Cognitive Development 62 (2022) 101180

Contents lists available at ScienceDirect

Cognitive Development

journal homepage: www.elsevier.com/locate/cogdev

Digital media inhibit self-regulatory private speech use in preschool children: The "digital bubble effect"☆

Vincenzo Bochicchio [a,*], Kayla Keith [b], Ignacio Montero [c], Cristiano Scandurra [d], Adam Winsler [b]

[a] *Department of Humanities, University of Calabria, Via Pietro Bucci Cubo 18/C, Arcavacata di Rende, CS, Italy*
[b] *College of Humanities and Social Sciences, George Mason University, Fairfax, USA*
[c] *Faculty of Psychology, Universidad Autónoma de Madrid, Madrid, Spain*
[d] *Department of Neuroscience, Reproductive Sciences, and Dentistry, University of Naples, Federico II, Napoli, Italy*

ARTICLE INFO

Keywords:
Private speech
Self-talk
Digital media
Self-regulation
Preschool children

ABSTRACT

Preschoolers spend much time with digital media and some are concerned about impacts on language development. Private speech (PS) is self-talk children use during play, representing a necessary form of self-regulation. This study examined whether modality (material vs. digital) matters for children's PS. Twenty-nine White 5-yr-olds (52% female) completed the Tower of London task twice - once as a material version and once on a tablet. Children used more PS on the material than digital version of the task (d=0.46). During the material task, the typical pattern of increased PS as difficulty increased appeared. However, during the digital task, PS declined as difficulty increased. Digital games may inhibit children's use of PS for self-regulation, having implications for executive function development.

1. Introduction

The way children play has radically changed in the last decades. Recent reports show that in Western countries, children spend most of their playing time in digital activities, using tablets, IPads, smart phones, computers, and other digital devices, and that engagement in digital activities has increased dramatically recently, especially during early childhood. A recent report (Smahel et al., 2020) showed that in the European Union, 80% of children aged 9–16 use daily a smartphone, and 43% a computer. Playing digital games is one of the most widespread activities for children: two in three children report playing digital games at least once a week, and 44% daily, with sensible differences in terms of gender and age, with boys more engaged in digital games than girls (30% points more), and older children being more involved in digital activities (Smahel et al., 2020). The situation is very similar on all continents (Burns & Gottschalk, 2019), and children and adolescents have only increased time spent using digital technology during the COVID-19 pandemic (Montag & Elhai, 2020), a notable concern for the World Health Organization (WHO, 2020). Also, younger children are starting to be more involved in digital activities. A recent report (Rideout & Robb, 2020) showed that daily use of screen media among

☆ The data that support the findings of this study are available from the corresponding author upon reasonable request. This research was approved by the University Ethical Committee of the University of Calabria. The authors received no specific funding for this work. The authors have no conflict of interest to report.

* Correspondence to: Department of Humanities, Università della Calabria, Via Ponte Bucci Cubo 18/C, 87036 Arcavacata di Rende, CS, Italy.
E-mail addresses: vincenzo.bochicchio@unical.it (V. Bochicchio), kkeith3@gmu.edu (K. Keith), nacho.montero@uam.es (I. Montero), cristiano.scandurra@unina.it (C. Scandurra), awinsler@gmu.edu (A. Winsler).

https://doi.org/10.1016/j.cogdev.2022.101180
Received 8 July 2021; Received in revised form 6 January 2022; Accepted 12 April 2022
Available online 27 April 2022
0885-2014/

US children aged 0–8 ranges from 49 min among those younger than 2, to two and a half hours among 2- to 4-year-olds, and more than three hours among 5- to 8-year-olds. In low-income urban communities, 75% of parents report that their 4-year-old child owns their own device, and over 90% of parents of children under 1 year of age report that their infants use/play with the parent's device daily (Kabali et al., 2015).

Given such dramatic shifts in the sensory, cognitive, and social experiences of children, it is no surprise that researchers have become interested in potential implications of digital play on child development (Stephen & Plowman, 2014). A growing amount of research over the last twenty years has been exploring the effects of digital devices on child development, focusing on such things as the development of digital educational settings (Bird & Edwards, 2015; Edwards & Bird, 2017), the dynamics of social interaction during digital play (Arnott, 2016; Danby, Evaldsson, Melander, & Aarsand, 2018), effects on child aggressive behavior (Anderson & Bushman, 2001; Groves & Anderson, 2015), links with clinical outcomes (Woo, White, & Lai, 2016), and positive and negative consequences for children's cognitive and emotional self-regulation. Most of the research, however, has focused on older children and adolescents, with less attention to digital play during early childhood.

During early childhood, play has long held special significance as being critical and playing a formative role in the development of foundational cognitive and social skills. Indeed, engagement with material objects and peers in physical games is thought to be necessary for normal cognitive and social development to occur (Pellegrini & Smith, 1998). Digital play with apps on digital devices, however, has been gradually replacing and substituting for traditional "hand-on" play, characterized by the manipulation of material toys. Traditional categorizations, theories, and taxonomies for play in childhood had to be updated recently (Marsh, Plowman, Yamada-Rice, Bishop, & Scott, 2016) to conceptualize digital play, and a growing amount of research has been exploring how the "digital playground" (Daiute & Lee, 2019) affects emotional and cognitive development, self-regulatory processes, learning, and wellbeing of young children.

One important developmental outcome for the preschool years is the emergence of behavioral self-regulation and executive functioning (EF), and the private speech or self-talk that preschoolers use for self-regulatory purposes during play and problem solving is thought to be important for EF development (Winsler, 2009). The current study examines the same preschool children's use of private speech during an identical EF task completed twice, once with traditional physical materials and once on a tablet. Below, we review relevant literature on digital media and child development, executive functioning, and private speech.

2. Developmental outcomes of digital media in children and adolescents

Physical and mental health outcomes deriving from prolonged exposure to digital devices in children and adolescents represent a recurrent concern for pediatricians, clinical psychologists, and parents, and a great amount of research has been conducted in this field (Mathers et al., 2009; Woo et al., 2016). We are far from general agreement on the effects of digital play and gaming on the physical and psychological health of children, adolescents, and youth, partly because so many different domains and outcomes have been studied, with diverse methods across many different age groups, and this makes it hard to compare results.

Studies have been conducted on older children's and adolescents' media use as being linked with poor quality of sleep (LeBourgeois et al., 2017: Staples, Hoyniak, McQuillan, Molfese, & Bates, 2021), increased depression and anxiety (Hoge, Bickham, & Cantor, 2017), heightened aggression and conduct problems (Ferguson, 2007; Groves & Anderson, 2015), externalizing behavior (McDaniel & Radesky, 2020), and obesity risk (Robinson et al., 2017). With the exception of obesity risk where direct causal effects are clearer, uncontested causal relations between exposure to digital games and clinical outcomes are harder to find (Ferguson, 2015; Kim, 2012). For adolescents at the extreme who spend all their time gaming at the expense of all other activities, there is now the notion of Internet Gaming Disorder (IGD), which takes the form of a compulsion, an impulse control disorder, and/or a behavioral addiction (Wichstrøm, Stenseng, Belsky, von Soest, & Hygen, 2019).

The over-use of digital games and exposure to digital devices do not necessarily directly or linearly affect children's socio-cognitive development and health negatively, as many factors come into play. A systematic review (Mihara & Higuchi, 2017) showed that age, gender, time spent playing games, types of games, parental styles and familial difficulties, interpersonal relations, and school/social functions, and even temperament/personality of children and adolescents are all factors that intervene in the development of negative outcomes from digital media. There is some evidence, however, that there is a negative linear association between total screen time and children's physical health, socio-emotional outcomes, and school achievement, and that a negative association between the time spent playing digital games and psycho-physical health outcomes (Sanders, Parker, del Pozo-Cruz, Noetel, & Lonsdale, 2019). Clinical outcomes of exposure to digital devices, thus, depend on age, amount, and type of their use and other factors, and therefore digital play may not be harmful "per se." This makes it difficult to offer clear guidelines for parents regarding appropriate digital technology practices for children and adolescents (Bochicchio et al., 2019; Straker, Zabatiero, Danby, Thorpe, & Edwards, 2018).

