6	0	600	600	1200	77	.05277
7	0	1620	120	1740	54	.00067
8	0	705	30	735	48	.00423
9	0	450	360	810	63	.00367
10	0	480	0	480	50	.00211
11	0	720	0	720	40	.02219
12	0	840	240	1080	48	.00278
13	0	300	540	840	46	.01231
14	0	180	120	300	44	.01070
15	0	1500	660	2160	54	.00079
16	0	300	120	420	64	.00603
17	0	480	300	780	56	.00004
18	0	1020	180	1260	52	.00080
19	0	540	180	660	40	.01325
20	0	360	60	420	38	.02217
21	0	420	60	480	64	.00612
22	0	900	960	1860	65	.03237
23	0	1260	600	1905	90	.18096
24	0	480	300	780	71	.01302
25	0	480	240	720	63	.00314
26	0	900	0	900	52	.00113
27	0	1260	420	2070	62	.00906
28	0	**	**	**	54	**
29	0	**	**	**	64	**
30	0	1110	780	1890	**	.64034

Note. ** No questionnaire gathering data for this value was returned by the participant.

Table 8

Montessori Individual Collected Data Totals and Cook's Distance Values

Participant ID	Montessori Exposure in Days	Passive Screen Time in Minutes	Active Screen Time in Minutes	Total Screen Time in Minutes	Working Memory *T*-Score	Cook's Distance Value
31	346	645	25	670	42	.01710
32	347	840	120	960	52	.00108
33	171	600	240	840	60	.00062
34	351	**	**	**	40	**
35	338	720	420	1140	38	.03491
36	170	300	0	300	46	.00306
37	174	240	0	240	54	.00006
38	351	330	270	600	40	.02825
39	341	300	120	480	56	.00007
40	343	1260	240	1500	62	.00674
41	169	600	60	660	73	.01361
42	171	300	60	360	50	.00134
43	351	**	**	**	60	**
44	340	300	240	540	60	.00252
45	351	210	210	420	60	.00262
46	337	840	0	840	72	.03336
47	349	505	60	565	58	.00045
48	339	360	60	420	58	.00081
49	164	600	270	870	54	.00005
50	346	1260	60	1320	46	.01851
51	336	360	0	360	67	.01475
52	346	2160	420	2580	64	.06154
53	336	**	**	**	42	**
54	351	**	**	**	54	**
55	351	**	**	**	38	**
56	344	420	540	960	62	.00875
57	171	**	**	**	38	**
58	349	420	420	840	38	.04634
59	155	310	0	310	73	**
60	159	240	230	470	**	.01856

Note. ** No questionnaire gathering data for this value was returned by the participant.

Discrepancies From Plan Presented in Research Method Chapter of the Proposal

Recruitment, and data collection and analysis varied from the plan put forward in the research method chapter of the study proposal in five ways: (a) dispersing BRIEF-P scoring summaries to families, (b) recruiting participants at PTA meetings and in car lines, (c) reminding participants to complete both questionnaires through email, (d) including weekly amount of parent-controlled *total* screen time as a fourth IV for data analysis, and (e) transcribing parent-controlled screen time hours and minutes into *all minutes* for data analysis.

First, although feedback from BRIEF-P scoring was available to families upon request, no participants requested these results. Second, due to COVID-19 precautions, I was not allowed to extend in-person invitations to parents inviting participation in the study or distribute invitation flyers alongside pick-up and drop-off car lines at either school. Also, no PTA meetings were held for either participating school during the study recruitment and data collection period. I did however introduce myself as the researcher through both schools' PTA Facebook groups and there extended a personal invitation to parents to participate in the study. In my post to each school's PTA Facebook group, I included a recruitment flyer with a QR code that linked to the study waiver and then both questionnaires.

A third divergence from the data collection plan presented in the research method chapter of the proposal became unexpectedly necessary when some parents used the QR code on recruitment flyers to access the study waiver and sign up for the study by providing the (a) email address, (b) child's birthdate, (c) child's sex, and (d) child's school but then did not complete one or both questionnaires. When this situation arose, I emailed a reminder to those participants. I did not realize these email reminders would be necessary when I wrote the study proposal. I continued to send a reminder every two weeks from the time the parent signed up for the study until either they submitted both questionnaires, or the study ended. Reminding participants through email to finish and submit both questionnaires increased the survey completion rate and strengthened the quality of the study. In a fourth discrepancy, I included weekly amount of parent-controlled *total* screen time as a fourth IV for data analysis. Total screen time was easily calculated by adding together weekly amounts of passive and active screen time, and I had collected these data with the Screen Time Questionnaire. However, I did not originally list weekly amount of parent-controlled screen time as an IV for this study in the research method chapter of the proposal. For the final study, I chose to analyze weekly amount of parent-controlled total screen time along with weekly amounts of parent-controlled passive and active screen time. Lastly, I transcribed all data collected on hours and minutes of passive, active, and total screen time into minutes for more precise and detailed data analysis.

In summary, very minor changes in the research design included (a) elimination of in-person recruitment for study participation due to COVID-19 restrictions at partnering schools, (b) emailed reminders sent to participants who signed up for the study but had not completed one or both study questionnaires within two weeks, and (c) analysis of total screen time. When I wrote the proposal, I did not realize how long COVID-19 would continue, and I did not realize I would need to remind participants who forgot to complete the questionnaires. Also, since I collected data on passive, active, and total screen time, it was easy and made sense to include the data on a fourth variable, *parent-controlled total screen time*, transcribe all parent-controlled screen time into minutes and include the new variable and data in SPSS-28 analyses.

Representativeness of the Convenience Sample to the Larger Early Childhood Population

Volunteer participants from two public school magnet programs formed the convenience sample that agreed to participate in the study and were geographically located within 20 miles of each other. The participating Montessori and non-Montessori preschools were both magnet programs in the same school district that were housed in urban neighborhoods but drew students from all areas of the city.

Table 1 in Chapter 3 summarizes school-aged diversity demographics for (a) the school district from which the study convenience sample was drawn and (b) the whole United States. The diversity by enrollment of this school district was 40% White, 25% Black or African American, 19% Hispanic/Latino, 10% Two or more races (multiracial), and 6% Asian or Asian Pacific Islander, with 47% of students qualifying for free or reduced-price lunch and 19% learning English. The school district's student population was representative of the larger U.S. early childhood population because it was comparable to the demographic diversity of children in the U.S. as a whole, which was 50% White, 14% Black, 26% Hispanic, and 5% Asian with 52% qualifying for free or reduced-price school lunch and 10% learning English as a second language.

I chose the study sample through non-probability convenience sampling. However, alignment (within an 11% margin) of sample diversity percentages with diversity nationwide showed that the study population was representative of the U.S. early childhood population. This alignment strengthened the external validity of the study. From this racially, culturally, and economically diverse applicant pool, children were chosen for attendance in each magnet program during a publicly held, equally weighted, random lottery drawing held once a year at the school district administration building. Both schools were populated with students from the same demographic of diverse, randomly selected applicants.

Results

Descriptive Statistics

I used two survey instruments in the study: the BRIEF-P and the Screen Time Questionnaire. There were four IVs: Montessori preschool exposure, parent-controlled active screen time, parent-controlled passive screen time, and parent-controlled total screen time. There was one DV: working memory function. SPSS-28 software was used to analyze the data. I calculated results for the BRIEF-P, including each child's working memory *T*-score, using PARiConnect (2021), the online psychological assessment service provided by the vendor of the BRIEF-P, PAR.

I collected data for the four IVs from parent participants using either online Screen Time Questionnaire protocols at SurveyMonkey (2022) or paper protocols (see Appendices D and E). I measured Montessori preschool exposure in days of Montessori preschool attendance. I calculated Montessori preschool exposure by asking the parent how many days their child had been absent from school during each year of Montessori or non-Montessori preschool attendance at the participating schools and subtracting absences from the total days school was in session. For data analysis, however, I recorded all non-Montessori students as having zero days of Montessori preschool exposure. Parents reported a child's parent-controlled passive screen time, active screen time, and total screen time in hours and minutes, as recorded each day for 1 week. For analysis, I converted all parent-controlled screen time from hours and minutes into all minutes. I gathered data on the DV, working memory function, when parents completed and submitted the BRIEF-P, and I derived *T*-scores for working memory from BRIEF-P answers (see Appendices B and C for sample BRIEF-P questions).

Descriptive statistics that characterize the study are included in Tables 9, 10, and 11 showing the mean, median, standard deviation, minimum, and maximum for each of the four IVs and one DV. I report compliance or non-compliance of study data with statistical assumptions of normality, linearity, and equality of variance in the next section.

