International Journal of Child-Computer Interaction 30 (2021) 100325

Contents lists available at ScienceDirect

International Journal of Child-Computer Interaction

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

Review article

A narrative review of methods used to examine digital gaming impacts on learning and cognition during middle childhood☆

Rachel M. Flynn[a,*], Erica Kleinknecht[b], Ashley A. Ricker[c], Fran C. Blumberg[d]

[a] San Francisco State University, 1600 Holloway Ave, San Francisco, CA, United States of America
[b] Pacific University Oregon, 2043 College Way, Forest Grove OR 97116, United States of America
[c] University of Colorado Boulder, 3100 Marine St. ARC A48, Boulder, CO 80303, United States of America
[d] Fordham University, 113 W. 60th St., Room 1008M, New York, NY 10023, United States of America

A R T I C L E I N F O

Article history:
Received 30 November 2020
Received in revised form 11 May 2021
Accepted 13 May 2021
Available online 18 May 2021

Keywords:
Digital games
Video games
Interactive games
Learning
Cognition
Digital game based learning
Academic achievement
Elementary school children
Middle childhood

A B S T R A C T

Middle childhood remains a privileged albeit understudied developmental period in studies examining child–computer interactions, particularly as it pertains to digital game play. Middle childhood also is marked by increasing digital game play, arguably the most common form of child–computer interactions during this developmental period. For example, children between the ages of 6 and 8 play digital games 60–90 min per day and 47% of 3rd to 8th grade teachers reported using digital games in their classrooms several times a week (Vega & Robb, 2019). Surprisingly, how content learning and cognition may be facilitated through digital gaming remains sparsely investigated among children during this period. In the studies that do examine the linkages between game play and content learning or cognition, research methodologies vary markedly. The goal of this narrative review is to help bring greater cohesion to the research literature, which often spans many disciplines. This review emphasizes the games, measurement of outcomes, and research designs that have been used to examine content learning and cognitive skills among children ages 6 to 12 in the context of digital games.

Contents

☆ The authors would like to acknowledge Corinne H. Miller, MLIS, Clinical Informationist, Northwestern University, Feinberg School of Medicine, Galter Health Sciences Library & Learning, Chicago, Illinois. Ms. Miller conducted the database search for this narrative review.

* Corresponding author.
E-mail addresses: rachelflynn@sfsu.edu (R.M. Flynn), eko@pacificu.edu (E. Kleinknecht), ashley.ricker@colorado.edu (A.A. Ricker), blumberg@fordham.edu (F.C. Blumberg).

https://doi.org/10.1016/j.ijcci.2021.100325
2212-8689/

1. Introduction and background

The impact of interactions with digital games on the cognitive abilities and academic content learning of 6 to 12-year-olds continues to attract the attention of researchers within the field of child–computer interaction (CCI), educators, and game designers as digital games become increasingly incorporated within classroom instruction (Dubé & Dubé, 2020; Vega & Robb, 2019). For example, in 2019, 47% of US 3rd to 8th grade teachers reported using digital games in their classrooms several times a week (Vega & Robb, 2019). Findings internationally also show the prevalence of digital game play in classrooms as tools for imparting or reinforcing academic skills and content-based learning (e.g., physics laws; Liao, Chen, & Shih, 2019) and for remediating or promoting the academic needs of neurodiverse students (e.g., identification of suffixes and prefixes; Vasalou, Khaled, Holmes, & Gooch, 2017). Further, the vast majority of educational or serious digital games target 6 to 12-year-olds (Ratan & Ritterfeld, 2009). These interactive games can now be played on a wide range of mediums, including tablets, mobile phones, video game consoles, hand-held video game controllers or computers. Therefore, we use the term digital games as this term transcends these mediums.

The use of digital games for educational purposes is grounded in the widespread appeal of game play as demonstrated by findings in 2020 showing that 214.4 million individuals played digital games in the US, 21% of whom were 18 years of age and younger (ESA, 2020). International findings in 2019 showed that about 11.6 million children ages 6–10 across France, Germany, Spain, and the UK, played digital games (GameTrack, 2019). Surprisingly, research examining the cognitive ramifications of digital game play, be it for recreational or formal learning purposes, remains limited among those aged 6 to 12, relative to the expanding body of work examining the learning affordances of digital games among young children (Calvert et al., 2019; Kirkorian, 2018), and the potentially larger corpus addressing the socioemotional consequences of digital game play such as increased violent affect and aggression, among adolescents (see Calvert et al., 2017; Gentile, Lynch, Linder, & Walsh, 2004). Recently, this gap has been highlighted by developmental psychologists (see Blumberg et al., 2019; Blumberg, Flynn, Kleinknecht, & Ricker, 2019) given the cognitive enhancements that may occur through digital game play among 6 to 12-years-olds such as metacognition (Ricker & Richert, 2021; Vandeventer & White, 2002), executive functions (Best, 2012; Flynn & Colon, 2016; Flynn & Richert, 2018; Staiano & Calvert, 2011), and problem-solving (Blumberg & Randall, 2013; Fisch, Lesh, Motoki, Crespo, & Melfi, 2011); skills that have been linked to academic performance (Best & Miller, 2010; Peng & Kievit, 2020). However, the paucity of research addressing middle childhood remains. This situation compromises our understanding of the efficacy of CCIs, such as digital game play for use in academic instruction among 6 to 12-year-olds, and best ways to measure and examine the impact of these interactions on children's behavior (see Blumberg et al., 2019; Blumberg, Flynn, Kleinknecht, & Ricker, 2019). As noted by Hourcade (2015), one research emphasis in the study of digital games within the CCI field is that of game impact on behavior. Here, we explore how this emphasis is approached methodologically in the literature.