More relevant for young children, some research has focused on the effects of exposure to digital activities on language development. Some works report that digital device use is associated with language delays in early childhood (van den Heuvel et al., 2019), and, in a review on the topic, Anderson and Pempek (2005) focus on the "video deficit effect," pointing out that children under 3 years of age do not learn and develop language skills from a screen as well as they do when they learn from a live person. The optimum conditions for learning language (and cognitive development, in general) is responsive, one-on-one interaction between a parent/caregiver and a child involving a physical object with the adult using high quality language with the child (Dore, Zosh, Hirsh-Pasek, & Golinkoff, 2017; Hirsh-Pasek et al., 2015). Studies show that parents use less diverse and lower-quality language and are less responsive with their young children when interacting/playing with a digital device compared to with physical objects and toys (Sosa, 2015; Wooldridge & Shapka, 2012; Zosh et al., 2015). The same is true for book reading – parents use less "meta" speech about the story and make fewer connections to children's lives when reading E-books compared to regular books, and as a result, 3-year-olds learn less during E-book reading (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013). Although language outcomes may differ depending on the content and interactivity involved in the application (Linebarger & Walker, 2005), exposure to digital media is generally negatively associated with the acquisition of linguistic competencies in early childhood, likely because the presence of digital tools tend to reduce quantity and quality of adult/child interactions (Dynia, Dore, Bates, & Justice, 2021; Ramírez, Hippe, & Shapiro, 2021). Given the social and contextual origins of private speech and the private speech internalization process from social interactions (Mulvihill, Carroll, Dux, & Matthews, 2020; Winsler, 2009), children might follow similar suboptimal language patterns when talking to themselves while playing with digital devices.

Indeed, mobile media devices are often called 'shut up toys,' things parents give to young children at times (understandably, no judgement intended) to keep them quiet, occupied, or to get them to calm down (Radesky, Schumacher, & Zuckerman, 2015). More than just the authors' anecdotal observations of parental behavior with digital devices and their children, systematic survey and naturalistic observational research studies confirm that parents frequently give children digital devices in settings that historically have been great opportunities for adult-child conversation, at mealtimes, in restaurants, in the car, when travelling or waiting for something. These lost opportunities for being exposed to rich language use delay language development (Chiong & Shuler, 2010; Dore et al., 2017; Radesky et al., 2014). Radesky et al. (2014), for example, found that 70% of parents used digital devices themselves or gave them to children while eating at restaurants, and often the parents themselves were almost fully absorbed with a device. Just the simple presence of technology (TV being on, a phone or tablet present) has long been associated with restricted or lower quality language use and poorer language learning in young children (Dore et al., 2017; Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009; Reed, Hirsh-Pasek, & Golinkoff, 2017). If parents repeatedly implicitly or explicitly expect children to be quiet when given digital toys, and children (and parents) are rewarded for doing so, it is logical to expect that children will get accustomed to being quiet/silent while interacting within their own digital media "bubble." From a Vygotskian theoretical perspective, which sees children's overt language use in the form of private speech during play activities in early childhood as important for self-regulatory development (discussed below), an important question to answer is whether increased time spent playing with digital devices, paired with less language use by children has any implications for self-regulatory development. Indeed, Radesky et al. (2015) called explicitly for more research to be conducted on the effects of digital devices on young children's self-regulation.

Little is known about influences of digital games on early childhood cognitive, behavioral, and socioemotional development (Blumberg et al., 2019). Playful activities in early childhood represent a crucial agent for cognitive, emotional, and cultural development (Ginsburg, 2007), and for millennia, this developmental agent has been characterized by both a multisensorial/multidimensional engagement in a material world and physical relationships with peers and adults (Riede, Johannsen, Högberg, Nowell, & Lombard, 2018). "Traditional play" in early childhood—i.e., physical and multisensorial/multidimensional engagement with "hands-on" toys, animals, and other human beings "in the presence"—has been considered a crucial work horse for the development of EFs, emotional and cognitive regulation, creativity, communication, and socio-cultural competencies (Vygotsky, 1967).

3. Executive functions, private speech, and digital play in childhood

EF is an umbrella concept gathering a set of cognitive processes and functions that allow us to self-regulate—i.e., to control, organize, and coordinate—our thoughts, emotional responses, and actions (Diamond, 2013). EFs refer to a set of cognitive abilities that support crucial mechanisms in an individual's self-regulation of goal pursuit (Hofmann, Schmeichel, & Baddeley, 2012). Anderson (2002) proposed a model that conceptualized EFs as "multiple process-related systems, that are inter-related, inter-dependent and function together as an integrated supervisory or control system" (pp. 72–73). A system of self-regulation is characterized by four distinct domains: (a) attentional control, (b) information processing, (c) cognitive flexibility, and (d) goal setting (Anderson, 2002). Zelazo, Qu, and Müller (2005) proposed a distinction between "hot" and "cool" self-regulatory process, highlighting that "cool" self-regulatory processes are elicited in abstract cognitive tasks, whereas "hot" self-regulatory processes are elicited when the tasks involved emotional and motivational aspects. Notwithstanding, the same authors stated that this dichotomy between "cool" and "hot" regulatory processes should not be overemphasized because cognitive and emotional aspects of experience always interact in the process of self-regulation of thought and behavior (Zelazo, Qu, & Kesek, 2010), and similar processes of self-regulation are elicited in both "cool" and "hot" conditions.

Most research to date on the effects of digital play on EF has been with older children and adolescents, a group for whom some initial essential building blocks of EF have already been formed in early-middle childhood (Davidson, Amso, Anderson, & Diamond, 2006). Although some research has focused on potential negative effects of video games on behavior problems, impulse control, and aggression ("hot" EF) (Anderson & Bushman, 2001), a small literature examining specific digital games is emerging showing positive effects on specific cognitive components of "cool" EF among older children (Boyle, Terras, Ramsay, & Boyle, 2014; Rachanioti, Bratitsis, & Alevriadou, 2018).

First of all, as with any medium including TV and educational games, it is clear that children do learn content from applications and computer programs and games (Hirsh-Pasek et al., 2015). In this regard, a recent literature review (Gao et al., 2020) showed that serious games—i.e., digital games specifically designed for educational and learning goals—could be a tool for promoting skills and learning activities in STEM (Science, Technology, Engineering and Mathematics) disciplines. In terms of effects on cognitive processes and development (as opposed to simple content learning), some research demonstrates that digital games in childhood can in some cases consolidate and enhance EFs and self-regulatory processes (Axelsson, Andersson, & Gulz, 2016; Boyle et al., 2014). Specific digital games have been designed for improving EFs, like *Gwakkamole*, that can enhance the EF subskill of inhibition in adolescents, improving speed and accuracy of goal-oriented activities (Homer, Ober et al. 2019), or *All You Can E.T.*, that can improve adolescents' (aged 12–16) EF skills in "hot" conditions (Homer, Plass, et al., 2019), or *Alien*, that can improve the EF-sub-skill of shifting in adolescents (aged 12–16). For instance, Homer, Plass, et al. (2019), using the Dimensional change card sorting task to the measure EF skills of participants at pre- and post-test, showed that the frequency with which new rules—i.e., the rules for feeding the aliens and thus avoiding "game over"—were presented during the game was associated with improvements on the teens' EF subcomponent of set shifting.

However, a general consensus on the capacity of digital play to enhance or harm child EF and cognitive and emotional self-regulation has not yet been achieved, with some reviews (Cudo & Jaśkiewicz, 2015; Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013) highlighting how difficult it is to interpret and compare results given the great diversity present in methodologies, research paradigms, and procedures. Also, little work has been conducted with younger, preschool samples when EF and self-regulatory skills are initially emerging.

According to Vygotskian theory, an important tool that preschoolers use to develop their executive functioning skills and gain regulatory control over their behavior is private speech (PS)—namely, the overt and partially internalized self-talk that children use while engaging in challenging problem solving and play activities (Vygotsky, 1962; Winsler, 2009). PS is not only useful during calm 'cool' cognitive activities but has been studied as crucial for emotional self-regulation in 'hot' frustrating and emotionally charged situations (Barkley, 1997; Day & Smith, 2013; Thibodeaux and Winsler, 2018; Winsler, 2009). The presence of overt/loud PS has a particular inverted U shape developmental trajectory in childhood, originally described by Piaget and Vygotsky (Piaget, 1923; Vygotsky, 1962), who postulated that PS increases progressively during infancy, reaching a peak during preschool years (age 4–6), and then progressively decreases during primary school. For the purposes of this study, it is important to highlight at least three main features of PS: 1) its social origin, 2) its link with EFs, and 3) its task-dependency.

With regard to the first point (i.e., origin), contrary to Piaget (1923), who affirmed the individualistic and egocentric nature of PS, Vygotsky and neo-Vygotskian scholars (Vygotsky, 1962; Winsler, 2009) have strongly claimed the social origin and nature of PS. Verbal interactions between adults and young children, whose function consists mainly to direct and regulate children's behavior, cognition, and emotions, gradually become internalized and children begin to "regulate" themselves—their thinking, behavior, and emotions—with PS, i.e., talking out loud to themselves. Thus, PS represents the progressive internalization of the early verbal interactions of the child, therefore maintaining its dialogic nature even if it does not express a direct communicative intention (Fernyhough, 2009). The social and dialogical nature of PS was established by (Vygotsky, 1962) who assessed the production of children's PS during play under different social conditions. He found that when children played in experimental conditions of perceived "communicative isolation" (when there wasn't someone around with whom the child could communicate), the production of PS dramatically decreased.These findings are particularly relevant for the hypotheses of this study (see below) – that children will produce less PS during digital play, perhaps because they are immersed in a condition of perceived artificial communicative isolation, a sort of "digital bubble."