Descriptive Statistics for Independent and Dependent Variables

Table 9 provides statistics on participants' Montessori preschool exposure. Table 10 shows statistics on parent-controlled passive, active, and total screen time, and Table 11 displays descriptive statistics on working memory function.

Table 9

Statistics for Montessori Preschool Exposure in Days

Mean	Median	Standard Deviation	Minimum	Maximum
144.1	150.00	156.47	0	351

Table 10

Statistics for Overall Parent-Controlled Screen Time in Minutes

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
Passive Screen Time	647.5	516.7	409.0	180	2160
Active Screen Time	231.1	187.5	225.4	0	960
Total Screen Time	888.0	780	542.5	240	2580

Table 11

Statistics for Working Memory Function as Measured by T*-scores on the BRIEF-P*

Mean	Median	Standard Deviation	Minimum	Maximum
54.37	54.0	13.397	0	90

Statistical Assumptions: Normality, Linearity, and Homoscedasticity

I verify or explain statistical assumptions of normality, linearity, and homoscedasticity for the study for these variables: Montessori preschool exposure in days (IV), total screen time minutes in 1 week (IV), passive screen time minutes in 1 week (IV), active screen time minutes in 1 week (IV), and preschoolers' working memory function as measured by *T*-scores on the BRIEF-P (DV). In general, linear regression can still be significant, even if the data are not linear (Pawel, 2018). And, since violation of normality does not contribute to bias or inefficiency in multiple regression analysis, "there are few consequences associated with a violation of the normality assumption"

(Statistics Solutions, 2013, para. 2). Also, according to Cribari-Neto (2004), heteroskedasticity does not bias the regression coefficients, but consistency and unbiasedness remain intact even if homoskedasticity is being violated. Where normality, linearity, and homoscedasticity are not verified, the robust character of multiple regression analysis still allowed for analysis of these data (Cribari-Neto, 2004; Pawel, 2018; Statistics Solutions, 2013).

Test Results of Normality for the Variables of the Study

I assessed the statistical assumption of normality with the Shapiro-Wilk and Kilmogorov-Smirnov tests using SPSS-28. As defined by Lærd Statistics (2018) "If the Sig. [or *p*] value of the Shapiro-Wilk test is greater than 0.05, the data [are] normal. If it is below 0.05, the data significantly deviate from a normal distribution" (para. 9). The Kilmogorov-Smirnov normality test shows that data for a variable are distributed normally if $p > 0.05$ (see also Geert van den Berg, 2022).

Montessori Preschool Exposure. Tests of normality for Montessori preschool exposure show data for this variable are not normally distributed. Data analysis revealed a value of $p < .001$, not greater than the alpha value of .05, on both the Kolmogorov-Smirnov and the Shapiro-Wilk statistics. Also, observed values for Montessori exposure do not follow the expected normal line on the normal quantile-quantile plot (see Table 12 and Figure 2).

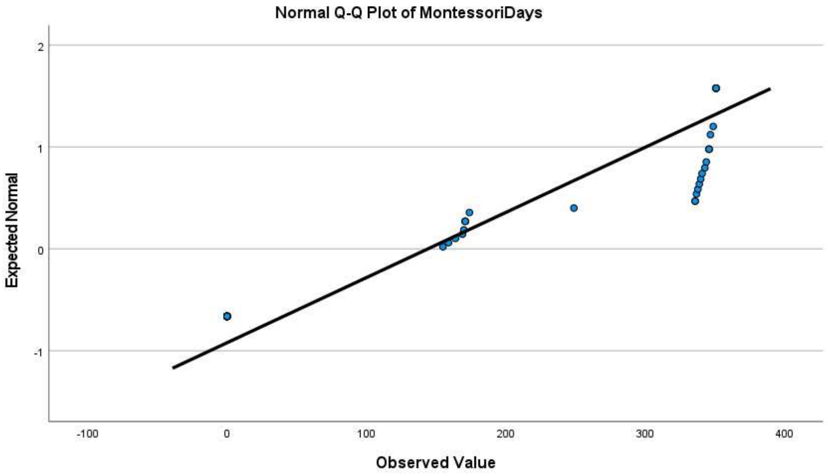
Table 12

Tests of Normality for Montessori Preschool Exposure in Days

Kolmogorov-Smirnov Statistic	*Df*	Sig. or p value	Shapiro-Wilk Statistic	*df*	Sig. or *p* value
.321	60	< .001	.732	60	< .001

Figure 2

Normal Quantile-Quantile Plot for Montessori Preschool Exposure in Days



Note. Reprinted from SPSS-28.

Parent-Controlled Passive Screen Time. Tests of normality for parent-controlled passive screen time show mixed results. Data for this variable are not normally distributed according to both Kolmogorov-Smirnov and Shapiro-Wilk tests with *p* = .001 for the Kolmogorov-Smirnov and *p* = < .001 for the Shapiro-Wilk statistics. However, observed values for parent-controlled passive screen time are distributed somewhat evenly along the expected normal line on the normal quantile-quantile plot (see Table 13 and Figure 3).

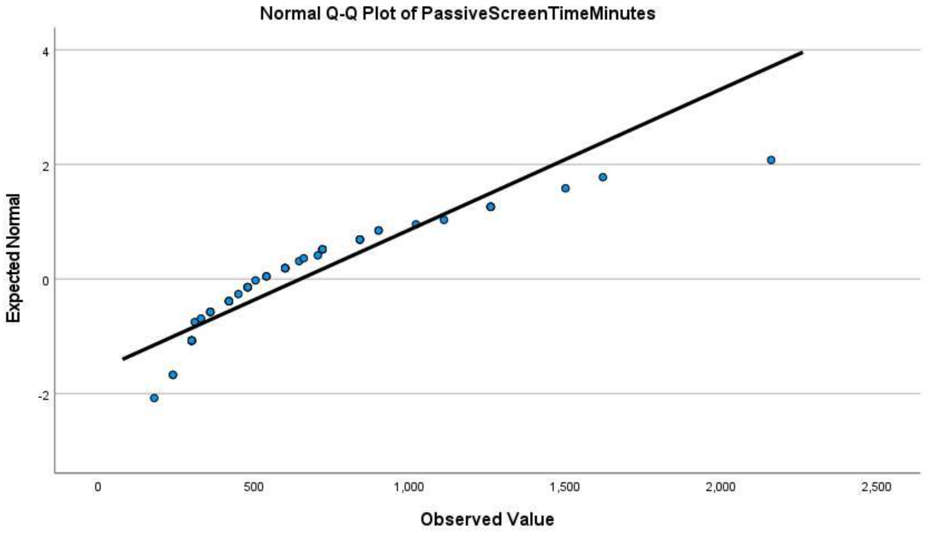
Table 13

Tests of Normality for Parent-Controlled Passive Screen Time in Minutes

Kolmogorov-Smirnov Statistic	*df*	Sig. or *p* value	Shapiro-Wilk Statistic	*df*	Sig.or *p* value
.163	52	.001	.845	52	<.001

Figure 3

Normal Quantile-Quantile Plot for Parent-Controlled Passive Screen Time in Minutes



Note. Reprinted from SPSS-28.

Parent-Controlled Active Screen Time. Tests of normality for parent-controlled active screen time show mixed results. Data for this variable are not normally distributed according to values of $p = .004$ for the Kolmogorov-Smirnov and $p < .001$ for the Shapiro-Wilk statistics, which are not greater than .05. Observed values for parent-controlled active screen time are fairly evenly distributed along the expected normal line on the normal quantile-quantile plot (see Table 14 and Figure 4).

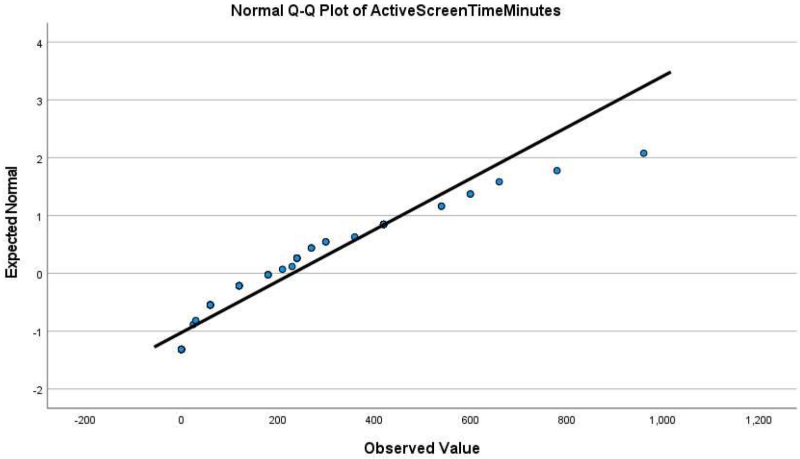
Table 14

Tests of Normality for Parent-Controlled Active Screen Time in Minutes

Kolmogorov-Smirnov Statistic	*df*	Sig. or p value	Shapiro-Wilk Statistic	*df*	Sig. or *p* value
.153	52	.004	.879	52	< .001

Figure 4

Normal Quantile-Quantile Plot for Parent-Controlled Active Screen Time in Minutes



Note. Reprinted from SPSS-28.