The goal of the current narrative review is to examine the research methods used in CCI research focused on digital game play. We have chosen such a review to qualitatively examine a wide breadth of studies that differ in methodologies and outcomes tested (Siddaway, Wood, & Hedges, 2019). Thus, our narrative review is intended to provide an overview of the current methodologies used in the literature, that we hope will help promote cross-disciplinary collaboration in the study of game play among children.

1.1. Related work

As we first initiated our screening of the literature, we identified review articles on digital games and learning or cognition. Generally, these reviews focused on a single population, cognitive skill, or academic subject area. For example, in a narrative review, Liu, Wu, and Chen (2013) surveyed the methods and trends in the research pertaining to special education. In another narrative review, Mayer, Parong, and Bainbridge (2019) addressed the efficacy of digital game play for enhancing cognitive skills, with specific emphasis on executive functions. In a systematic review, Hussein, Ow, Cheong, and Thong (2019) focused on digital game-based learning in science education. Tsai and Tsai (2018) examined, via meta-analytic techniques, the pooled effect of game play on vocabulary learning in the context of second-language acquisition. We also found reviews that examined the efficacy of digital game play for promoting cognition, more broadly construed. For example, Ke (2016) using a systematic review, examined game design heuristics, or the means by which game design features facilitated purposeful learning opportunities. Similarly, using a narrative review structure, Blumberg, Altschuler, Almonte, and Mileaf (2013) examined which cognitive mechanisms (e.g., mental rotation, strategy, and problem solving) were stimulated in a variety of digital games, and Mayer et al. (2019) examined the cognitive skill affordances evident in commercially available games.

Overall, our survey of extant reviews shows that research methods were not a specific focus. In this narrative review, we spotlight a broad view of methods that researchers across different disciplines adopted when studying CCI among neurotypical and neurodiverse children within the middle childhood period. Such efforts should help to guide next steps in the field of CCI research focused on digital game-based learning in academic and clinical practices among students in the middle childhood period.

1.2. Narrative review aims and research questions

Our narrative review was designed to address three research questions. First, we examined whether researchers selected commercially available digital games or created their own games when examining the efficacy of digital game play for cognitive skill and academic content knowledge enhancement. Second, we considered the measurement tools researchers used for capturing and evaluating content learning and cognitive skill enhancement, with a particular focus on whether researchers examined direct outcomes (i.e., academic learning or cognitive skills) or indirect outcomes (i.e., engagement or student reported success). Third, we reviewed the extent to which researchers used similar or more varied research methods to examine child–computer interactions.

2. Methodology

The research reviewed addressed multiple outcomes and different hypotheses regarding the impacts of CCI on content learning and cognition. The process of gathering and reporting findings in a narrative review shares steps with systematic reviews used to avoid bias, such as searching at least two databases, and utilizing multiple key-word combinations (Siddaway et al., 2019). We took steps at each point in the search, screen, and selection phases to avoid selection bias. However, we recognize that our search strategy may have failed to generate a set of articles without a biased representation of extant work.

2.1. Identification and search strategy

To identify relevant literature, we searched four databases (Scopus, ERIC, PsychInfo and OVID Medline) spanning the years 2010–2020. Searching four databases was intended to reduce the potential for biased sampling. Initial inclusion and exclusion criteria were that articles must be peer-reviewed articles and published in English-language journals. We also included studies featuring neurodiverse participants. We utilized a title-keyword search, such that all articles needed to include variants of both our major search terms of "interactive digital games" and "cognitive or learning outcomes" in the title. The first set of terms captured digital games. Various combinations of the following title keywords were used in conjunction with the different iterations of game (e.g., gaming or gamification): interactive, digital, video, electronic, mobile, touch screen, tablet, online, application/app, computer, android, iOS/iPhone, exergame, serious. The second set of search terms captured cognitive and academic outcomes and included different iterations of the following title keywords: knowledge acquisition, learning, academic, test or school performance, academic or schools achievement, math, algebra, science/STEM, computational thinking, letter learning, literacy, reading ability, skills or capabilities, executive control or function, attention, metacognition, item recall, memory, remember, spatial skill, orientation or navigation, problem solving, information processing. This process generated a set of 292 peer reviewed articles for possible inclusion in the narrative review.

While it is possible that narrowing our search by keyword-title created an unanticipated bias, the search still resulted in a wide variety of papers that guided our review. To ensure that the screening process for articles to be included in the review remained as objective as possible, each of the four authors screened the same 20 articles and evaluated their appropriateness for the review. All disagreements were resolved through discussion. Papers were then selected for a full read and ultimately included in the review based on the following criteria:

1. Study participants must be in the targeted age range of 6–12.
2. The manuscript presented an empirical research study.
3. Studies included participants playing a digital game which excluded any study whereby video game experience was measured via self-report.
4. Studies needed to include an outcome that could be categorized as academic skills or content based learning outcomes (e.g., phonemic awareness, botany facts) or as cognitive abilities (e.g., executive functioning, problem solving).