Regarding the second point (i.e., link with EFs), as a form of internalization of early verbal "other-regulation," PS performs a crucial role in EF because it creates psychological distance between the self and objects, situations, events, and tasks in which the child is involved (Müller, Jacques, Brocki, & Zelazo, 2009). In this way, PS helps children in becoming progressively more aware of their own behavior, goal-oriented activity, and even emotions, enabling them to exercise gradually an executive control on their activity, thoughts, and feelings.

Finally, as regards the third point (i.e., task-dependency), a great amount of experimental research finds a strong positive association between task difficulty and production of PS (Berk, 2014; Montero & de Dios, 2006), i.e., the more task difficulty increases (within reason) the more PS used by the child. When task difficulty increases, the child resorts to PS to overcome obstacles and critical moments, and organize alternative problem-solving strategies. When all is well and the child becomes competent with a task that is not presenting difficulty, overt PS tends to decrease. Several studies (Berk & Spuhl, 1995; Duncan & Pratt, 1997) show that when children successfully complete the same task multiple times, overt PS decreases while covert PS and silence increase.

It is critical to note that, starting from the seminal works of Piaget (Piaget & Claparède, 1923) and Vygotsky (1962) almost a hundred years ago, all the research observations, experimental paradigms, and theory on PS have involved children interacting with physical, material, and "hand-on" toys, tasks, and objects. Very few studies have investigated the production of children's PS in the "digital playground" (i.e., during digital games and/or other activities with digital devices). One observational study, Crescenzi-Lanna (2020) found that preschool children experience a variety of emotions during games with digital apps—such as enjoyment, enthusiasm, surprise, and frustration—and that engagement in digital gaming is accompanied by production of both social speech (SS) and PS, but the authors did not compare rates of PS produced in the traditional playground with that produced in the digital playground.

Although a formal comparison between children's use of PS with both digital and materials objects has not been conducted to date, some private speech researchers have happened to use a variety of different tasks and modalities in their task batteries, with some tasks happening to be administered on a digital device or computer and others physically to the same children (Mulvihill, Matthews, Dux, & Carroll, 2021; Winsler, Abar, Feder, Rubio, & Schunn, 2007; Winsler, LaRocque, Keith, & Abar, 2021). Inspection across tables reported in these various works on the frequency of PS utterances of various types used by the children across tasks reveals that the number of self-talk utterances is higher in the material tasks. For example, there were 6–7 utterances per minute in the physical Duplo task but only 3–5 utterances per minute for the computerized card-sort task in Mulvihill et al. (2021), and 7–8 PS utterances per minute on the physical Tower of Hanoi yet only 1–2 per minute on 2 computerized EF tasks used in Winsler et al. (2007,2021). Importantly, although they are the same children engaging in multiple tasks in these studies, children were never given the same task to complete in both formats. The critical test needed, and what we do in the current study, is to give the same preschool children in a counter-balanced, repeated-measures format, the very same EF task (Tower of London - ToL) twice, once with physical materials and once on a tablet. In addition to examining the quantity and quality (different types of utterances) of PS used by the children in the two formats, we explore links with task difficulty since the task itself had three levels of difficulty.

4. The current study

The current study explored the production of PS in a sample of preschoolers during the same game/task administered twice—once with traditional, physical materials and once on a digital device. We assessed and compared also the production of social speech produced during the task/game in both versions. Given the literature reviewed above reporting that digital device use is associated with language delays in early childhood (van den Heuvel et al., 2019), and that high engagement in the “digital playground” may have negative effects on children’s language production (Dore et al., 2017), we hypothesized that a) children would use less PS (both overall and task-relevant, self-regulatory speech) during the digital game compared to the physical/material version; and b) the same pattern would not be observed in children’s social speech. We further expected, consistent with the prior research discussed above, to see the typical pattern of more PS (both overall and task-relevant) as task difficulty increases, at least in the physical version of the task. We did not have particular hypotheses on whether this pattern would be observed during the digital task.

5. Method

5.1. Participants

Twenty-nine White and native Italian-speaking 5-year-old children (age range: 59–67 months; *M*: 61.7; *SD*: 3.05), in their third year of the Italian kindergarten system (52% female), individually completed the exact same ToL task twice—once as a material version and once on a tablet. The inclusion criteria of participants were: (1) being 5-years old; (2) being a native Italian speaker (according to parent report); (3) not presenting with any relevant clinical disorder (i.e. Autism, Attention Deficit Hyperactivity Disorder, Cognitive impairments) according to teacher and parent report. All final participants satisfied all inclusion criteria. In terms of sample size, our original goal was to get 40 children total, a target determined by an initial power analysis (to get 80% power to detect a small-to-medium effect size), and prior norms in the PS research area.

Participation was voluntary and we obtained signed informed consent from parents. Considering socio-demographic background, families had medium-high socio-economic status and parents were generally highly educated. The kindergarten was located at a university and available exclusively to children of academic professionals (professors and staff), thus participants were children with rather educated parents. Children were very familiar with digital tools, as some activities in the kindergarten program the children attended were digital.

5.2. Procedures

Twenty-five children completed both versions (material and digital) of the Tower of London task (ToL; Shallice, 1982). This task has been used in previous PS and EF research with preschoolers (Fernyhough & Fradley, 2005). For the material task, two identical copies of the ToL apparatus were used, each consisting of three pegs of same lengths inserted into a wooden base, and a total of five colored wooden disks. One apparatus was manipulated by the experimenters, to present the target disc configuration to the child, and the other was manipulated by the child, to obtain the configuration presented in the first apparatus. The digital version of the ToL was retrieved from https://www.brainturk.com/tol, and the child was invited to play using a tablet. The tablet measured 10.17×6.42×0.30 in., and signaled the achievement of the target configuration with a short beep (there were no other extraneous sounds or distractions). The material and digital version presented the exact same task items in terms of number and configurations of the disks (the material version matched/followed the digital version’s item set).

Due to scheduling difficulties, child absences, and technological/recording errors, four children completed the material task but did not complete the digital version. Thus, for preliminary analyses on just the material task, we included all children, but those children are not included in repeated-measures analyses involving both versions of the task. Twelve children (48%) received the material version first and 13 (52%) experienced the digital version first, and about three weeks passed between administrations. Children were asked to play in a familiar, separate room at their preschool, where children often perform various school/play activities, and in both game sessions—digital and material—children were assisted by two experimenters (a male [first author] and a female [student assistant]). Instructions were given to the child by the experimenter and the student was responsible for setting up the target stimuli during the physical version.

The TOL had three levels of increasing difficulty (Level 1, with three discs; Level 2, with four discs; and Level 3, with five discs), and each level contained 5 trials. Level 1 was preceded first by a demonstration trial (Level D, with three discs), during which an experimenter completed a trial showing the child how to play, and then a testing trial (Level 0, with three discs), during which the child was asked to complete the trial with the assistance of the experimenters. The items were identical in both versions—digital and material—and appeared in the same order within the task. The child was seated individually at a small table with the video camera (and internal microphone) about 24 in. away in front of the child. The experimenters initially sat on each side of the child but then once the child was doing the task alone, they both increased their distance to about 30 in. behind the child. Play sessions were videotaped for later coding and transcribing, with a total of over 1400 min of video records. Each session took about 20 min in all, but the actual number of minutes transcribed and analyzed per participant (after removing initial rapport-building conversation and the introductory training item periods) on average was 13.34 min ($SD = 4.9$) for the digital and 11.25 min ($SD = 4.1$) for the physical game.

Performance on the task is calculated as the total number of legal moves it took for the child to complete the trials/items. For the material version of the task, the total number of legal moves used to complete Level 1 was 20.31 on average (divided by 5 items = 4.06 moves per trial). For Level 2, the mean was 35.55 moves to completion (divided by 5 items = 7.11 moves per trial), and for Level 3, it was 54.55 (divided by 5 items = 10.91 moves per trial). This indicates that indeed the levels did increase in difficulty for the children. Unfortunately, the computerized version of the task did not provide us with children's number of moves to completion, so performance could not be calculated for the digital task. The study was approved by the university ethics committee and complied with the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects.

5.3. Coding system

Children's speech was transcribed from videos by two independent researchers individually, and each utterance was coded as either private speech (PS) or social speech (SS), and by task relevancy and degree of internalization (full volume vs. muttering/whispering), following a predetermined coding system. The coding system used was based on that of Winsler, Fernyhough, McClaren, and Way (2005), with slight adaptations made to explore different types of social speech. The coding system is in Table 1. The two autonomous transcriptions were discussed and disagreements confronted, in order to obtain a third definitive set of codes for each utterance. In the case of discordance, a third researcher was asked to see the video and the related transcription/codes and indicate which utterance's codification was better suited.

Inter-rater reliability was calculated with Cohen's kappa on the videos of 6 children (20.7% of the total sample, 211 utterances), randomly chosen. Reliability/kappa for the categorization of the utterances as PS vs. SS was.965, and reliability for agreement on the categorization of PS utterances as either overt task relevant, vocalizations with unclear meaning, and covert inaudible muttering) was.833, indicating good agreement.