Parent-Controlled Total Screen Time. Tests of normality for parent-controlled total screen time show mixed results. Data analysis revealed a value of $p < .001$, not greater than the alpha value of .05, on both the Kolmogorov-Smirnov and the Shapiro-Wilk statistics. However, observed values for parent-controlled total screen time are somewhat evenly distributed along the expected normal line on the normal quantile-quantile plot (see Table 15 and Figure 5).

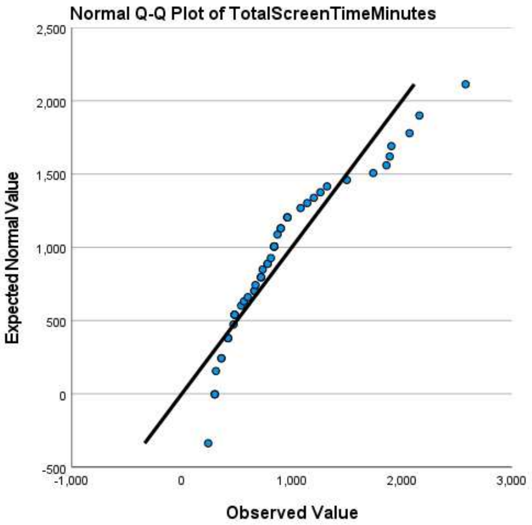
Table 15

Tests of Normality for Parent-Controlled Total Screen Time in Minutes

Kolmogorov-Smirnov Statistic	*df*	Sig. or *p* value	Shapiro-Wilk Statistic	*df*	Sig. or *p* value
.197	52	< .001	.866	60	< .001

Figure 5

Normal Quantile-Quantile Plot for Parent-Controlled Total Screen Time in Minutes



Note. Reprinted from SPSS-28.

Working Memory Function. Tests of normality for working memory function show mixed results about the normal distribution of this variable. A result for the Kolmogorov-Smirnov statistic of *p* = .200 shows normal distribution. However, the Shapiro-Wilk statistic shows a value of *p* = .003, indicating a deviation from normal distribution. Observed values for working memory are distributed normally along the expected normal line on the normal quantile-quantile plot, except for two outliers (see Table 16 and Figure 6).

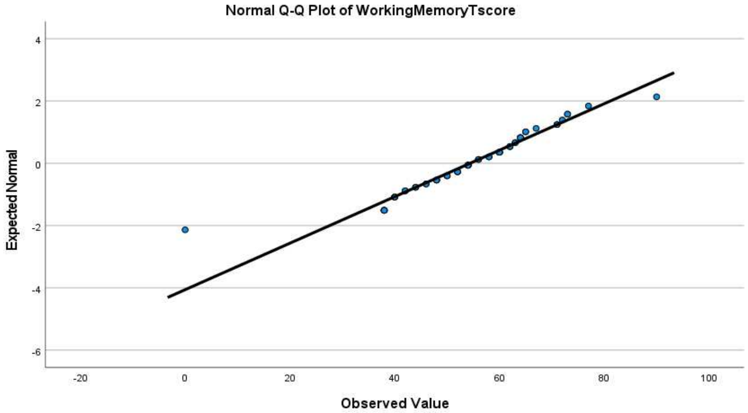
Table 16

Test of Normality for Working Memory Function as Measured by T-*Scores on BRIEF-P*

Kolmogorov-Smirnov Statistic	*df*	Sig. or *p* value	Shapiro-Wilk Statistic	*df*	Sig. or *p* value
.094	60	.200	.934	60	.003

Figure 6

Normal Quantile-Quantile Plot for Working Memory Function as Measured by T-*scores on the BRIEF-P*



Note. Reprinted from SPSS-28.

Test Results for Linearity Between the DV and Each IV

Montessori Preschool Exposure (IV) and Working Memory Function (DV). Tests of linearity for the interaction of Montessori preschool and working memory function provide mixed results. Data analysis shows the assumption of linearity had been violated with a non-significant value of *p* = .218, which is larger than the alpha value of .05. Contradictorily, there is also no significant deviation from linearity, as indicated by Sig. or *p* = .710 which is a deviation from linearity value greater than .05. A scatterplot revealed no linear correlation between the variables (see Table 17).

Table 17

Tests of Linearity With Montessori Preschool Exposure in Days and Working Memory Function as Measured by T-*scores on the BRIEF-P.*

Montessori by Working Memory	Sum of Squares	*df*	Mean Square	*F*	Sig. or *p* value
Linearity	222.286	1	222.286	1.571	.218
Deviation from Linearity	1983.513	18	110.195	.779	.710

Parent-Controlled Passive Screen Time (IV) and Working Memory Function (DV). Tests of linearity for the interaction of parent-controlled passive screen time and working memory function show mixed results. Data analysis shows the assumption of linearity has been violated with a non-significant value of *p* = .349, which is larger than .05. Contradictorily, there is also no significant deviation from linearity, as indicated by Sig. or *p* = .433. A scatterplot revealed no linear correlation between the variables (see Table 18).

Table 18

Tests of Linearity With Parent-Controlled Passive Screen Time in Minutes and Working Memory Function as Measured by T*-scores on the BRIEF-P*

Passive Screen Time by Working Memory	Sum of Squares	*df*	Mean Square	*F*	Sig. or *p* value
Linearity	115.663	1	115.663	.909	.349
Deviation from Linearity	2989.750	22	135.898	1.067	.433

Parent-Controlled Active Screen Time (IV) and Working Memory Function (DV). Tests of linearity for the interaction of parent-controlled active screen time and working memory function show mixed results. Data analysis shows the assumption of linearity had been violated with a non-significant value of *p* =.118, which is larger than .05. Contradictorily, there is also no significant deviation from linearity, as indicated by Sig. *or p* = .142. A scatterplot revealed no linear correlation between the variables (see Table 19).

Table 19

Tests of Linearity With Parent-Controlled Active Screen Time in Minutes and Working Memory Function as Measured by T*-scores on the BRIEF-P*

Active Screen Time by Working Memory	Sum of Squares	*df*	Mean Square	*F*	Sig. or *p* value
Linearity	282.253	1	282.253	2.571	.118
Deviation from Linearity	2400.067	14	171.433	1.561	.142

Parent-Controlled Total Screen Time (IV) and Working Memory Function (DV). Tests of linearity for the interaction of parent-controlled total screen time and working memory function find mixed results. Data analysis shows the assumption of linearity has been violated with a non-significant value of *p* = .200, which is greater than the alpha value of .05. Contradictorily, there is also no significant deviation from linearity, as indicated by *p* = .756. A scatterplot revealed no linear correlation between the variables (see Table 20).

Table 20

Tests of Linearity With Parent-Controlled Total Screen Time in Minutes and Working Memory Function as Measured by T*-scores on the BRIEF-P*

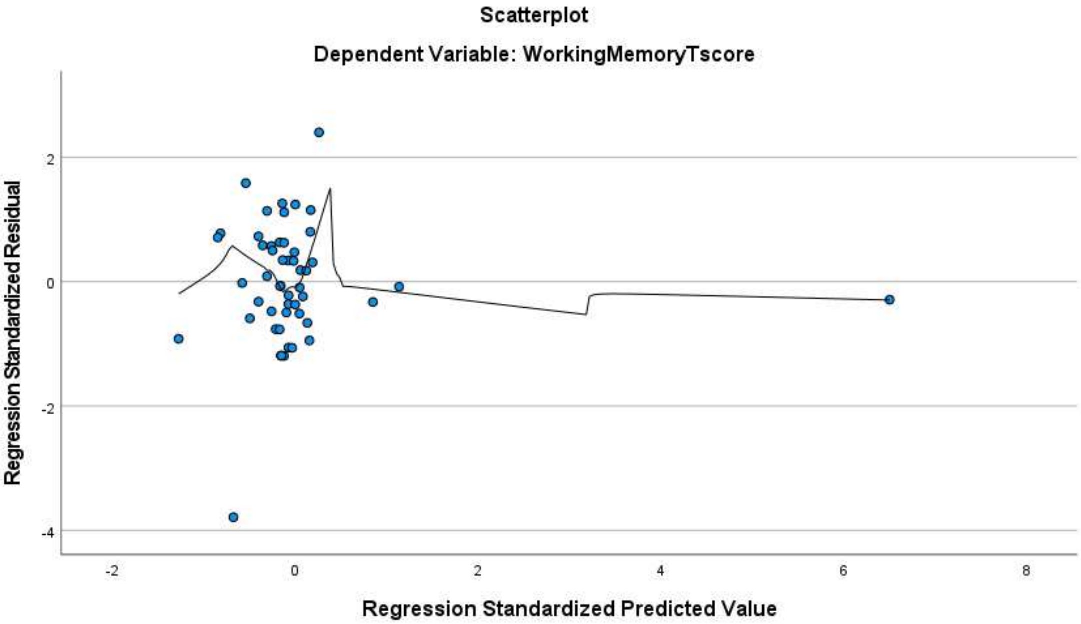
Total Screen Time by Working Memory	Sum of Squares	*df*	Mean Square	*F*	Sig. or *p* value
Linearity	264.858	1	264.858	1.764	.200
Deviation from Linearity	3298.362	29	113.737	.758	.756