The screening process yielded 73 articles eligible for inclusion in our review. These articles appeared in 47 different peer reviewed journals spanning several distinct disciplines (see Table 1). We present an overview of the types of games used in these studies, the different measures that were used to assess outcomes, and the various research designs utilized to test questions about the feasibility and impact of digital game engagement for learning and cognition. Given the large number of articles and the broad scope of the review, we detail a select number of methodological exemplars. Thus, not all articles are specifically featured beyond parenthetical references (Note: all 73 articles are referenced in text and a list can be found in the Appendix). No numerical summaries of the various methods are shared to avoid misleading readers about how these methods would be represented in a systematic literature review.

3. Findings

3.1. What games are researchers using?

Game choice is an important methodological consideration as game play potentially influences children's academic learning and/or cognitive skills. Indeed, the type and quality of the game used in research extends beyond manipulation affordances to possibilities for outcome and moderator measurement. Most of the studies we reviewed included games developed by researchers. Far fewer studies included commercially available games.

3.1.1. Researcher-developed games

In general, the educational games that have been developed for elementary school-age children are designed to teach academic subject content (e.g., literacy and math) as opposed to affiliated skills that pertain more indirectly to that content (e.g., social and occupational skills) (Ratan & Ritterfeld, 2009). In fact, many of the games found in our review were primarily developed as part of federally-funded or internationally-funded investigations designed to promote the academic or basic cognitive skills of a given group of students. These funding agencies included the Institute for Educational Science and National Science Foundation (e.g., Bergey, Ketelhut, Liang, Natarajan, & Karakus, 2015; Homer, Plass, Rose, MacNamara, Pawar, & Ober, 2019), the Spanish Government (Furió, González-Gancedo, Juan, Seguí, & Rando, 2013), and the European Commission (e.g., Vasalou et al., 2017).

Many researcher-developed educational games delivered academic content as a lesson that resembled an interactive game. Ratan and Ritterfeld (2009) defined such educational games as those that allow for skill practice (e.g., solving math problems to move on to the next level) in which the practice is narrow and repetitive. In 2009, these types of games were highly prevalent (see Ratan & Ritterfeld, 2009, for a content analysis) and according to our review, remain as such. However, not all researcher-developed games focused on specific academic content. Some emphasized training cognitive skills by, for example, providing practice in problem-solving and decision-making (e.g., Rosetti, Gómez-Tello, Maya, & Apiquian, 2020) and others via "gamifying" cognitive tasks emphasizing practice of executive functions (e.g., Bikic, Leckman, Christensen, Bilenberg, & Dalsgaard, 2018; Song, Yi, & Park, 2020).

3.1.2. Commercially available games

Many commercially available games found on the shelf or in the app store are designed for multiple purposes including recreation, entertainment, and education and are often marketed to teachers, parents, and children (Hirsh-Pasek et al., 2015). Surprisingly, a limited number of commercial games were highlighted in our review (e.g., studies utilizing commercial games: Best, 2012; Checa-Romero, 2016; Gao, Hannan, Xiang, Stodden, & Valdez, 2013; O'Rourke, Main, & Hill, 2017). Commercially available games cited could be characterized as exploratory, open-ended/ sandbox games such as *Lego Creator Island* (Ricker &

Table 1
Summary of journals that published the articles reviewed.

Journal of publication	Number reviewed
Computers & Education	9
Educational Technology Research and Development	4
International Journal of Child-Computer Interaction	4
Computers in Human Behavior	3
Educational Technology & Society	3
Interactive Learning Environments	3
British Journal of Educational Technology	2
Games for Health Journal	2
IEEE Access	2
Journal of Computer Assisted Learning	2
Journal of Science Education and Technology	2
PLoS One	2
American Journal of Preventive Medicine	1
Australian Journal of Teacher Education	1
Biological Rhythm Research	1
Child Development Perspectives	1
Cognitive Development	1
Developmental Neurobiology	1
Developmental Science	1
Educational Studies in Mathematics	1
Electronic Journal of e-Learning	1
ELT Journal	1
European Child & Adolescent Psychiatry	1
Frontiers in Psychology	1
Games and Culture	1
Human Technology	1
IEEE Transactions on Haptics	1
Information	1
International Journal of Advanced Trends in Computer Science and Engineering	1
International Journal of Emerging Technologies in Learning	1
International Journal of Environmental Research and Public Health	1
International Journal of Human-Computer Interaction	1
International Journal of Technology and Design Education	1
Journal of Abnormal Child Psychology	1
Journal of Attention Disorders	1
Journal of Cognition and Development	1
Journal of Educational Computing Research	1
Journal of Sport and Health Science	1
Journal on Multimodal User Interfaces	1
Mathematics Education Research Journal	1
Pediatric Exercise Science	1
PNAS	1
Psicologia: Reflexão e Crítica	1
Scandinavian Journal of Medicine & Science in Sports	1
Scientific Reports	1
Simulation & Gaming	1
Technology, Knowledge and Learning	1

Note. The 73 articles reviewed for methods were published across 47 peer-reviewed journals.

Richert, 2021), challenge-based action video games like *Raving Rabbids* (Franceschini, Trevisan, Ronconi, Bertoni, Colmar, Double, Facoetti, & Gori, 2017), cognitive skills training game like *Brain Workshop* (Araújo & de Almondes, 2015), and active video games like *Just Dance 4* (Flynn & Colon, 2016). Commercial games such as the Kinect-based game *Kinems,* which has been designed specifically to improve cognitive and academic skills for children with special needs (Kourakli, Altanis, Retalis, Boloudakis, Zbainos, & Antonopoulou, 2017) also were used.