5.4. Analysis strategy

First, we conducted preliminary analyses to see if children's PS and SS use varied as a function of gender and order of task administration (digital -material vs. material-digital). There were no gender differences in the frequency of any of the PS or SS variables according to independent-sample T-tests, and so gender was ignored for the remainder of the analyses. Similarly, no differences were observed in the quantity of PS or SS during either version of the task depending on task order - whether they did they the digital or physical version first. Order of task was, thus, also ignored for the remainder of the analyses.

We then report the frequency of PS and SS during both versions of the task, both overall and by subtype of PS and by levels of task difficulty. We ran a variety of ANOVA models with either task version (digital, material), and/or task difficulty (Level 1, 2, 3), as repeated-measures, with either overall PS or SS, or subcategories of PS as the dependent measures. Paired T-tests and correlations were used to compare the relative frequency of PS and SS use within task type. As is common with PS research, the distributions for variables on frequency of utterances tend to be rather skewed given that some children never speak or say very little and other are more verbose. Thus, we confirmed the results reported below having to do with means with relevant nonparametric analyses based on medians.

Table 1
Speech Coding System.

Social Speech	
Definition: Utterances that are explicitly addressed to another person as indicated by glance, pronoun or name use, or touch	
Categories	*Examples*
1) Requests for aid	"And now?" "And then what? The red disk?"
2) Comments on the game or performance addressed to the experimenter	"This is very easy for me." "It's like the previous one."
3) Task-irrelevant social speech	"Do you know my dad has a very big office here at university?" "Can you play another game with me later?"
Private Speech	
Definition: Utterances that are not explicitly addressed to another person	
Categories	*Examples*
4) Overt task-relevant	"The red here, the green here, and the yellow here" "I put that here, and then… that!"
5) Overt task-irrelevant	"Choo-choo" "Ba, Ba."
6) Vocalizations/noises without a clear meaning (including exclamations)	"Ehm" "Oh!!!"
7) Partially overt inaudible muttering (Lip movements mimicking words but too quiet/silent to make out)	–

6. Results

6.1. Total private and social speech

Table 2 shows overall frequencies of children's use of PS and SS during both versions of the task. The mean number of utterances used overall is provided along with the percentage of children who used either PS (of any type) or SS during the material and digital version of the task. This is also broken down by difficulty level of the task items. As seen in the top rows of the Table 2, every child (100%) used at least some self-talk during both versions of the task, whereas only 41% and 38% of the children engaged in SS during the material and digital version of the Tower task, respectively. Thus, PS was much more common than SS for both versions of the task, both in terms of frequency, F (1,20) = 26.11, $p < .001$, $d = 1.12$, and in terms of the proportion who used each type of speech (McNemar X^2 (1) = 13.07, $p < .001$ for material; McNemar X^2 (1) = 8.10, $p < .01$ for digital). The interaction between task type (digital, material) vs. speech type (PP, SS) was significant for total number of utterances, F (1,20) = 8.81, $p < .01$, indicating that although PS was always more frequent than SS, PS was particularly frequent during the material version of the task. Finally, the correlation between PS and SS utterances was significant, $r = 0.56$; $p < .01$, indicating that children who used more PS also tended to be the ones who used more SS.

Relevant to our main question, as hypothesized, the children used significantly more overall PS during the material version of the task compared to the digital version (Table 2), F (1,20) = 8.65, $p < .01$, $d = 0.46$. Also seen in Table 2 is how PS frequency changed as a function of task difficulty. Importantly, there was a significant difficulty-by-task modality interaction, F (1,20) = 5.46, $p < .05$. More specifically, as would be expected by theory and as hypothesized, PS increased in frequency as the item levels got more difficult during the physical version of the tower task. However, the opposite pattern was seen for the digital version with linearly decreasing PS use as the task progressed. The interaction with task difficulty (and implicitly the main effect for task modality) is displayed visually in Fig. 1.

A different pattern was observed for SS. Use of SS was more prominent at the beginning of the task with items of Level-1 difficulty and linearly reduced as the children progressed through to the more difficult items for both versions of the task, main effect for difficulty, F (1,20) = 6.83, $p < .05$. Increased SS at the beginning of the task was particularly true for the digital version but the effect of task type and the interaction between task type and difficulty were not statistically significant. Anecdotally, much of the SS consisted of early requests for help in understanding how the task or the tablet worked.

6.2. Subtypes of private speech

Results reported above refer to overall PS and SS utterances. Here we examine the subtypes of PS. PS utterances were categorized undecipherable utterances/exclamations (PS0), task-irrelevant PS (PS1), task-relevant utterances (PS2), and partially internalized inaudible whispering and muttering (PS3). Because of the small sample and the distributions that follow from the rare events explored here, we also used nonparametric analyses (Wilcoxon signed-rank tests for paired samples) to confirm differences across task type. Table 3 shows the mean frequency for each of these types of PS by task modality and task difficulty. Means are reported rather than medians because the medians were often zero. Also shown in Table 3 is the proportion of the sample that exhibited at least one utterance for each subtype overall. Because task-irrelevant PS was so rare in all conditions (only 3 children emitted 1 such utterance each), it was not analyzed further.

Overall, 41% of the children used *undecipherable utterances/exclamations* (PS0) during the material task, slightly higher than the proportion who used such speech during the digital task (38%). In terms of number of utterances, this type of PS was more common in the material than in the digital task, $W = 6.00$, $p < .05$, $d = 0.42$. For both versions, indecipherable speech decreased in frequency as task difficulty increased, but this linear pattern was not statistically significant, nor was there an interaction between task difficulty and task modality.

For overt *private speech relevant to the task* (PS2), Table 2 shows that half of the children (48%) used such speech during the material session and 43% did so during the digital session. Although slightly more task-relevant PS was found during the material session, the difference was not significant, $W = 18.50$, $p = .19$. In terms of changes in frequency of PS2 as a function of task difficulty, the main effect for task difficulty (across both tasks combined) was not significant, however, the interaction between difficulty and modality was significant, F (1,20) = 5.32, $p < .05$. Overt-task relevant PS (PS2) showed the expected increase as difficulty level increased in the material task, but with the digital task, relevant speech declined in frequency with increasing item difficulty. This pattern is illustrated in Fig. 2.

Table 2
Means (*SDs*) and Percentages Used of Private and Social Speech by Task Type and Difficulty Level.

	Total Private Speech Utterances M (SD)	*Percent who used Private Speech*	*Total Social Speech Utterances M (SD)*	*Percent who used Social Speech*
Material game	20.76 (22.77)	100%	1.90 (4.50)	41.4%
Level 1	7.43 (7.93)	79%	1.19 (2.87)	28%
Level 2	8.29 (9.81)	86%	.52 (1.08)	24%
Level 3	9.90 (9.54)	90%	.71 (1.38)	24%
Digital game	12.38 (13.68)	100%	3.76 (6.19)	37.9%
Level 1	5.00 (6.07)	76%	2.19 (3.44)	38%
Level 2	3.90 (5.16)	62%	.90 (2.19)	28%
Level 3	3.48 (4.79)	55%	.67 (1.62)	14%

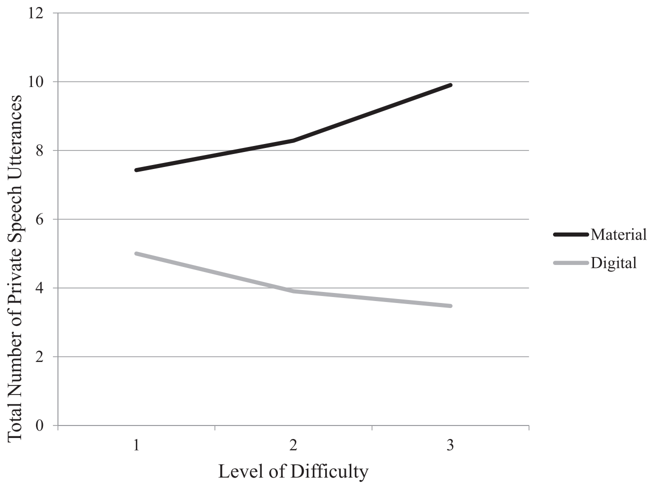

Fig. 1. Main Effect of Modality, and Modality by Difficulty Interaction.

Table 3
Means (SDs) and [% who exhibited] of Subtypes of Private Speech by Task Type and Difficulty Level.