Test Results for Homoscedasticity of DV

Data for the DV violate the assumption of homoscedasticity, as shown in the scatterplot in Figure 7. Creation of a scatter plot in SPSS-28 with the DV tested for homoscedasticity, or whether residual error of the DV is consistent across different values of the variable, reveals an inconsistent pattern. An inconsistent pattern displayed on the scatterplot reveals that the relationship is heteroskedastic since the best fit Loess line is not flat, smooth, or parallel to the X-axis and the data does not fall evenly and equal distance from the line.

Figure 7

Scatterplot Demonstrating Homoscedasticity for the DV: Working Memory Function as Measured by T*-scores on the BRIEF-P*



Note. Reprinted from SPSS-28.

Statistical Analysis of Findings

One RQ and one hypothesis, with null and alternate representations, underpinned this study. Multiple regression analysis using SPSS-28 software revealed whether relationships existed between the IVs and DV. The RQ and null and alternate hypotheses were as follows:

> RQ: Is there a relationship between weekly amount of parent-controlled passive screen time (IV); weekly amount of parent-controlled active screen time (IV); and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV)?
>
> H_0: There is no relationship between weekly amount of parent-controlled-passive screen time (IV), weekly amount of parent-controlled active screen time; (IV); and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).
>
> H_a: There is a relationship between weekly amount of parent-controlled passive screen time (IV); weekly amount of parent-controlled active screen time (IV); and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).

Regression analysis was used to investigate the influence on children’s working memory function of (a) Montessori preschool exposure, (b) parent-controlled passive screen time, (c) parent-controlled active screen time, and (d) parent-controlled total screen time. The results show that there is no relationship between any of the four IVs and the DV. Findings indicate that Montessori preschool exposure has no statistically significant relationship to working memory function in the pre-school-aged participants (β = -.045, *p* = .761). Parent-controlled passive screen time has no statistically significant relationship to working memory function for the pre-school-aged children who participated in this study (β = -.602, *p* = .592). Parent-controlled active screen time and working memory function in pre-school-aged children have no statistically significant relationship (β = -.180, *p* = .765). Parent-controlled total screen time and working memory function in pre-school-aged children also have no statistically significant relationship (β = .864, *p* = .539). Table 21 shows the statistical analysis of coefficients in the study.

Table 21

Statistical Analysis: Coefficients

	Unstandardized	Coefficients	Standardized Coefficients		
Independent Variables	*B*	Std. Error	Beta	*t*	Sig. or *p* value
(Constant)	53.496	3.629		14.743	<.001
Montessori	-.003	.011	-.045	-.305	.761
Passive Screen Time	-.017	.031	-.602	-.540	.592
Active Screen Time	-.010	.32	-.180	-.301	.765
Total Screen Time	.019	.030	.864	.620	.539

Note. DV is Working Memory Function

Additional Tests of Hypothesis That Emerged From Analysis of Main Hypothesis

Although there were no statistically significant relationships between any of the four IVs of this study and the DV, a *t* test conducted on parent-controlled active screen time indicated a significant difference between the number of parent-controlled active screen time minutes for Montessori and non-Montessori students *t* (45.78) = 1.94, *p* = .029). I found no significant difference between Montessori and non-Montessori preschoolers for either minutes of parent-controlled *passive* screen time or parent-controlled *total* screen time. However, children enrolled in the Montessori program engaged in statistically significantly fewer minutes of parent-controlled *active* screen time than their non-Montessori peers. Table 22 reports the group statistics for children enrolled in non-Montessori preschool (Group 0) and children enrolled in Montessori preschool (Group 1) and also *t*-test and one-sided *p* values for children exposed versus not exposed to Montessori preschool.

Table 22

Group Statistics

Variables	Program	*N*	Mean	Standard Deviation	*t*	One-Sided *p*
Working Memory	.00	29	56.86	11.948		
	1.00	29	53.76	11.093	1.025	.155
Passive Screen Time	.00	28	283.93	260.062		
	1.00	24	169.38	160.883	.963	.170
Active Screen Time	.00	28	698.04	376.441		
	1.00	24	588.33	444.800	1.938	.029
Total Screen Time	.00	28	997.50	555.210		
	1.00	24	760.21	508.947	1.607	.057

Summary

Results of regression analysis supported the null hypothesis (H_0) and rejected the alternative hypothesis (H_a) for this study. Based on study findings, there is no relationship between weekly amount of parent-controlled-passive screen time (IV), weekly amount of parent-controlled active screen time; (IV); weekly amount of parent-controlled total screen time; (IV); and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV). There is, however, a statistically significant relationship between parent-controlled active screen time and Montessori preschool exposure, with children having Montessori preschool exposure engaging in significantly less parent-controlled active screen time than preschoolers who had no exposure to a Montessori program. These results and findings will be interpreted and discussed in Chapter 5.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this quantitative study was to examine the working memory function of preschoolers, in Montessori and non-Montessori learning environments, who engaged in varying amounts of parent-controlled passive, active, and total screen time for any relationship between preschoolers' working memory function; Montessori preschool program exposure; and amount of parent-controlled passive, active, and/or total screen time. I conducted a quantitative survey investigation of preschool parents and children. A cross-sectional, one-time survey was used to collect data from a convenience sample of parents of pre-school-aged children. The survey contained two instruments: the Screen Time Questionnaire and the BRIEF-P. I used the BRIEF-P (Gioia et al., 2003b) to assess the working memory function of the children. The Screen Time Questionnaire, a survey instrument that I designed, included questions on each child's (a) age, (b) school name, (c) number of days of school absence, (d) amount in hours and minutes of passive screen time over 1 week, (e) amount in hours and minutes of active screen time over 1 week, and (f) amount in hours and minutes of total screen time over 1 week. During data analysis, the hours and minutes of parent-controlled screen time were converted into all minutes, and total screen time was analyzed as a fourth IV not included in the original proposal for this study.

All study participants were parents of pre-school-aged children who were enrolled in magnet school programs in the largest public school district in their state. Both preschool programs were located in the same medium-sized, midwestern U.S. city, with half of participating families attending a magnet Montessori preschool program and the other half a magnet non-Montessori preschool program. Both magnet programs were nationally accredited, overseen by USDE (2022) and CHEA (2019), and populated with applicants from urban, suburban, and rural areas of the school district who were randomly selected for enrollment during a publicly held lottery drawing.

I conducted the study to investigate factors that might impact young children's working memory function. As I discussed in Chapter 2, there is a gap in the literature on the study topic. The findings reveal no statistically significant relationship between (a) working memory function, and either (b) amount of parent-controlled passive, active, and/or total screen time or (c) Montessori preschool exposure. However, a statistically significant difference was discovered between the number of minutes of parent-controlled active screen time of the children with Montessori preschool exposure and the children enrolled in the non-Montessori program. The Montessori students engaged in significantly fewer minutes of parent-controlled active screen time during a week than their non-Montessori peers.