3.2. How are researchers measuring learning and cognitive outcomes?

Another methodological consideration for researchers is whether game play directly targets specific content knowledge and skill attainment, general learning mechanisms, or indirectly enhances, for example, sustained interest in engagement with content, and self-perceptions of learning (e.g., Bergey et al., 2015). The former type of outcome often has been referred to as a direct outcome which refers to how well one has mastered domain specific knowledge and/or related skills needed to acquire or master that knowledge. Direct outcomes also include general cognitive skill enhancement of, for example, executive function (i.e., attention networks) or metacognitive skills resulting from game play. By comparison, indirect outcomes, as noted above, address more affective indicators of learning that may correlate with learning and skill acquisition and/or enhancement (e.g., enjoyment of game play, perceived mastery of content). In this section, we first describe the measurements of direct and indirect outcomes used in studies of games measuring content learning, followed by a review of the measurements used to capture direct and indirect outcomes in studies of games measuring cognitive skills.

3.2.1. Methodological approaches to measuring content learning

Direct Outcomes. Direct outcomes have largely been used in games that address mathematics, science (both natural and social), and literacy/ language skills. Also included in this work are indicators of critical thinking about the specific subject matter, as opposed to gains in factual or procedural knowledge alone (e.g., Checa-Romero, 2016; Hussein, Ow, Cheong, & Thong, 2019).

Our survey of the work showed that measurements of math learning were quite prominent (e.g., Deater-Deckard, El Mallah, Chang, Evans, & Norton, 2014; Masek, Boston, Lam, & Corcoran, 2017; Pitchford, Chigeda, & Hubber, 2019; Tazouti, Boulaknadel, & Fakhri, 2019) whereby mathematical ability and math learning outcomes were defined in diverse ways. For example, Bakker, van den Heuvel-Panhuizen, and Robitzsch (2016) employed measures of declarative knowledge, procedural knowledge, and conceptual knowledge/insight in multiplication. Es-Sajjade and Paas (2020) created a math test of 15 traditional equations consistent with those that children might solve in school, and Moyer-Packenham et al. created math assessments that aligned with US Common Core State Standards by grade (2019). Alternatively, Goldin et al. (2014) measured mathematics using children's actual school grades as their outcome variable.

In the domain of natural science education, some researchers created subject matter assessments that resembled in-class exams. For example, Hussein, Ow, Cheong, Thong, and Ebrahim (2019) constructed a multiple choice test of critical thinking about science and ecology and Anderson and Barnett (2013) created an exam of physics concepts (electrostatics and electromagnetics). Rather than researcher-designed assessments, Hwang, Yang, and Wang (2013) recruited teachers to create assessment tests of ecology knowledge. Similarly, Yang (2017) recruited teachers to create an outcome assessment of social studies knowledge. Other research teams modified standardized assessment tools. For example, Sun and Gao (2016) adapted a standardized measure of student knowledge about cosmology, and Harker-Schuch, Mills, Lade, and Colvin (2020) adapted an existing instrument designed to assess climate-science knowledge.

In the research we reviewed examining literacy and language skills, measures included letter/word recognition (Ronimus, Kujala, Tolvanen, & Lyytinen, 2014; Ronimus & Lyytinen, 2015), general language skills (Ronimus, Eklund, Pesu, & Lyytinen, 2019), second language acquisition (Butler, Someya, & Fukuhara, 2014; Chu, Wang, & Wang, 2019; Sampayo-Vargas, Cope, He, & Byrne, 2013), and reading skills (e.g., Bigueras, 2020; Pitchford et al., 2019). Children's literacy/language skill was measured in diverse ways. In some studies, a task embedded within the game was used to assess whether game play influenced skill gains such as word matching or recognition (e.g., Chu et al., 2019; Ronimus et al., 2014). Other researchers used teacher evaluations of children's skill attainment (e.g., Goldin et al., 2014) or standardized literacy and reading assessments (e.g., Pitchford et al., 2019; Ronimus et al., 2019). Yet another approach taken by Ronimus et al. (2019) was to examine literacy independent from game play with a researcher-administered battery including a word reading skill assessment, a standardized spelling accuracy test, the reading fluency assessment from the Woodcock-Johnson III Test of Achievement, and a reading comprehension task constructed for the study.

Indirect Outcomes. Our review showed that the indirect learning outcomes related to content learning frequently measured included motivation (Es-Sajjade & Paas, 2020; Hussein, Ow, Cheong, & Thong, 2019; Hwang et al., 2013), learning attitudes (Yang, 2017), and whether students found the games enjoyable (Imlig-Iten & Petko, 2018; Murphy & Darrah, 2015) or engaging (Deater-Deckard et al., 2014; Ronimus & Lyytinen, 2015). Self-report indicators of learning preferences or styles also appeared in the literature (e.g., Dourda, Bratitsis, Griva, & Papadopoulou, 2014; Hwang, Sung, Hung, Huang, & Tsai, 2012) as did challenges to learning such as frustration (Anderson & Barnett, 2013), anxiety about one's ability to master given content (Yang, Lin, & Chen, 2018), and cognitive load (Chu et al., 2019; Hwang et al., 2013; Yang, 2017).