	Utterances without clear meaning (incl. exclamations) (PS0) *M (SD) [%]*	Overt-Task irrelevant speech (PS1) *M (SD)*	Overt-task relevant speech (PS2) *M (SD)*	Covert Inaudible muttering (PS3) *M (SD)*
Material Total	2.10 (5.02) [41.4%]	.10 (0.31) [10.3%]	4.86 (10.08) [48.3%]	13.69 (8.00) [96.4%]
Level 1	1.00 (2.39)	.10 (0.31)	1.38 (2.22)	4.95 (5.88)
Level 2	.90 (2.00)	.00 (0)	1.76 (3.29)	5.62 (6.66)
Level 3	.81 (1.69)	.00 (0)	3.19 (6.80)	5.90 (5.61)
Digital Total	.71 (1.55)[38.1%]	0 (0) [0%]	4.24 (8.39) [42.9%]	7.42 (5.41) [95.2%]
Level 1	.19 (0.512)	.00 (0)	2.05 (4.52)	2.65 (2.47)
Level 2	.38 (0.740)	.00 (0)	1.24 (3.30)	2.29 (2.41)
Level 3	.14 (0.478)	.00 (0)	.95 (2.36)	2.38 (2.51)

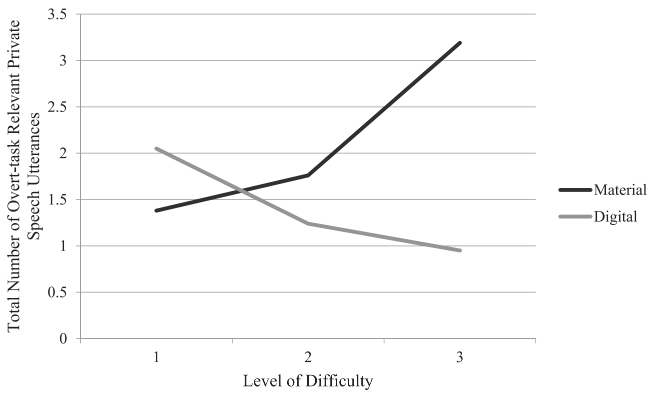

Fig. 2. Increase in Overt-Task Relevant PS in Material Task but decrease in Digital.

The final subcategory of PS was partially covert inaudible muttering and whispers (PS3). As seen in the last column of Table 3, almost all children engaged in this advanced form of verbal mediation (95–96%) during the tasks, however significantly more of it (about twice as much) was observed during the material version of the task, [modality main effect $F\,(1{,}20) = 7.49$, $p < .05$, $d = 0.94$; Wilcoxon $W = 37.5$, $p < .05$]. This form of PS increased slightly as the task got harder during the material version of the Tower task, and decreased slightly over time during the digital task, although the main effect for difficulty and the difficulty-by-modality interaction terms were nonsignificant. This pattern can be seen in Fig. 3.

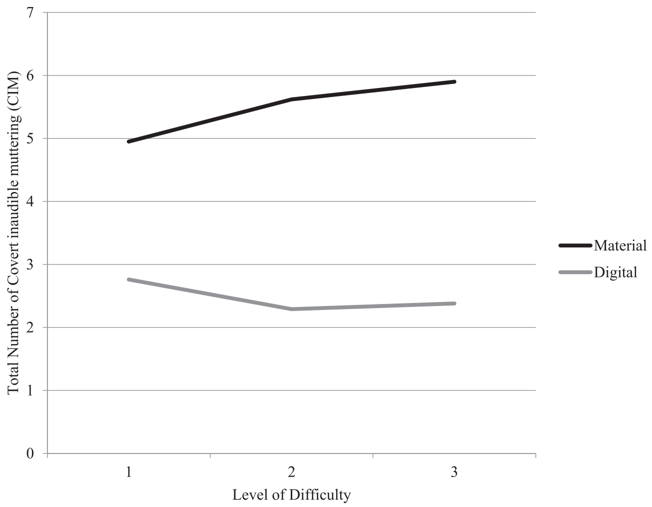

Fig. 3. Inaudible Muttering Increases in Material Task and Decreases in Digital.

7. Discussion

This study explored young children's use of private speech during an EF task (Tower of London) administered twice to the same children —once with traditional physical materials and once on a digital tablet. Young children are spending more and more time these days playing with digital devices rather than with physical materials (Burns & Gottschalk, 2019; Smahel et al., 2020). Digital devices for young children appear to lead to less responsive and stimulating parent-child interactions (Wooldridge & Shapka, 2012), and to less or lower quality adult language use (Zosh, Verdine, Filipowicz, Golinkoff, Hirsh-Pasek, & Newcombe, 2015). Moreover, children and adults use less social speech when interacting with digital devices (Ewin, Reupert, McLean, & Ewin, 2021), and for this reason tablets and phones, sometimes called 'shut-up toys', are often given to children with the explicit purpose of getting them to be quiet (Radesky et al., 2015). If such devices also lead to supressed use of private speech (PS) in young children, and if use of PS is critical for the normal development of verbal mediation, self-regulation, and executive function, as some believe (Winsler, 2009), then it is important to know whether digital play suppresses children's self-regulatory use of private speech.

We hypothesized that digital play inhibits production of private speech. The results support our hypothesis, showing that children produced less PS, both overall, and task-relevant self-regulatory PS during the digital version compared to the material version of the game. Our study is the first to have directly compared the production of PS during the same task administered twice to the same children, once with physical materials and once on a digital device, and thus represents an important contribution to the literature. Below, we speculate as to discuss why digital devices might suppress children's private speech and we discuss implications of our findings for practice and for future research.

It is useful here to reconsider some original findings from Vygotsky's early work. As an attempt to demonstrate the social nature and origin of private speech, Vygotsky (1962) created a critical experimental setting with preschoolers, assessing their production of PS during a typical social condition with a peer engaging in the same activity in the room, and then placing children in a variety of different conditions that created "communicative isolation," like pairing the child with a (known-to-be) deaf child who didn't speak, with other hearing children who were known not to speak Russian, or adding extreme physical distance between the child and their peer, and/or adding loud orchestra sounds making it impossible for the children to hear other voices. Vygotsky (1962) found that children in any of the conditions of communicative isolation were generally more silent than the children in the normal conditions of play with a peer nearby, production of PS declined by 70–80%. Vygotsky (1962) drew the conclusion that PS derives from social speech and for this reason when children perceived themself as "isolated" from playmates (i.e., unable to be heard and/or understood), they ceased talking to the self.

Our results are comparable with those of Vygotsky if we posit that digital devices also create "digital bubbles" of relative "communicative isolation." In our study, children played with both versions of the task, the digital version and material, in the same room where two experimenters were somewhat present and in a larger space where other children carried out usual school activities, but during the digital task, the production of PS decreased dramatically, similar to the Vygotsky's experiments where conditions of communicative isolation were created. Digital games may lead young players to enter a communicative isolation bubble, where other individuals and activities are artificially "blocked out" and rendered somewhat inaudible and invisible. In other words, digital games seem to create a sort of "digital bubble" around the child, which inhibits the production of PS for self-regulatory purposes.

Our heuristic hypothesis of a "digital bubble effect" does not refer to levels of children's engagement during play. We agree with those who state that traditional categories of "activity" and "passivity" need to be reconceptualised when applied to the digital playground (Mustola, Koivula, Turja, & Laakso, 2018). Even the seminal notion of "interpassivity" (Fizek, 2018; Gekker, 2018) – that is, the idea that the user of a digital tool is more passive that active and/or creative, because they simply comply with programmed technology (Sarkis, 1993) – seems to be ineffective in explaining why children are more silent during digital games, particularly because children during digital games express the same levels of engagement, agency, and participation as those experienced during traditional/material games. In other words, we do not believe that the production of PS decreases during digital games because children are more passive, and, thus, the digital playground should not be conceptualized as an “interpassive” setting. It is not a question of how passive the setting is, but perhaps how “immersive” digital playgrounds are.

“Immersion” has been defined as a strong quality of digital technology (Slater & Wilbur, 1997) as it proposes a simulation of reality, and “an objective measure of the extent to which the system presents a vivid virtual environment while shutting out physical reality” (Cummings & Bailenson, 2016, p. 3). The experience of immersion requires basically a computer and a display, and has fundamentally two interrelated and co-occurring characteristics, i.e., the capacity of simulating an external reality, and the capacity of “blocking out” the physical world (Bailey and Bailenson, 2017). Naturally, the experience of immersion in digital technology comes with different degrees that depend on the capacity of the digital system to simulate with sensory fidelity an external reality isolating the user from the physical world. Indeed, some digital contexts can be so immersive that users experience the sensation of being “present” in the digital simulation (Cummings & Bailenson, 2016), rather than in the physical place where they actually are. Each screen simulation, each digital game, is simulating a reality with which the user interacts, and expresses some level of immersion, and therefore some level of isolation, even if minimal. The “digital bubble,” according to our hypothesis, may therefore be an effect of the experience of immersion, and may be described as some level of isolation from the physical world, produced by interaction with digital simulations.