Interpretation of the Findings

To examine the relationships between working memory function and Montessori preschool exposure, and/or amount of parent-controlled passive, active, or total screen time, I used the cognitive load theory and the construct of executive function, especially working memory. In the United States, preschool children use some type of screen media an average of 2-3 hours per day (McNeill et al., 2019), with most viewing time devoted to television (Jusienė et al., 2017; Kostyrka-Allchome et al., 2017). However, use of mobile screen media devices among young children is on a steep rise (Kabali et al., 2015;

Kostyrka-Allchome et al., 2017; Paudel et al., 2017; Radesky et al., 2014, 2016). The literature indicates that the cognitive load (Sweller et al., 2011, 2019) created by a screen media application either supports or hinders working memory function and affects the usefulness of the application as a learning tool (Huber et al., 2018; Lillard et al., 2015; L.-Y. Lin et al., 2015; Mayer, 2017). Also, elements missing or present in a pre-school-aged child's learning environment are associated with decline in working memory function, according to researchers (Brock et al., 2018; Conway et al., 2019; de Wilde et al., 2016; Gade et al., 2017; Passolunghi & Costa, 2016; Peng & Fuchs, 2017; Thierry et al., 2016; Volckaert & Noël, 2015). Montessori (1909/1964) learning environments have been found to include elements supportive of working memory function (Diamond & Lee, 2011; Fabri & Fortuna, 2020; Ginns et al., 2016; Lillard & Else-Quest, 2006; Lillard & Heise, 2016) such as reduction of outside distractions, engagement of multiple senses, and attention on one new concept at a time (Blakey & Carroll, 2015; Sweller et al., 2011, 2019). Some findings from the current study either confirm, disconfirm, or extend findings from the literature. I interpreted the results of this study in light of the ways its IVs were related to its DV in the results of other, peer-reviewed studies that examined the same variables. Discussion of key findings is organized by interaction of the DV, working memory function, with each IV: Montessori preschool exposure, parent-controlled total screen time, parent-controlled passive screen time, and parent-controlled active screen time. The hypotheses were as follows:

> H_0: There is no relationship between weekly amount of parent-controlled passive screen time (IV), weekly amount of parent-controlled active screen time; (IV);

and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).

*H*ₐ: There is a relationship between weekly amount of parent-controlled passive screen time (IV); weekly amount of parent-controlled active screen time (IV); and/or Montessori preschool program exposure (IV); and working memory function in pre-school-aged children (DV).

Links Between Montessori Preschool Exposure and Working Memory Function

A review of research literature uncovered studies that found statistically significant, positive connections between working memory function and Montessori preschool exposure (Bagby et al., 2012; Courtier et al., 2019; Darcy, 2014; Denervaud et al., 2019; Diamond & Lee, 2011; Lillard, 2012; Lillard & Else-Quest, 2006; Lillard & Heise, 2016; Yussen, 1980). Findings of the current study disconfirm these positive results. So did Lillard et al. (2017) who found that Montessori students performed higher on the Woodcock-Johnson IIIR Tests of Achievement than non-Montessori peers even when Montessori students' working memory was lower than peers, casting doubt on a direct connection between Montessori exposure and working memory function (Bagby & Sulak, 2018). Two other studies also found no relationship between Montessori education and working memory function (Kvintova et al., 2022; Persoon, 2017). The findings of the current study confirm and extend the findings from these three studies by showing no relationship between Montessori preschool exposure and working memory function even while factoring in children's screen time.

Of all reviewed studies where researchers investigated connections between Montessori exposure and working memory, including seminal studies, nine out of twelve showed statistically significant correlation between the two variables, with only three of twelve showing no significant connection. The result of the current study aligns with the minority finding of no significant relationship between Montessori exposure and working memory function. This alignment with the minority finding may indicate a discrepancy in findings between study conductors with direct access to child participants for executive function evaluation and those without direct access. In most studies that found a link between Montessori and working memory, researchers assessed the children's executive functions, including working memory, with direct tests such as the Head, Toes, Knees, and Shoulders task (McClelland et al., 2021). For the current study, I did not have direct access to child participants necessitating assessment of working memory function through BRIEF-P questionnaires filled out by the children's parents. Perhaps methodology affected study findings.

A Link Between Montessori Preschool Exposure and Active Screen Time

Statistically significant results arising from data analysis that negatively linked Montessori preschool exposure with amount of active screen time prompted review of the literature on the relationship between Montessori preschool and active screen time. An exhaustive review of research literature revealed no published research studies examining a relationship between Montessori preschool exposure and amount of screen time, including active screen time. The current study is a seminal study, the only study finding a statistically significant negative relationship between Montessori preschool exposure and amount of active screen time, such as video games, and interactive computer use (see Table 22 in Chapter 4).

However, several studies on the attitudes toward screen time of Montessori teachers and parents offer insight on possible reasons for the statistically negative relationship between Montessori preschool exposure and amount of active screen time discovered by the current study. Research found that the amount and type of screen time young children engaged in depended on the priorities of their parents or in other words, the family culture (Asplund et al., 2015; Howe et al., 2017). For example, Howe et al. (2017) found that parenting style and family type rather than child temperament, were associated with 2-year-olds' television viewing.

In 2011, an official statement by the American Montessori Society supported preparation of Montessori students for "the challenges of a global society" through use of "best practices and the multitude of new ways our children can absorb information" (AMS, 2011 as cited in Prosper, 2018, p. 43), including active screen media applications. Montessori educators have worked to comply with AMS recommendations by bringing technological devices and apps into the Montessori classroom (Bayer, 2018; Behnamnia et al., 2020; Buckleitner, 2015; Elkin et al., 2014; Elkind, 2016; Owen & Davies, 2020; Scippo & Ardolino, 2021), incorporating Montessori pedagogy into educational apps (Looijenga et al., 2020; Pérez-Pérez et al., 2021; K. Smith, 2017), or both (Miranda et al., 2017; Zehra Çakir, & Altun Yalçin, 2020). However, Jones (2017) found that although the Montessori teachers in their study expressed high levels of competence with technological tools and positive views of technology in general, the teachers "struggled to include instructional technology in ways that are consistent with the Montessori paradigm” (p. 1).

This ambivalence about active screen media use as an educational tool permeates the Montessori community, including parent attitudes (Holbrook, 2021; McDonald, 2016; Rosin, 2013; Rupp, 2016; Sharkins et al., 2016; Stuart, 2017). Montessori (1936/1966, 1949/1989) philosophy and culture elevates the importance of sensory, hands-on activity for young children. Indeed, Montessori teachers consider use of as many of a child’s physical senses as possible with their preparation of each pedagogical presentation, learning material, and educational activity (Montessori, 1909/1964). The heavy emphasis on hands-on, sensory-rich learning in Montessori philosophy and learning environments may have had an effect of diminishing young children’s screen time in families whose children are enrolled in Montessori preschool. Adherence to Montessori philosophy by Montessori parents could explain the findings of the current study negatively linking Montessori preschool exposure to parent-controlled active screen time.

Links Between Total Screen Time and Working Memory Function

Takeuchi et al.’s (2015) longitudinal study of 290 children found that regardless of sex, age, or socioeconomic status, the more hours of screen time a child had, the bulkier the hypothalamus, septum, sensorimotor area, visual cortex, and frontopolar cortex of their brain became. This altered brain affected emotional responses, arousal, aggression, vision, and language-based reasoning ability; and verbal IQ scores lowered proportionally with the number of hours of screen time per day. Not surprisingly, current research studies have also found statistically significant connections between amount of total screen time and the brain's working memory function. Some studies have linked increased total screen time with a decrease in working memory function (De Lucena Martins et al., 2020; McHarg et al., 2020b; McMath et al., 2020; Vohr et al., 2021; Z. Zhang, Adamo et al., 2022). On the other hand, Beatty and Egan's (2020) research analysis surprisingly discovered a small but significant *positive* correlation between 5-year-old children's nonverbal reasoning, which is closely related to executive function (Duff et al., 2005), and screen use of *over* three hours per day. Still, findings of the current study disconfirm both negative and positive connection between total screen time and working memory function by finding no statistically significant link between increases in total screen time and working memory function. Likewise, current research by Carson et al. (2017), McHarg et al. (2020a, 2020b), McNeill et al. (2020), San Martin Soares et al., (2021), and Z. Zhang, Wiebe et al. (2022) also found no significant difference in working memory between young children who met the AAP (2016) screen time recommendation of 1 hour or less total screen time per day and those who did not. These null findings, highlighting no difference in working memory whether total screen time was low or high, could indicate that influences not accounted for in the studies just mentioned or the current study may have statistically moderated the effects of total screen time on working memory. Findings may also indicate that an evolution of screen media for young children may have made larger than recommended screen time have less impact on working memory function than it did in the past. Or, in the case of the present study, the parent population choosing to take the extra steps necessary to enroll their children in the two lottery-chosen, public magnet schools might also have intentionally regulated the screen time of their children to stay largely within AAP (2016) guidelines. Conscientious parents of children in magnet programs may have monitored their children's total screen time in such a way that the narrow range of screen time reported for the study produced no significant effect on working memory.

Links Between Passive Screen Time and Working Memory

Screen media applications used by young children come in several varieties, but the screen media present in most family households over the past eight decades has been television. Therefore, much peer-reviewed research has focused on the effects of television viewing on human development and found several aspects of screen media that could affect a developing brain. For example, variant light emissions (H.-C. Jung et al., 2017; Mander, 2002; Sourman et al., 2018; Zhu et al., 2019), fantasy content (Lillard et al., 2015; Rhodes et al., 2020), adult content (Carson et al., 2015), seductive details unrelated to the learning objectives of an educational media application (Park, Korbach, & Brünken, 2015; Pink & Newton, 2020), and other video or audio elements of a screen media application could all contribute to extraneous rather than germane cognitive load and affect working memory function (Squire, 2011; Sweller, 2011, 2019).