Assessment of learners' self-efficacy also was evident in the work we examined. For example, Bergey et al. (2015) included an indicator of students' computer and scientific inquiry self-efficacy, whereas Hussein, Ow, Cheong, and Thong (2019) measured students' science self-efficacy. Sung and Hwang (2018) included a measure of students' self-efficacy in the context of a collaborative group, and Chu et al. (2019) and Infante et al. (2010) examined whether group collaboration related to learning.

3.2.2. Methodological approaches to measuring cognitive outcomes

Direct and Indirect Outcomes. Here, we discuss the approaches used in the literature to operationalize and capture cognitive skills that might be impacted by digital gaming. Most of the research we reviewed examined executive functioning (EF) with attention to the component processes of working memory, attention, inhibition, and cognitive flexibility. However, we reviewed a small body of literature examining cognitive outcomes such as metacognition (Ricker & Richert, 2021) and problem-solving (Fisch et al., 2011). Researchers also examined moderators of cognitive improvements such as number of game logins (Song et al., 2020), game performance (Flynn, Richert, Staiano, Wartella, & Calvert, 2014; Song et al., 2020), and individual difference factors such as motor ability (Benzing & Schmidt, 2019), and heart rate (Best, 2012; Flynn & Richert, 2018). Another group of studies examined indirect outcomes such as enjoyment or engagement, boredom, frustration, and time-on-task (e.g., Best, 2012; Flynn & Colon, 2016; Homer et al., 2019; Weerdmeester, Cima, Granic, Hashemian, & Gotsis, 2016).

Common measures of EF were those assessing specific components such as working memory, attention, inhibition, and cognitive flexibility (e.g., Go/No-Go, Dimensional Change Card Sort, Stroop or Flanker Tasks) or standardized neuropsychological batteries that measured all components of EF (e.g., Benzing & Schmidt, 2019; Dovis, Van der Oord, Wiers, & Prins, 2012, 2015; Flynn & Richert, 2018; Homer et al., 2019; Rosetti et al., 2020; Song et al., 2020; Tahiroglu et al., 2010). Further, EF was often measured pre- and post-game play using standardized paradigms, although these cognitive skills also were assessed during game play through gamified cognitive tasks (e.g., Bikic et al., 2018; Song et al., 2020) or via commercial games that may not have been designed to enhance cognitive skills such as exergames (e.g., Benzing & Schmidt, 2019; Best, 2012; Flynn & Richert, 2018). For example, Song et al. (2020) used the game CoCon, which was adapted from cognitive testing paradigms and designed with a narrative game structure similar to commercial recreational games. Specifically, this game was designed to assess sustained attention, working memory, inhibition, response selection, and categorization via 10 "subgames". A subsample of work reviewed included clinical measures of children's cognition or behavior among neurodiverse populations (e.g., attention deficit hyperactivity disorder (ADHD), impulsivity, autism spectrum disorders (ASD), or special needs more broadly; Chukoskie, Westerfield, & Townsend, 2018; Crepaldi et al., 2020; Flynn & Colon, 2016; Garcia-Redondo, Garcia, Areces, Nunez, & Rodriguez, 2019; Mercado, Escobedo, & Tentori, 2020; Weerdmeester et al., 2016). Examples of clinical measurements used in the literature included standardized parent or teacher report measures of ADHD (e.g., *ADHD VragenLijs*, Weerdmeester et al., 2016; *ADHD-T*, Mercado et al., 2020) or clinical measures conducted by researchers (e.g., *Diagnostic Interview Schedule for Child-Parent Version*, *Evaluation of the Deficit of Attention Hyperactivity Scale*; Garcia-Redondo et al., 2019).

Among the literature examining cognitive skills other than EF, were those that measured metacognition and problem-solving. For example, Ricker and Richert (2021) used the *Jr. Metacognitive Awareness Inventory* to examine whether children's metacognitive awareness differed based on the characteristics of digital games that they played (e.g., level of interactivity). Fisch et al. (2011) measured problem-solving in the context of a researcher-developed game in which elementary school-age students' strategies for solving a given set of math problems were examined over time using data mining techniques.

3.2.3. Exemplar studies where content learning and cognitive outcomes are measured

Most of the studies reviewed examined either content-based learning or cognitive skills. However, we reviewed several articles in which both direct learning of academic outcomes and cognitive skills were examined in the same study (e.g., Butler et al., 2014; Castellar, All, de Marez, & Van Looy, 2015; Goldin et al., 2014; Kourakli et al., 2017; Liao et al., 2019; Vanbecelaere et al., 2020). For example, Franceschini and colleagues measured reading skills using a word recognition task, execution time, and number of errors during a reading session among children with dyslexia who played action video games (2017). In this study, changes in children's working memory and attention before and after the action video game play, were also examined as a potential moderator of reading improvements (Franceschini et al., 2017). In another example where cognition and learning outcomes were measured in tandem, Goldin et al. (2014) measured inhibitory control and cognitive flexibility using a battery of standardized tasks including an Attentional Network Test (ANT), Stroop task, and Tower of London task. These tools were used to examine whether changes in cognitive control were predictive of school performance in mathematics and language skills.