Obviously, our hypothesis of a “digital bubble effect” is just heuristic and needs to be further developed in future work. Further research should demonstrate its consistency and its long-term effects, particularly on verbal skills, cognitive development, EF, and emotional and behavioral self-regulation, particularly because PS dramatically decreased during the digital game, and PS has been shown to be a crucial tool that children use to develop their EF skills and gain regulatory control over their behaviour (Müller et al., 2009). Other explanations for the suppressive effect of digital media on children’s private speech are certainly available. Most notably, simple behavioral principles could be at play. If indeed parents expect and repeatedly reinforce children for being quiet when handed electronic media, then children will get used to behaving in that way when in they are front of a screen.

It is worth noting children’s use of social speech in the current study showed a different pattern, with less difference between conditions, and if anything, more social speech was observed with the experimenters during the tablet-version of the task. We did not hypothesize a digital effect on children’s social speech because of the rather artificial and constrained nature of the social setting created – two experimenters present, the giving of instructions, a task given to the child, etc. Prior studies showing reduced social speech with digital devices have taken place in the more natural setting of parents playing or reading together with their children in a more open-ended way (Ewin et al., 2021). Social speech is generally not expected to behave the same way as private speech in PS research as the social setting and people/relationships involved are what tends to determine children’s social speech.

Finally, we also explored whether private speech frequency varied as a function of task difficulty, and we found that the relation between PS and task difficulty was different during the digital vs. material version of the game. During the material ToL, consistent with previous findings (Berk, 2014; Montero & de Dios, 2006; Winsler, 2009), we found the typical pattern of increased use of PS as the difficulty level of the items increased, however, somewhat surprisingly, during the digital version of the ToL, PS declined notably as the level of difficulty increased. This latter pattern is completely new and uncharted in PS research and needs to be explored in future research.

One possibility is that the “immersion” that takes place in digital games (and seems to inhibit the production of PS) does not take place immediately, but rather gradually. That is, the more the child is engaged in the digital game, the more s/he plunges into digital reality, blocks out the real world, isolates the self, and PS gradually decreases along with it. It is hard to say whether the process of immersion in digital devices, similar to the degree of “absorption” seen in digital reality (Radesky et al., 2014), depends on the level of engagement in the game and the difficulty of the task, or more simply by increasing time spent in the digital game session. In the current study, time spent and item difficulty level were confounded because items got more difficult over time, so it is not clear if the decrease over time in PS was due to increased task difficulty or just increasing time engaging with the digital tool, or both. Future research should shed light on this peculiar pattern link between the production of PS and difficulty during digital games, perhaps by assessing the production of PS during the same digital game but in different conditions, for instance, comparing the production of PS during two different digital sessions, a first session in which the level of engagement/task difficulty is constant and a second session with the same child, in which the task difficulty increases over time. In this way it could be possible to understand if the process of immersion and the “digital bubble effect” depend on the level of engagement/difficulty or on screen time.

Our findings showed also that the pattern of production of social speech followed a similar trend, namely, that SS gradually decreased as task difficulty and time spent with the digital game increased. We found also that SS utterances during the digital game were higher in the first two levels of difficulty than in the same levels of difficulty in the material game. Reducing SS over time is consistent with the notion of the child becoming increasingly isolated and immersed in the digital bubble over time. Although more SS at the beginning of the digital task could just be due to the tablet used being new to the children. Indeed, many of the early SS utterances were requests for help or clarification about how the tablet worked.

We have to acknowledge that the current study has limitations that could affect the consistency and generalization of our findings, and consequently of the hypothesis that children might experience a “digital bubble effect” during digital games. First, we found a relatively high amount of undecipherable speech, which was most likely due to the testing space being somewhat noisy, and the quality of the recording not being great. This could have had an effect in coding of speech for task relevancy. However, such coding challenges and decisions would not have affected the main results of more overall private speech seen in general during the material task. Second, our small sample size limited our statistical power. A future replication of this study with a larger sample size would be advisable. Third, our sample was consisted of a fairly homogenous group of White, 5-year-old, Italian children who were very familiar with digital devices, and who had rather highly educated parents. Future studies should replicate this experiment with a larger and more heterogeneous sample to insure generalizability across a wide variety of children. Fourth, the lack of task performance data for the digital version of the task eliminated our ability to examine whether speech-performance relations varied as a function of task modality. Future research needs to determine if reduced PS use during digital EF tasks is related to children's task performance. Finally, the task used here, the ToL, was a solitary and non-interactive digital game. Increasingly, digital games entail some forms of off-line and/or on-line interaction with other humans or robots. Future research should verify the presence/absence of the "digital bubble effect" during more interactive digital tasks.

8. Conclusions

The nature of children's play has not only dramatically changed over the last decades, but it is destined to become even more digitalized in the future. As the COVID-19 pandemic has already shown in 2020 and 2021, more educational and child recreational practices are being delivered through digital platforms. Our findings showing that digital games may have a negative impact on young children's use of self-regulatory private speech during problem-solving activities are important for parents, psychologists, and educators, as they should be aware of the risks of the "digital bubble" on children's language use. Ensuring sufficient time for children to play with physical, material toys in addition to their digital devices would appear to be important for young children's social, cognitive, and language development. It is for these reasons, that organizations such as the American Academy of Pediatrics recommend limiting screen time for young children (Chassiakos et al., 2016). Moving forward, larger and more detailed longitudinal studies need to be performed in order to clearly identify effects of digital activities in early childhood, to help refine and update guidelines and policies for children's digital playground.

References

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science, 12*(5), 353–359. https://doi.org/10.1111/1467-9280.00366

Anderson, D. R., & Pempek, T. A. (2005). Television and very young children. *American Behavioral Scientist, 48*(5), 505–522. https://doi.org/10.1177/0002764204271506

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Arnott, L. (2016). An ecological exploration of young children's digital play: framing children's social experiences with technologies in early childhood. *Early Years, 36*(3), 271–288. https://doi.org/10.1080/09575146.2016.1181049

Axelsson, A., Andersson, R., & Gulz, A. (2016). Scaffolding executive function capabilities via play-&-learn software for preschoolers. *Journal of Educational Psychology, 108*(7), 969. https://doi.org/10.1037/edu0000099

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

Berk, L. E. (2014). Children's private speech: An overview of theory and the status of research. In R. M. Diaz, & L. E. Berk (Eds.), *Private Speech: From Social Interaction to Self-regulation.* Psychology Press.

Berk, L. E., & Spuhl, S. T. (1995). Maternal interaction, private speech, and task performance in preschool children. *Early Childhood Research Quarterly, 10*(2), 145–169. https://doi.org/10.1016/0885-2006(95)90001-2

Bird, J., & Edwards, S. (2015). Children learning to use technologies through play. *British Journal of Educational Technology, 46*, 1149–1160. https://doi.org/10.1111/bjet.12191

Blumberg, F. C., Deater-Deckard, K., Calvert, S. L., Flynn, R. M., Green, C. S., Arnold, D., & Brooks, P. J. (2019). Digital games as a context for children's cognitive development: Research recommendations and policy considerations. *Social Policy Report, 32*(1), 1–33. https://doi.org/10.1002/sop2.3

Bailey, J. O., & Bailenson, J. N. (2017). Immersive virtual reality and the developing child. In F. Blumberg, & P. Brooks (Eds.), *Cognitive Development in Digital Contexts* (pp. 181–200). Academic Press.

Boyle, E., Terras, M. M., Ramsay, J., & Boyle, J. M. (2014). Executive functions in digital games. In T. M. Connolly, T. Hainey, E. Boyle, G. Baxter, & P. Moreno-Ger (Eds.), *Psychology, Pedagogy, and Assessment in Serious Games* (pp. 19–46). IGI Global.

Burns, T., & Gottschalk, F. (2019). Children and digital technologies: Trends and outcomes. In T. Burns, & F. Gottschalk (Eds.), *Educating 21st Century Children. Emotional Well-being in the Digital Age* (pp. 33–51). OECD Publishing.

Chassiakos, Y. L. R., Radesky, J., Christakis, D., Moreno, M. A., Cross, C., & the Council on Communications and Media. (2016). Children and adolescents and digital media. *Pediatrics, 138*(5), e1–e18. https://doi.org/10.1542/peds.2016-2593

Bochicchio, V., Maldonato, N.M., Valerio, P., Vitelli, R., Dell'Orco, S., Scandurra, C. (2019). A review on the effects of digital play on children's cognitive and socio-emotional development. *9th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*, 261–266. doi:10.1109/CogInfoCom.2018.8639945.

Chiong, C., Shuler, C. (2010). Learning: Is there an app for that? Investigations of young children's usage and learning with mobile devices and apps. The Joan Ganz Cooney Center at Sesame Workshop. ⟨http://wwwtc.pbskids.org/read/files/cooney_learning_apps.pdf⟩.

Crescenzi-Lanna, L. (2020). Emotions, private speech, involvement and other aspects of young children's interactions with educational apps. *Computers in Human Behavior, 111*, Article 106430. https://doi.org/10.1016/j.chb.2020.106430

Cudo, A., & Jaśkiewicz, M. (2015). The impact of computer action games on the cognitive system: A short review. In M. McGreevy, & R. Rita (Eds.), *Proceedings of the 3rd Biannual CER Comparative European Research Conference* (pp. 228–231). Sciemcee.