Peer-reviewed research on the connection between passive screen time, such as television viewing, and working memory function has yielded mixed results. Lillard et al. (2015) and Rhodes et al., (2020) found watching fantastical versus realistic children's television to be associated with significantly poorer working memory performance in young children. Other researchers also discovered significantly negative correlations between young children's working memory function and passive screen time (B. Y. Hu et al., 2020; N. Veraksa et al., 2021). On the other hand, Yang et al. (2017) found television watching positively correlated with executive function, encompassing working memory, in a study conducted with Chinese preschoolers, and Toh et al. (2021)'s study of smart phone engagement among young adults also found that screen time positively predicted working-memory-specific abilities.

The results of the current study contradict findings that passive screen time is either negatively or positively linked to working memory function. This study found no statistically significant relationship between passive screen time and working memory function. Other research studies have also found no significant relationship between passive screen time and working memory (Vohr et al., 2021; Z. Zhang, Adamo et al., 2022). The variety of findings on the relationship between passive screen time and working memory function, including negative, positive, and null, may indicate the presence of modifying influences on working memory not accounted for by all cited studies. The current study attempted to offer insight on the relationship between passive screen time and working memory by examining, alongside screen time, the effect of Montessori and non-Montessori preschool exposure on working memory. Study of all factors that could affect working memory, including how variables interact, could help explain varying results.

Links Between Active Screen Time and Working Memory

Researchers explored the possibility that screen media could be used as a more effective teaching tool if it incorporated strategies to make it active, namely enhancing narratives with turn-taking prompts using a questioning character (Krcmar & Cingel, 2017; Piotrowski, 2014; Strouse et al., 2013), providing responsive feedback (Roseberry et al., 2014; Strouse et al., 2013), or giving the child agency or control of the device via computer mouse or touch screen (Hirsh-Pasek et al., 2015; E. L. Schroeder & Kirkorian, 2016; Xie et al., 2018). Also, Jusienė et al. (2020) postulated that "the interactivity of content enables children to engage in digital realities as if they were part of those realities" (p. 1). However, studies examining the effects when all three interactive strategies were employed found that interactivity was no better than passive viewing for near transfer tasks and worse than viewing for far transfer tasks (Alade et al., 2016; McEwen & Dubé, 2015; E. L. Schroeder & Kirkorian, 2016). An exception was when pointing and gesturing movements were incorporated into educational applications that used screen media, which did promote positive learning outcomes (Agostinho et al., 2020). E. L. Schroeder and Kirkorian (2016) suggested that young children's cognitive resources were overtaxed by the task of interacting with the screen, which left little room in the working memory for educational content. Anderson and Davidson (2019) attributed the observed differences in learning during passive versus active screen media use to the activation of completely different brain networks during the two types of media interaction. Viewing of television and other passive media activated the default mode network (DMN) of the brain and spurred temporal and spatial learning while use of interactive screen media deactivated the DMN and enhanced stimulus-response-goal-associative learning (Anderson & Davidson, 2019).

A review of literature that explored the effects of active screen time on working memory function revealed mixed results. Some peer-reviewed research found that active screen time was negatively correlated with working memory function (Dong & Potenza, 2017; McEwen & Dubé, 2015; Peebles et al., 2018; E. L. Schroeder & Kirkorian, 2016). Highly interactive tablet computer applications and video games challenged the cognitive load on working memory of children and reduced learning (McEwen & Dubé, 2015; Parong & Mayer, 2018; Peebles et al., 2018; E. L. Schroeder & Kirkorian, 2016). Possibly, cognitive load increased as interactivity increased or researchers attempted to teach biologically primary social-emotional perceptions that 3- to 5-year-olds were not brain-developmentally ready to control, learn, understand, or perceive (Peebles et al., 2018). A recent study conducted with 10-month-old infants found touchscreen exposure was positively correlated with a cognitive executive function score that included working memory (Lui et al., 2021). And a study with older children found video game and computer use significantly positively affected 11- to 15-year-old males' working memories as measured by the Digit Span backward score (San Martin Soares et al., 2021).

However, other recent studies found no significant positive or negative correlation between active screen time and children's executive function, including working memory function (Carson et al., 2017; B. Y. Hu et al., 2020; San Martin Soares et al., 2021; N. Veraksa et al., 2021; Z. Zhang, Adamo et al., 2022). The current study confirms these null results, also finding no significant positive or negative relationship between working memory function and active screen time for pre-school-aged children and disconfirms the results of studies finding negative or positive correlations. But this study also extends findings of other studies because of its examination of Montessori preschool exposure alongside active screen time. Squire (2011) made a connection between Montessori education and effective video games for learning. Although Squire did not reference cognitive load theory (Sweller et al., 2011, 2019), Montessori practices (1909/1964) that produced successful learning due to support of working memory also produced successful learning when applied to screen media (Mayer, 2017; Squire, 2011). A certified former Montessori teacher, Squire (2011) drew parallels between the kind of participatory, focused learning in Montessori education and what he termed *high quality video games*.

The null results of the current study may indicate a need for more intense focus on the kinds of cognitive load on the working memory produced by children's screen media applications. Research results have been inconclusive or mixed about how active participation with screen media affects young children's cognitive load and working memory function. Ultimately, learning outcomes are the key to determining if cognitive load is ideal. A disconnect between optimistic projections for active screen media's potential as a learning tool and actual effects of active screen media on working memory function highlight a need to turn to the descriptions of research-backed cognitive load effects in the cognitive load theory for guidance (Sweller et al., 2011, 2019). Evidence has indicated that the interactivity in active screen media applications can easily increase element interactivity and cause overwhelming intrinsic or extraneous cognitive load on student's working memory (Parong & Mayer, 2018). So even if a student feels strongly motivated to use an active educational screen media application, such as a video game, they will only learn from the application if app-created cognitive load is not too high.

Carson et al. (2017) called for more empirical evidence to support or deny a difference between passive and active screen media in their effects on development of cognitive functions including working memory. As Troseth et al. (2016) pointed out, research needs to spark principles for media use that guide people who teach and care for young children in choosing the type of media use that will support children's learning.

Limitations of the Study

The study had several limitations. Use of a convenience sample of volunteers rather than random selection of participants meant that results of the study could only reveal associations between variables, not causation. The absence of random selection meant that factors other than type of preschool enrollment and time spent using screen media at home could have caused variations in working memory function, which could also have weakened internal validity. BRIEF-P test reviews confirmed its reliability and content validity, but no measure is perfect (Sherman & Brooks, 2010). Through the Screen Time Questionnaire, I gathered information that showed a snapshot of each child's parent-controlled passive, active, and total screen time by collecting tallies on that use from parents. I relied on the vigilance of parent observation of their own child's screen time and also on parent memory. Children may have had screen time outside a parent's presence while in the care of other family and non-family members without the parent's knowledge. Without each participating parent's direct observation and timed and immediate recording of their child's use of screen media, the construct validity of the study could have been weakened.

The pool of participants for both schools were magnet school parents and children. The parents all had to fill out applications for the magnet school lottery drawing and send their child to a school outside their neighborhood school boundaries. The parents of children in both programs showed high commitment to their children’s education by going the extra mile to enroll them in special magnet school programs. These parents’ commitment to endure inconvenience for higher educational opportunities for their children may have influenced the outcome of this study because reports of children’s screen time from both schools were low. Perhaps parents of magnet students were also vigilantly limiting the amount of screen time their children were exposed to. This parent vigilance may affect the external validity of the study since the population of young children and parents may not be representative of the general population.

Also, the study was conducted during an ongoing COVID-19 pandemic. Restrictions in some ways disrupted the character of the education provided in the city where this study was conducted. School gatherings were permitted for preschool and elementary age children during both the 2020-2021 and 2021-2022 school years, despite the COVID-19 pandemic. Pre-school-aged children attended the participating preschool programs in-person, six hours a day, five days a week. However, time spent in preschool programs was altered by social distancing, with children required to remain six feet apart for four months and interact only within cohorts of four or five children for the remaining eight months of school attendance in 2020-2021 and during all of the 2021-2022 school year. Importantly, faces of all children and adults were covered by masks when indoors that only allowed eyes to be exposed during both school years. Clearly, these restrictions altered typical practices of all early childhood programs when compared to practices during other two-year periods. Dramatic play, socialization skills, and communication that involved reading facial expression and body language during verbal interaction were typical practices in preschool programs that were of necessity modified in programs that remained open during the COVID-19 pandemic. These COVID-19 restrictions were mandated by state laws and school-district-wide policies that were the same for both participating early childhood programs.