3.3. Which designs are researchers using?

Researchers interested in examining the relationships between digital gaming, content learning, and cognitive skills have many options available in terms of research design. We reviewed work ranging from case studies to experimental designs, including both, business as usual and active control groups. Research settings varied from lab-based studies to naturalistic settings (e.g., classrooms, homes, and out-of-school programs). We share below the most prevalent types of designs we found and highlight exemplar studies to illustrate their methodological strengths.

3.3.1. Non-experimental designs

Many studies utilized non-experimental designs to explore how and what children learned from digital games. These studies allowed for an in-depth and nuanced description of the complex relationships between digital gaming, children's cognitive abilities, and learning within the game. Similarly, these designs allowed for feasibility and usability testing before conducting a carefully controlled experiment.

Usability and Feasibility Designs. The usability and feasibility studies we reviewed varied in their sample sizes, methodologies, and purposes. Overall, these studies examined whether children were able to play a game, if they enjoyed it, or which features of games engaged them. These studies were often conducted to assess the feasibility of incorporating games into classroom settings (e.g., Anderson & Barnett, 2013; Bigueras, 2020; Infante et al., 2010), extending learning at home via games (e.g., Lee, Mauriello, Ahn, & Bederson, 2014; Rosetti et al., 2020), or as a novel treatment for children with ADHD (e.g., Weerdmeester et al., 2016). Infante et al.'s (2010) work serves as an exemplary usability study regarding game-play in classrooms. These researchers piloted their game, which was designed to teach content material collaboratively (i.e., three children to a screen), in a classroom setting with 36 six-year-old students. They gathered qualitative information during and after a game play session with children who had not yet learned to read, write, or use a computer. Feasibility data were gathered, for example, via teacher observation of student play and post-game interviews, qualitative indicators of children's satisfaction with the game play experience, evaluations of students' ability to use the hardware and software effectively and master game strategies, and examination of students' collaborative game play in small groups.

The work of Rosetti et al. (2020) serves as a good example of testing the feasibility of using games for learning outside the classroom. Here, Rosetti et al. (2020) examined whether children's game-play behavior differed based on context (i.e., in home vs. in school) and the relationship between engagement in the game and neuropsychological outcomes. The researchers sought to determine if the cognitive training game could improve cognition by screening children with a traditional standardized neuropsychological battery of cognitive functions before and after playing a cognitive training game. In another feasibility study focused on cognitive outcomes, Weerdmeester et al. (2016) examined whether engagement with an active video game (i.e., exergame) outside the school context would improve a range of ADHD symptoms. The feasibility data collected focused on student enjoyment of the novel clinical intervention (i.e., using an exergame as treatment).

Other data gathering techniques noted in the usability/feasibility studies we reviewed were semi-structured interviews, focus groups, and non-verbal data collection (e.g., Anderson & Barnett, 2013; Holbert & Wilensky, 2014; Kyriakides, Meletiou-Mavrotheris, & Prodromou, 2016; Lee et al., 2014). For example, Anderson and Barnett (2013) randomly selected a small subset of their larger sample to probe students' understanding further by having them draw pictures of the concepts learned. Usability or feasibility studies, like those reviewed here, are useful as they help researchers design controlled or randomized studies, or, in the case of researcher-designed games, to inform researchers about how to enhance games used to make them more conducive to learning or more enjoyable for users.

Case Studies and Collective Case Designs. Case studies are more than examinations of a single case and can involve careful evaluation of either individual or small groups of children (i.e., collective case designs; Mills, Durepos, & Wiebe, 2010). Case studies differ from feasibility studies as they are designed to yield rich descriptions of children's behavior, or motivation to play or engage in the game over short periods of game play (e.g., Avila-Pesantez, Delgadillo, & Rivera, 2019; Ke & Im, 2014; Silva da Cunha, Travassos Junior, Guizzo, & de Sousa Pereira-Guizzo, 2016). For example, Vasalou et al. (2017) examined the interactions of eight children with dyslexia while playing a suite of games designed to promote skills related to word decoding, spelling, and fluency. The researchers used qualitative analysis to examine the growth of collaborations during game play such as negotiations of competition and impasses. The researchers also examined the role of an adult tutor in the game play setting by assessing whether the tutor's resolution of individual children's impasses during game play allowed for "teachable moments" among the larger group of students. Overall, the researchers' focus was less on the content learned than the nature of the game–student, student–student and student–tutor interactions that promoted the learning of content.

In fact, we reviewed many case studies that collected robust data, including that of Tsai, Yu, and Hsiao (2012), who examined eight sixth-grade students' behaviors in the context of a game designed to share facts about saving electricity in one's home. The researchers first gathered information addressing students' prior knowledge about the game content as reflected in their grades from the prior academic year, thus creating groups with high and low prior knowledge. Over the course of six weeks, including 40 min of game play each week, extensive student information was gathered that included observations of student behaviors, examinations of worksheets that students completed during game play, recordings of their in-game behaviors and of students' think-alouds, and post-game interview responses about students' perceptions of game enjoyability and efficacy for learning. The wealth of data gathered about these eight students allowed conclusions to be drawn regarding how children's interest and actions in the game impacted what they learned and how they experienced that learning.