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology, 19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740

Daiute, C., & Lee, C. D. (2019). Studying cognitive development in digital playgrounds. *Cognitive Development, 49*, 51–55. https://doi.org/10.1016/j.cogdev.2018.11.007

Danby, S., Evaldsson, A.-C., Melander, H., & Aarsand, P. (2018). Situated collaboration and problem solving in young children's digital gameplay. *British Journal of Educational Technology, 49*, 959–972. https://doi.org/10.1111/bjet.12636

Day, K. L., & Smith, C. L. (2013). Understanding the role of private speech in children's emotion regulation. *Early Childhood Research Quarterly, 28*(2), 405–414. https://doi.org/10.1016/j.ecresq.2012.10.003

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

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dynia, J. M., Dore, R. A., Bates, R. A., & Justice, L. M. (2021). Media exposure and language for toddlers from low-income homes. *Infant Behavior and Development, 63*, Article 101542. https://doi.org/10.1016/j.infbeh.2021.101542

Dore, R. A., Zosh, J. M., Hirsh-Pasek, K., & Golinkoff, R. M. (2017). Plugging into word learning: The role of electronic toys and digital media in language development. In F. C. Blumberg, & P. J. Brooks (Eds.), *Cognitive Development in Digital Contexts* (pp. 75–91). Academic Press. https://doi.org/10.1016/B978-0-12-809481-5.00004-3.

Duncan, R. M., & Pratt, M. W. (1997). Microgenetic change in the quantity and quality of preschoolers' private speech. *International Journal of Behavioral Development, 20*(2), 367–383. https://doi.org/10.1080/016502597385388

Edwards, S., & Bird, J. (2017). Observing and assessing young children's digital play in the early years: Using the digital play framework. *Journal of Early Childhood Research, 15*(2), 158–173. https://doi.org/10.1177/1476718×15579746

Ewin, C. A., Reupert, A., McLean, L. A., & Ewin, C. J. (2021). Mobile devices compared to non-digital toy play: The impact of activity type on the quality and quantity of parent language. *Computers in Human Behavior, 118*, Article 106669. https://doi.org/10.1016/j.chb.2020.106669

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *Psychiatric Quarterly, 78*, 309–316. https://doi.org/10.1007/s11126-007-9056-9

Ferguson, C. J. (2015). Do Angry Birds make for angry children? A meta-analysis of video game influences on children's and adolescents' aggression, mental health, prosocial behavior, and academic performance. *Perspectives on Psychological Science, 10*(5), 646–666. https://doi.org/10.1177/1745691615592234

Fernyhough, C., & Fradley, E. (2005). Private speech on an executive task: Relations with task difficulty and task performance. *Cognitive Development, 20*(1), 103–120. https://doi.org/10.1016/j.cogdev.2004.11.002

Fernyhough, C. (2009). Dialogic thinking. In A. Winsler, C. Fernyhough, & I. Montero (Eds.), *Private speech, executive functioning, and the development of verbal self-regulation*. Cambridge University Press.

Fizek, S. (2018). Interpassivity and the joy of delegated play in idle games. *Transactions of the Digital Games Research Association, 3*(3), 137–163. https://doi.org/10.26503/todigra.v3i3.81

Gao, F., Li, L., & Sun, Y. (2020). A systematic review of mobile game-based learning in STEM education. *Education Technology Research and Development, 68*, 1791–1827. https://doi.org/10.1007/s11423-020-09787-0

Gekker, A. (2018). Let's not play: interpassivity as resistance in 'Let's Play'videos. *Journal of Gaming & Virtual Worlds, 10*(3), 219–242. https://doi.org/10.1386/jgvw.10.3.219_1

Ginsburg, K. R. (2007). The importance of play in promoting healthy child development and maintaining strong parent-child bonds. *Pediatrics, 119*(1), 182–191. https://doi.org/10.1542/peds.2006-2697

Groves, C. L., & Anderson, C. A. (2015). Negative effects of video game play. In R. Nakatsu, M. Rauterberg, & P. Ciancarini (Eds.), *Handbook of Digital Games and Entertainment Technologies* (pp. 1–26). Springer.

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting education in "educational" apps: Lessons from the science of learning. *Psychological Science in the Public Interest, 16*(1), 3–34. https://doi.org/10.1177/1529100615569721

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174–180. https://doi.org/10.1016/j.tics.2012.01.006

Hoge, E., Bickham, D., & Cantor, J. (2017). Digital media, anxiety, and depression in children. *Pediatrics, 140*(Supplement 2), S76–S80. https://doi.org/10.1542/peds.2016–1758 G

Homer, B. D., Ober, T. M., Rose, M. C., MacNamara, A., Mayer, R. E., & Plass, J. L. (2019). Speed versus accuracy: Implications of adolescents' neurocognitive developments in a digital game to train executive functions. *Mind, Brain, and Education, 13*, 41–52. https://doi.org/10.1111/mbe.12189

Homer, B. D., Plass, J. L., Rose, M. C., MacNamara, A. P., Pawar, S., & Ober, T. M. (2019). Activating adolescents' "hot" executive functions in a digital game to train cognitive skills: The effects of age and prior abilities. *Cognitive Development, 49*, 20–32. https://doi.org/10.1016/j.cogdev.2018.11.005

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., & Leister, K. P. (2015). Exposure and use of mobile media devices by young children. *Pediatrics, 136*(6), 1044–1050.

Kim, J. Y. (2012). The nonlinear association between Internet using time for non-educational purposes and adolescent health. *Journal of Preventive Medicine and Public Health = Yebang Uihakhoe chi, 45*(1), 37–46. https://doi.org/10.3961/jpmph.2012.45.1.37

Kirkorian, H. L., Pempek, T. A., Murphy, L. A., Schmidt, M. E., & Anderson, D. R. (2009). The impact of background television on parent-child interaction. *Child Development, 80*(5), 1350–1359. https://doi.org/10.1111/j.1467-8624.2009.01337.x

LeBourgeois, M. K., Hale, L., Chang, A. M., Akacem, L. D., Montgomery-Downs, H. E., & Buxton, O. M. (2017). Digital media and sleep in childhood and adolescence. *Pediatrics, 140*(Supplement 2), S92–S96. https://doi.org/10.1542/peds.2016–1758 J

Linebarger, D. L., & Walker, D. (2005). Infants' and toddlers' television viewing and language outcomes. *American Behavioral Scientist, 48*(5), 624–645. https://doi.org/10.1177/0002764204271505

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J., & Scott, F. (2016). Digital play: A new classification. *Early Years, 36*(3), 242–253. https://doi.org/10.1080/09575146.2016.1167675

Mathers, M., Canterford, L., Olds, T., Hesketh, K., Ridley, K., & Wake, M. (2009). Electronic media use and adolescent health and well-being: Cross-sectional community study. *Academic Pediatrics, 9*(5), 307–314. https://doi.org/10.1016/j.acap.2009.04.003

Mihara, S., & Higuchi, S. (2017). Cross-sectional and longitudinal epidemiological studies of Internet gaming disorder: A systematic review of the literature. *Psychiatry and Clinical Neurosciences, 71*(7), 425–444. https://doi.org/10.1111/pcn.12532

McDaniel, B. T., & Radesky, J. S. (2020). Longitudinal associations between early childhood externalizing behavior, parenting stress, and child media use. *Cyberpsychology, Behavior and Social Networking, 23*(6), 384–391. https://doi.org/10.1089/cyber.2019.0478

Montag, C., & Elhai, J. D. (2020). Discussing digital technology overuse in children and adolescents during the COVID-19 pandemic and beyond: On the importance of considering Affective Neuroscience Theory. *Addictive Behaviors Reports, 12*, Article 100313. https://doi.org/10.1016/j.abrep.2020.100313

Montero, I., & de Dios, M. J. (2006). Vygotsky was right. An experimental approach to the study of the relationship between private speech and task performance. *Estudios de Psicología, 27*, 175–189. https://doi.org/10.1174/021093906777571709

Müller, U., Jacques, S., Brocki, K., & Zelazo, P. D. (2009). The executive functions of language in preschool children. In A. Winsler, C. Fernyhough, & I. Montero (Eds.), *Private speech, executive functioning, and the development of verbal self-regulation*. Cambridge University Press.

Mulvihill, A., Matthews, N., Dux, P.E., & Carroll, A. (2021). Task difficulty and private speech in typically developing and at-risk preschool children. Unpublished manuscript.