Finally, my biases could potentially have influenced study outcomes. First, I was employed part-time in the study-partnering, non-Montessori preschool program, although no parents who took part in the study had children enrolled in my classroom. Second, I have a master's degree in Montessori education and am a certified Montessori early childhood teacher.

Recommendations

Recommendations for further research are based on study results and limitations of the study. The first recommendation is related to the finding that there was no statistically significant link between Montessori preschool exposure and working memory function. More research needs to be done about how specific classic Montessori preschool activities align with cognitive load effects. That kind of research could provide a better understanding of the intrinsic, extraneous, or germane cognitive load inherent in each classic Montessori activity and lead to a determination of the effects of the activities on working memory function. Furthermore, researchers might find more clarity about the effects of Montessori pedagogy on working memory by exploring links between

Montessori preschool exposure and working memory with in-person measures of working memory. In-person measures that assess a child directly could be used in combination with questionnaires about children filled out by parents and teachers for richer data. Some examples of in-person measures of working memory include the Head Toes Knees Shoulders Revised (McClelland et al., 2021); spectral analysis of heart rate; eye tracking to measure pupil dilation and microaccade movements during fixed eye gaze (Duchowski et al., 2018; Fridman et al., 2018; Kaluarachchi et al., 2021; Krejtz et al., 2018; Krzysztof et al., 2018; Szulewski et al., 2019); functional magnetic resonance imaging to measure cerebral blood flow indicating neural activity; and electroencephalography to capture alpha, beta, and theta brain wave rhythms (Antonenko & Keil, 2018; Vanneste et al., 2021). Another direct measure is analysis of speech complexity during learning, which undergoes a reduction in lexical density with an increase in cognitive load (F. Chen et al., 2016).

The second series of recommendations is related to the study finding that there was no statistically significant link between passive, active, or total screen time and working memory function. For this study, I measured screen time strictly in minutes spent in passive and/or active engagement with screen media. I scrutinized the number of minutes along with children's working memory T-scores using regression analysis to discover any links between screen time and working memory function. A measure that provides more thorough data on screen engagement, such as the ScreenQ, could reveal relationships between working memory and other characteristics besides frequency of use and level of interactivity (Hutton, Huang et al., 2020; Toh et al., 2021; Yang et al., 2017).

ScreenQ measures (a) access to screens, (b) content viewed, (c) co-viewing, (d) checking frequency, and (e) problematic use (Hutton, Huang et al., 2020). Also, if researchers conduct studies on different populations of young children, a more representative sample of the general population could reveal how larger variations in screen time between children affect the findings about the effect of screen time on children's working memories. Finally, researcher assessment of working memory through direct contact with children could strengthen the validity of future studies (Antonenko & Keil, 2018; F. Chen et al., 2016; Krejtz et al., 2018; McClelland et al., 2021; Vanneste et al., 2021).

The last recommendation is related to the limitations of this study. This study was done with pre-school-aged children in Montessori and non-Montessori public magnet schools in a medium-sized midwestern city in the U.S. Therefore, researchers could replicate this study in other types of early childhood programs located in larger or smaller cities to determine if results are similar. In addition, researchers could design another study with random selection rather than a volunteer convenience sample. Finally, a researcher conducting this study when children are not masked during COVID-19 could also see a potential change in study results.

Implications

This study will contribute to positive social change in several ways. First, individual 3-to-6-year-old children will benefit from the focus of the study, both its intent and results. The intent of the study was to explore links between Montessori preschool exposure, passive or active screen time, and working memory function with a goal to gain insight into the impact on working memory of cognitive load produced by (a) different preschool programs and (b) levels of engagement with screen media. Working memory is an executive function essential to purposeful learning so optimizing its function benefits young children at a time of life when they are rapidly learning. Results showed no significant effect on working memory of screen time, at least not at the amounts of average screen time per day reported of (a) 2.38 total, 1.64 passive, and .68 active screen time hours for the non-Montessori, and 1.81 total, 1.4 passive, and .40 active screen time hours for the Montessori early learners. These findings reveal levels of screen time that have potentially benign effects on pre-school-aged children's working memory function. Also, the results of this study showed that when participants were drawn from the same pool of public-school students whose parents participated in a magnet school lottery, no significant difference in working memory function emerged between children who were exposed to either Montessori or non-Montessori preschool. This finding suggests congruent cognitive load and working memory support from both nationally accredited, public early childhood magnet schools that participated in the study. Perhaps the developmentally appropriate practices targeted by both participating early childhood programs that were striving to comply with the high standards of national accreditation support young learners' working memory function.

Potential for positive change exists at the organizational level. As teachers of young children and early childhood policy makers and administrators make decisions about curricula for the young children within their stewardship, this study can help them to incorporate guidelines and practices that support ideal cognitive load and working memory function. Specifically, levels of passive, active, and total screen time at the levels reported in this study had no link to children’s working memory. These findings give leeway to early childhood educators to incorporate screen media technology into their curricula. Also, findings from this study indicate that high quality non-Montessori and Montessori preschool programs have similar non-statistically significant effects on young children’s working memory function. These findings also give policy makers, administrators, and teachers freedom to try creative ideas within the published guidelines for high quality programs of their accreditation agencies without fear of reducing working memory capacity in children, particularly if they incorporate educational practices that line up with cognitive load effect research (Sweller et al., 2011, 2019).

The findings of this study may also advance knowledge in the field of Learning, Instruction, and Innovation because they are supportive of incorporating screen media technology, including passive, active, and total screen time, into early childhood learning environments. Findings show no statistically significant effect of screen time on working memory function of pre-school-aged children. Study findings are supportive of the virtually wide-open potential of screen media technology to be adapted for education, including early childhood education. Although some previous studies have shown screen time had negative effects on young children’s working memory function, this study showed no significant correlation between screen time and working memory.

Another contribution that this study makes to positive social change is in relation to improved professional practice of instructional strategies created to incorporate cognitive load effects (Sweller et al., 2011, 2019). Cognitive load effects influence learning outcomes because of the levels of extraneous, intrinsic, and germane cognitive load they impose on a child's working memory (Sweller et al., 2011, 2019). Any instructional strategy, whether carried out in the context of a screen media application or early childhood program, either supports or hinders working memory function. Overloading the working memory with extraneous information that is not intrinsic or germane to the learning objective decreases meaningful learning. Montessori pedagogy incorporates instructional strategies that reduce extraneous cognitive load and thereby support working memory function according to the previous research cited. The current study found no significant relationship between working memory function and Montessori preschool exposure versus exposure to another preschool program. These results could indicate that instructional strategies used in the non-Montessori program also reduced extraneous cognitive load. Study results mirror most research on effective to working memory of passive and active screen time – no effect.

Conclusion

Unless creators of screen media applications take cognitive load into account, the apps run the risk of having too much element interactivity overloading the working memory to be useful as learning tools. Pedagogy for preschool programs created by educators who consider cognitive load effects supports working memory and helps children learn. The findings of this study support potential for early childhood programs to use instructional strategies, including use of carefully selected screen media applications, that take into account the cognitive load effects delineated in the cognitive load theory and support working memory in young children. Creating learning opportunities for young children that support working memory function will improve intentional learning for the children. Each incidence of successful learning for a precious young child is a positive social change.

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Appendix A: Permission to Use the Behavior Rating Inventory of Executive Function-Preschool Version

PAR PERMISSION BRIEF-P

DV

Deja Vanterpool <dvanterpool@parinc.com>

To: Paula Mamani <email address redacted>

Mon 7/12/2021 10:14 AM

The BRIEF-P is permissible by PAR to use in research studies as long as the individual has a degree from an accredited 4-year college or university in psychology, counseling, speech-language pathology, or a closely related field plus satisfactory completion of coursework in test interpretation, psychometrics and measurement theory, educational statistics, or a closely related area; or license or certification from an agency that requires appropriate training and experience in the ethical and competent use of psychological tests. No special permission is necessary for the use of this product.

Best regards,

Deja Vanterpool,
Customer Support Specialist
t 800.331.8378 | **w** parinc.com

Appendix B: Three Sample Questions from the Behavior Rating Inventory of Executive Function-Preschool Version (English Language)

N = Never S = Sometimes O = Often

2. When given two things to do, remembers only the first or last N S O

32. Needs help from an adult to stay on task N S O

59. Has trouble remembering something, even after a brief period of time N S O

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Appendix C: Three Sample Questions from the Behavior Rating Inventory of Executive Function-Preschool Version (Spanish Language)

N = Nunca A = A veces F = Frecuentemente

2. Cuando se le da dos cosas que hacer, recuerda únicamente la primera o la última	N	A	F
32. Necesita la ayuda de una persona adulta para poder continuar realizando una tarea	N	A	F
59. Tiene dificultades para recorder las cosas, aún después de haber transcurrido muy poco tiempo	N	A	F

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Appendix D: Screen Time Questionnaire (English Language)

Screen Time Questionnaire

1. Your child's school____.
2. How old is your child? _______________ years __________________ months.

   Or your child's birthday____.
3. Child's gender____.
4. Today's Date____.
5. How many Days has your child been Absent THIS School Year?_____________.
6. Did your child attend this school Last School Year? ______________________.