3.3.2. Quasi-experimental and experimental designs

Many of the studies we reviewed employed quasi-experimental or experimental designs that included measurement of outcomes before and after game play (pre- to post-test designs). Some of these studies did not use a control group as the game was meant to complement traditional teaching (Murphy & Darrah, 2015). Other researchers compared digital game play to traditional teaching methods to determine whether games could replace traditional classroom activities (e.g., Castellar et al., 2015). We also found studies that used active control conditions, which allowed researchers to determine which game features might aid learning; a key concern for those investigations designed to examine the efficacy of a given game for skill or content acquisition. Some quasi-experimental designs employed a person by treatment design using individual difference factors or within-person designs to examine change. Finally, a small subset of studies included rigorous longitudinal designs or randomized control trials to test questions of interest.

Quasi-Experiments. Inclusion of comparison and/or control groups tended toward two approaches. One approach entailed using a digital game play condition and comparing the outcomes to a condition in which a typical teaching technique was used (e.g., teacher-led or self-directed workbooks; Hussein, Ow, Cheong, & Thong, 2019; Yang, 2017). Another approach entailed using active control groups to compare two different types of game play experience (e.g., varying game features or comparing different types of games; Araújo & de Almondes, 2015; Bakker et al., 2016; Beserra, Nussbaum, Oteo, & Martin, 2014; Lin et al., 2018). Goldin et al.'s study (2014) provided a good example of using an active control group. Specifically, the researchers compared two different video game groups over a 10-week period examining both executive functioning (EF) and academic outcomes. One group played three adaptive games designed to train EF while the other group played three games that were less cognitively demanding. The games were chosen to be equally motivating and to require the same types of motor responses, to control for game differences. This methodological approach allowed researchers to determine whether improvements in EF and academic outcomes were specific to the games focused on facilitating EF.

Other researchers used active control groups that varied game features. For example, in their investigation of ways to facilitate improvements in EF through game play practice, Homer et al. (2019) had students play a version of a researcher-developed game whereby the characters were designed to be emblematic of hot cognition (i.e., showed an emotional expression and were portrayed in color) or of cool cognition (i.e., showed neutral expressions and were portrayed in black and white). This comparison allowed researchers to determine the most appropriate stimuli for facilitating EF.

Hussein, Ow, Cheong, Thong, and Ebrahim (2019) employed a traditional teaching (i.e., business-as-usual) control condition with a pre- and post-test design using a game designed to engage critical thinking about ecology. To test the effectiveness of the game for promoting school children's skills, they partnered with four 5th-grade classrooms in Kajang district, Malaysia whereby two classrooms served as part of the treatment condition and two as part of the control condition. By blending control classrooms with pre- and post-assessments, Hussein, Ow, Cheong, and Thong (2019) were better situated to draw generalizable conclusions from student involvement with the game.

Other researchers compared a traditional teaching control condition with two experimental groups, such as using an active control group in which features of the game were varied. For example, Yang (2017) examined pre- to post-test gains in social studies for fifth grade students in northern Taiwan who played a digital game that promoted learning about domestic and foreign food culture. The authors hoped to learn whether the type of feedback provided through the game impacted learning behavior. Yang randomly assigned three classrooms to three conditions: a conventional learning group, a digital game group with minimal feedback (e.g., correct or incorrect) and a digital game group with corrective feedback (e.g., feedback that explains the error). The design of this study allowed for gaining insight into the best practices for in-game feedback and for determining whether the digital game was comparable to traditional teaching.

Jere-Folotiya et al. (2014) conducted a large-scale study ($N = 573$) with six different control groups to examine if a game played on a cellphone would improve literacy skills of first graders in Zambia, Africa. First, the researchers randomly selected 42 schools from the 102 possible government schools and then randomly assigned classrooms to either a control group or one of five intervention groups. The intervention groups varied on two factors; who played the game and the amount of training a teacher received. There were three levels of play whereby students only played the game, teachers only played the game, or students and teachers played the game. Teachers' training on how to implement the game varied in extensiveness. Overall, this type of study allowed the researchers to determine the level of teacher training and involvement needed to increase learning outcomes and ultimately how best to implement the game into a school system.

We also reviewed several studies that employed a person by treatment design, either by recruiting children by gamer status (e.g., Ronimus & Lyytinen, 2015), grouping them into gamer vs. non-gamer categories (e.g., Ricker & Richert, 2021) or by grouping participants based on other individual difference factors, such as learning anxiety (Yang et al., 2018), or emotional intelligence (Yang, Quadir, & Chen, 2019). Further, van den Heuvel-Panhuizen, Kolovou, and Robitzsch (2013) grouped participants by the individual difference factors to examine how engaging at home with an online dynamic game supported children's math skills. Here, software was monitoring children's game-play behavior. The researchers used two quasi-factors, grade (4th, 5th, and 6th) and strategy use profile, to examine differences in pre-post change on a paper-and-pencil test of algebraic skill. This approach allowed for the examination of the effects of strategy use on algebraic success and whether the effects were consistent across age groups (van den Heuvel-Panhuizen et al., 2013).

While not all researchers grouped children by individual differences factors as part of their research design, many controlled for individual differences statistically by using an Analysis of Covariance approach (e.g., Beserra, Nussbaum, & Oteo, 2019; Flynn & Richert, 2018; Franceschini et al., 2017), which allows researchers to determine how certain factors (e.g., enjoyment or prior video game experience) influence changes in content learning or cognition. Within-subjects designs were less common in our review than between-subjects designs, especially those that tested multiple experimental conditions within children (e.g., Best, 2012; Block et al., 2018; Furió et al., 2013). Among those that did utilize a within-subjects design, one that deserves mention is Block et al. (2018) who investigated differential impacts of exercise breaks and action-based video game breaks on math learning. During an 8-hour learning session, children experienced each of four types of breaks: low-intensity exercise, moderate-intensity exercise, high-intensity exercise, and a sedentary computer game. Because the breaks only varied in type of activity, the researchers allowed for each participant to serve as their own control.