Mulvihill, A., Carroll, A., Dux, P. E., & Matthews, N. (2020). Self-directed speech and self-regulation in childhood neurodevelopmental disorder: Current findings and future directions. *Development and Psychopathology, 32*, 205–2017. https://doi.org/10.1017/S0954579418001670

Mustola, M., Koivula, M., Turja, L., & Laakso, M. L. (2018). Reconsidering passivity and activity in children's digital play. *New Media & Society, 20*(1), 237–254. https://doi.org/10.1177/1461444816661550

Parish-Morris, J., Mahajan, N., Hirsh-Pasek, K., Golinkoff, R. M., & Collins, M. F. (2013). Once upon a time: parent–child dialogue and storybook reading in the electronic era. *Mind, Brain, and Education, 7*(3), 200–211. https://doi.org/10.1111/mbe.12028

Pellegrini, A. D., & Smith, P. K. (1998). Physical activity play: The nature and function of a neglected aspect of play. *Child Development, 69*(3), 577–598. https://doi.org/10.1111/j.1467-8624.1998.tb06226.x

Piaget, J., & Claparède, É. (1923). *Le langage et la pensée chez l'enfant*. Paris: Ed. Delachaux et Niestlé,.

Powers, K. L., Brooks, P. J., Aldrich, N. J., Palladino, M. A., & Alfieri, L. (2013). Effects of video-game play on information processing: A meta-analytic investigation. *Psychonomic Bulletin & Review, 20*(6), 1055–1079. https://doi.org/10.3758/s13423-013-0418-z

Rachanioti, E., Bratitsis, T., & Alevriadou, A. (2018). Cognitive games for children's executive functions training with or without learning difficulties: An overview. *Proceedings of the 8th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion* (pp. 165–171). New York: Association for Computing Machinery,. https://doi.org/10.1145/3218585.3218665

Radesky, J. S., Kistin, C. J., Zuckerman, B., Nitzberg, K., Gross, J., Kaplan-Sanoff, M., … Silverstein, M. (2014). Patterns of mobile device use by caregivers and children during meals in fast food restaurants. *Pediatrics, 133*(4). https://doi.org/10.1542/peds.2013-3703

Radesky, J. S., Schumacher, J., & Zuckerman, B. (2015). Mobile and interactive media use by young children: The good, the bad, and the unknown. *Pediatrics, 135*, 1. https://doi.org/10.1542/peds.2014-2251

Ramírez, N. F., Hippe, D. S., & Shapiro, N. T. (2021). Exposure to electronic media between 6 and 24 months of age: An exploratory study. *Infant Behavior and Development, 63*, Article 101549. https://doi.org/10.1016/j.infbeh.2021.101549

Reed, J., Hirsh-Pasek, K., & Golinkoff, R. M. (2017). Learning on hold: Cell phones sidetrack parent-child interactions. *Developmental Psychology, 53*(8), 1428–1436.

Rideout, V., & Robb, M. B. (2020). *The common sense census: Media use by kids age zero to eight, 2020*. Common Sense Media,.

Riede, F., Johannsen, N. N., Högberg, A., Nowell, A., & Lombard, M. (2018). The role of play objects and object play in human cognitive evolution and innovation. *Evolutionary Anthropology: Issues, News, and Reviews, 27*(1), 46–59. https://doi.org/10.1002/evan.21555

Robinson, T. N., Banda, J. A., Hale, L., Lu, A. S., Fleming-Milici, F., Calvert, S. L., & Wartella, E. (2017). Screen media exposure and obesity in children and adolescents. *Pediatrics, 140*(Supplement 2), S97–S101. https://doi.org/10.1542/peds.2016–1758 K

Sanders, T., Parker, P. D., del Pozo-Cruz, B., Noetel, M., & Lonsdale, C. (2019). Type of screen time moderates effects on outcomes in 4013 children: Evidence from the Longitudinal Study of Australian Children. *International Journal of Behavioral Nutrition and Physical Activity, 16*, 117. https://doi.org/10.1186/s12966-019-0881-7

Sarkis, M. (1993). Interactivity means interpassivity. *Media Information Australia, 69*(1), 13–16. https://doi.org/10.1177/1329878×9306900104

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences, 298*(1089), 199–209. https://doi.org/10.1098/rstb.1982.0082

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments, 6*(6), 603–616. https://doi.org/10.1162/pres.1997.6.6.603

Smahel, D., Machackova, H., Mascheroni, G., Dedkova, L., Staksrud, E., Ólafsson, K., Livingstone, S., & Hasebrink, U. (2020). EU Kids Online 2020: Survey results from 19 countries. *EU Kids Online*. https://doi.org/10.21953/lse.47fdeqj01ofo

Sosa, A. V. (2015). Association of the type of toy used during play with the quantity and quality of parent-infant communication. *JAMA Pediatrics, 170*(2), 132–137. https://doi.org/10.1001/jamapediatrics.2015.3753

Staples, A. D., Hoyniak, C., McQuillan, M. E., Molfese, V., & Bates, J. E. (2021). Screen use before bedtime: Consequences for nighttime sleep in young children. *Infant Behavior and Development, 62*, Article 101522. https://doi.org/10.1016/j.infbeh.2020.101522

Stephen, C., & Plowman, L. (2014). Digital play. In L. Brooker, M. Blaise, & S. Edwards (Eds.), *Sage handbook of play and learning in early childhood* (pp. 330–341). Sage.

Straker, L., Zabatiero, J., Danby, S., Thorpe, K., & Edwards, S. (2018). Conflicting guidelines on young Children's screen time and use of digital technology create policy and practice dilemmas. *The Journal of Pediatrics, 202*, 300–303. https://doi.org/10.1016/j.jpeds.2018.07.019

Thibodeaux, J., & Winsler, A. (2018). What do youth tennis athletes say to themselves?: Observed and self-reported self-talk on the court. *Psychology of Sport & Exercise, 38*, 126–136. https://doi.org/10.1016/j.psychsport.2018.06.006

van den Heuvel, M., Ma, J., Borkhoff, C. M., Koroshegyi, C., Dai, D., Parkin, P. C., … Birken, C. S. (2019). Mobile media device use is associated with expressive language delay in 18-month-old children. *Journal of Developmental and Behavioral Pediatrics, 40*(2), 99–104. https://doi.org/10.1097/DBP.0000000000000630

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, Mass: MIT Pr. (Original work published 1934),.

Vygotsky, L. S. (1967). Play and its role in the mental development of the child. *Soviet Psychology, 5*, 6–18.

WHO. World Health Organization (2020). Excessive screen use and gaming considerations during #COVID19. Retrieved from ⟨http://www.emro.who.int/mnh/news/considerations-for-young-people-on-excessive-screen-use-during-covid19.html⟩.

Wichstrøm, L., Stenseng, F., Belsky, J., von Soest, T., & Hygen, B. W. (2019). Symptoms of internet gaming disorder in youth: predictors and comorbidity. *Journal of Abnormal Child Psychology, 47*(1), 71–83. https://doi.org/10.1007/s10802-018-0422-x

Winsler, A. (2009). Still talking to ourselves after all these years: A review of current research on private speech. In A. Winsler, C. Fernyhough, & I. Montero (Eds.), *Private speech, executive functioning, and the development of verbal self-regulation* (pp. 3–41). Cambridge University Press.

Winsler, A., Fernyhough, C., McClaren, E.M., & Way, E. (2005). Private speech coding manual. Unpublished manuscript. George Mason University, Fairfax, VA, USA. Available at ⟨http://classweb.gmu.edu/awinsler/Resources/PsCodingManual.pdf⟩.

Winsler, A., LaRocque, R., Keith, K., & Abar, B. (2021). *Parent-child interaction, scaffolding, and private speech, among children with ASD*. Manuscript under review.

Winsler, A., Abar, B., Feder, M., Rubio, D. A., & Schunn, C. (2007). Private speech and executive functioning among high functioning children with autistic spectrum disorders. *Journal of Autism and Developmental Disabilities, 37*, 1617–1635. https://doi.org/10.1007/s10803-006-0294-8

Wooldridge, M. B., & Shapka, J. (2012). Playing with technology: Mother–toddler interaction scores lower during play with electronic toys. *Journal of Applied Developmental Psychology, 33*(5), 211–218. https://doi.org/10.1016/j.appdev.2012.05.005

Woo, E. H., White, P., & Lai, C. W. (2016). Impact of information and communication technology on child health. *Journal of Paediatrics and Child Health, 52*(6), 590–594. https://doi.org/10.1111/jpc.13181

Zelazo, P. D., Qu, L., & Müller, U. (2005). Hot and cool aspects of executive function: Relations in early development. In W. Schneider, R. Schumann-Hengsteler, & B. Sodian (Eds.), *Young children's cognitive development: Interrelationships among executive functioning, working memory, verbal ability, and theory of mind* (pp. 71–93). Erlbaum.

Zelazo, P. D., Qu, L., & Kesek, A. C. (2010). Hot executive function: Emotion and the development of cognitive control. In S. D. Calkins, & M. A. Bell (Eds.), *Human brain* (pp. 97–111). Washington, DC: American Psychological Association.

Zosh, J. M., Verdine, B. N., Filipowicz, A., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2015). Talking shape: Parental language with electronic versus traditional shape sorters. *Mind, Brain, and Education, 9*(3), 136–144. https://doi.org/10.1111/mbe.12082