   If so, how many days were they Absent From School LAST School Year?_____.

Screen Time Daily Count

Monday: Total Screen Time_____ Passive Screen Time_____ Active Screen Time______

5am – 8am: Total Screen Time_______, How much Passive? _____ How much Active? _______

8am - 11am: Total Screen Time_______, How much Passive? _____ How much Active? _______

11am – 2pm: Total Screen Time_______, How much Passive? _____ How much Active? _______

2pm – 5pm: Total Screen Time_______, How much Passive? _____ How much Active? _______

5pm – 8pm: Total Screen Time_______, How much Passive? _____ How much Active? _______

8pm – 11pm: Total Screen Time_______, How much Passive? _____ How much Active? _______

11pm – 5am: Total Screen Time_______, How much Passive? _____ How much Active? _______

Tuesday: Total Screen Time____ Passive Screen Time______ Active Screen Time______

5am – 8am: Total Screen Time_______, How much Passive? _____ How much Active? _______

8am - 11am: Total Screen Time_______, How much Passive? _____ How much Active? _______

11am – 2pm: Total Screen Time_______, How much Passive? _____ How much Active? _______

2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________
5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________
8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________
11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________
Wednesday: Total Screen Time____ Passive Screen Time______ Active Screen Time______
5am – 8am: Total Screen Time________, How much Passive? ______ How much Active? ________
8am - 11am: Total Screen Time________, How much Passive? ______ How much Active? ________
11am – 2pm: Total Screen Time________, How much Passive? ______ How much Active? ________
2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________
5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________
8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________
11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________

Thursday: Total Screen Time____ Passive Screen Time______ Active Screen Time______
5am – 8am: Total Screen Time________, How much Passive? ______ How much Active? ________
8am - 11am: Total Screen Time________, How much Passive? ______ How much Active? ________
11am – 2pm: Total Screen Time________, How much Passive? ______ How much Active? ________
2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________
5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________
8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________
11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________

Friday : Total Screen Time____ Passive Screen Time______ Active Screen Time______
5am – 8am: Total Screen Time________, How much Passive? ______ How much Active? ________
8am - 11am: Total Screen Time________, How much Passive? ______ How much Active? ________
11am – 2pm: Total Screen Time________, How much Passive? ______ How much Active? ________
2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________
5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________
8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________
11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________

Saturday: Total Screen Time____ Passive Screen Time______ Active Screen Time______

5am – 8am: Total Screen Time________, How much Passive? ______ How much Active? ________

8am - 11am: Total Screen Time________, How much Passive? ______ How much Active? ________

11am – 2pm: Total Screen Time________, How much Passive? ______ How much Active? ________

2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________

5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________

8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________

11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________

Sunday: Total Screen Time____ Passive Screen Time______ Active Screen Time______

5am – 8am: Total Screen Time________, How much Passive? ______ How much Active? ________

8am - 11am: Total Screen Time________, How much Passive? ______ How much Active? ________

11am – 2pm: Total Screen Time________, How much Passive? ______ How much Active? ________

2pm – 5pm: Total Screen Time________, How much Passive? ______ How much Active? ________

5pm – 8pm: Total Screen Time________, How much Passive? ______ How much Active? ________

8pm – 11pm: Total Screen Time________, How much Passive? ______ How much Active? ________

11pm – 5am: Total Screen Time________, How much Passive? ______ How much Active? ________

Week Total: **Week Total Screen Time__________________**

Week Passive Screen Time_________________

Week Active Screen Time___________________

Summary Questions

Question A: How much TOTAL Screen Time for the week for your child?

A_1 7 or less hours

A_2 8-14 hours

A_3 15-28 hours

A_4 29-35 hours

A_5 36-49 hours

A_6 More than 49 hours

Answer__________________

Question B: How much PASSIVE Screen Time for the week for your child?

B_1 7 or less hours

B_2 8-14 hours

B_3 15-28 hours

B_4 29-35 hours

B_5 36-49 hours

B_6 More than 49 hours

Answer__________________

Question C: How much ACTIVE Screen Time for the week for your child?

C_1 7 or less hours

C_2 8-14 hours

C_3 15-28 hours

C_4 29-35 hours

C_5 36-49 hours

C_6 More than 49 hours

Answer__________________

Appendix E: Screen Time Questionnaire (Spanish Language)

Cuestionario sobre el tiempo en pantalla

1. La escuela de su hijo ____.

2. ¿Qué edad tiene su hijo?________años_________meses.

   o el cumpleaños de su hijo____.

3. Género del niño______________.

4. Fecha de hoy____.

5. ¿Cuántos días ha estado ausente su hijo ESTE año escolar?______________.

6. ¿Su hijo asistió a esta escuela el año pasado?________________________.

   En caso afirmativo, ¿cuántos días se ausentaron de la escuela el ÚLTIMO año escolar? ____.

Recuento diario de tiempo en pantalla

Lunes: Tiempo total en pantalla________Tiempo pasivo en pantalla________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Martes: Tiempo total en pantalla_______Tiempo pasivo en pantalla______Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Miércoles: Tiempo total en pantalla________Tiempo pasivo en pantalla_________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Jueves: Tiempo total en pantalla________Tiempo pasivo en pantalla_________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Viernes: Tiempo total en pantalla__________Tiempo pasivo en pantalla__________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Sábado: Tiempo total en pantalla__________Tiempo pasivo en pantalla__________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Domingo: Tiempo total en pantalla_______Tiempo pasivo en pantalla________Tiempo activo en pantalla___________

5am – 8am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8am - 11am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11am – 2pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

2pm – 5pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

5pm – 8pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

8pm – 11pm: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

11pm – 5am: Tiempo total en pantalla________, ¿Cuánto pasivo?_______¿Cuánto de Activo?___________

Total Semanal:

Tiempo Total Semanal en pantalla______________________

Tiempo Pasivo Total Semanal en pantalla________________

Tiempo Activo Total Semanal en pantalla_________________

Preguntas de Resumen

Pregunta A: ¿Cuánto tiempo TOTAL en pantalla pasa su hijo a la semana?A_1
7 horas o menos
A_2 8-14 horas
A_3 15-28 horas
A_4 29-35 horas
A_5 36-49 horas
A_6 Más de 49 horas
Respuesta_______________________

Pregunta B: ¿Cuánto tiempo PASIVO en pantalla pasa su hijo a la semana?B_1
7 horas o menos
B_2 8-14 horas
B_3 15-28 horas
B_4 29-35 horas
B_5 36-49 horas
B_6 Más de 49 horas
Respuesta_______________________

Pregunta C: ¿Cuánto tiempo ACTIVO en pantalla pasa su hijo a la semana?
C_1 7 horas o menos
C_2 8-14 horas
C_3 15-28 horas
C_4 29-35 horas
C_5 36-49 horas
C_6 Más de 49 horas
Respuesta_______________________

Appendix F: Permission to Conduct Study in Public School District Partner Site

Xxxxxxx,Xxx

To: Mamani,Paula Thu 3/4/2021 7:06 PM

Cc: Xxxxxxx,Xxxxxx; Xxxxx,Xxxxxxx; Xxx,Xxxx; Xxxxxxxx,Xxxxxxx; Xxxx,Xxxxxx; XxXxxxxx,Xxxxx

Paula,

You have been approved to conduct your parent survey, however we ask that you wait until after Spring Break on April 12 to distribute your survey to the parents at Xxxxxxx Xxxxx and Xxxxxx. The district is currently conducting a parent survey, and we want to ensure that parents complete this survey before another one is given. Separating the two distributions would lead to better results for you and the district. Your assessment manual will be in our office if you wish to pick it up, or we can send it to you by school mail. Let our office staff, Xxxxxx Xxxxx or Xxxxx XxXxxxx know which you would prefer. Best wishes in your dissertation, and I look forward to hearing about your results.

Sincerely,
Xxx

Xxx X. Xxxxxxx
Chief of Elementary School Leadership
Xxxx Xxxxx Xxxxxxxxx Xxxxxxx
XXXX X. Xxxxxxx Xxxxxx
Xxxx Xxxxx, XX XXXXX-XXXX
Phone: (XXX) XXX-XXXX
FAX: (XXX) XXX-XXXX
Email: xxx.xxxxxxx@xxxx.k12.xx.us