Longitudinal Designs. Studies that used longitudinal designs involving more than two time points were limited in our review and mostly found in case study designs (e.g., Dourda et al., 2014;

Tsai et al., 2012) that followed players over several weeks of game use. However, the few longitudinal studies that we found contained large sample sizes allowing for a strong analytic approach and increased generalizability (e.g., Bakker et al., 2016; Furió et al., 2013; Goldin et al., 2014; Vanbecelaere et al., 2020). For example, Bakker et al. (2016) followed a near-representative sample of school-aged children in the Netherlands from grade 1 to grade 3 (n = 719). Their multiplicative reasoning (declarative knowledge, procedural knowledge, and conceptual knowledge/insight) as a function of engagement with mini-games (i.e., short, focused games that are easy to learn) was examined either in the school or home context, or in combination. By examining children's multiplicative reasoning repeatedly as a function of where the child engaged in the game, the researchers could investigate the immediate and long-lasting effects of context.

Randomized Control Trials (RCTs). These types of designs were the least prevalent in our review. RCTs have obvious strengths as they allow for investigation of causality. However, RCTs are typically more expensive and labor intensive than quasi-experimental designs. Further, researchers working with children in schools or clinical settings are also faced with the challenges of providing differential interventions to children at random. The majority of studies that employed RCT designs examined the impacts of digital gaming on content learning and/or cognitive skills in clinical or neuro-atypical samples, such as children with ADHD (e.g., Bikic et al., 2018; Dovis et al., 2015) or ASD (e.g., Serret et al., 2017).

For example, Dovis et al. (2015) investigated the impact of a computer game they designed to train EF skills among children with ASD in the context of three tasks assessing either working memory, cognitive flexibility, or inhibition. Children were randomly assigned into one of three conditions: (1) fully active condition where all three EF tasks were played in training mode and the difficulty adapted to children's performance; (2) partially active condition where the cognitive flexibility and inhibition tasks were played in training mode, but the working memory task was played in placebo mode, where children completed all trials on the easiest level and the difficulty level was not adjusted in response to the child's performance; and (3) full placebo condition where all three EF tasks were in placebo mode such that the difficulty level was not adjusted in response to the child's performance. By using this experimental design, the researchers could draw causal conclusions about the efficacy of adaptively adjusting difficulty levels within the game and were able to unpack the benefits of task specific training for specific cognitive outcomes among children with ASD.

4. Discussion

Our review highlights several key methodological considerations for researchers interested in examining digital gaming as an important CCI with the potential to enhance cognitive skills and content knowledge acquisition among 6 to 12-year-old children.

4.1. Considerations for types of games

Many of the games cited in our findings were researcher-developed and intended to influence cognition or content learning. These games were largely didactic in nature and ostensibly used to gamify teaching. However, we also saw a small subset of studies that used commercially developed games. We see the challenge for researchers as deciding when it is better to design a game for the purposes of their research versus when it is better to use a commercially available game.

A disadvantage to using researcher-developed games is that they typically are made using smaller development budgets than commercial games which has implications for the quality and playability of the game and for children's sustained engagement with them. Further, children might engage with these games differently than commercially available games, limiting their generalizability to how children learn from or enhance their cognitive skills via more widely available educational or recreational games. However, the use of researcher-developed games has advantages whereby it allows researchers to adapt games as warranted for players, especially in the context of usability and feasibility testing, as highlighted in our review. This approach also allows researchers to experimentally manipulate features of the games to test hypotheses addressing how these features might influence content learning and/or cognitive skills.

Although very few studies that we reviewed examined commercially available games, a case can be made for their use as children in middle childhood spend many hours playing them (ESA, 2020; GameTrack, 2019). A disadvantage to their use is the limited flexibility and control researchers have over aspects of the game, as most commercially available games do not legally allow for changes to the game or its underlying coding. However, commercial games are readily accessible, can be played in diverse settings, and are ecologically valid thereby enabling researchers to capture the skill enhancement and learning that may occur in recreational and more formal learning settings.

4.2. Considerations for measuring outcomes

We also surveyed the outcomes researchers chose to measure and their methodological approaches to capturing those outcomes. We observed greater emphasis on learning outcomes as related to content and academic skills (e.g., phonemic recognition) than on cognitive outcomes (e.g. cognitive flexibility and metacognition). However, this imbalance may have reflected our search strategy, in which the keywords selected may have constrained the studies we found.

Overall, our review showed that researchers focused on outcomes related to content learning and critical thinking using diverse measures. The majority of studies included researcher-constructed assessments, with the occasional use of standardized tests, and teacher-created evaluations of a given subject matter or skill set. Some researchers further tailored their measures to better assess specific student populations which enhanced the ecological validity of their findings for those populations. Among these studies, we found that researchers often included both direct and indirect measures of content learning in their work. A promising trend we observed was a shift toward the interplay between direct and indirect outcomes. These examinations included evaluating indirect outcomes as predictors of direct outcomes (e.g., engagement as a predictor of math improvement from serious gaming; Deater-Deckard et al., 2014), considering indirect outcomes as influencing factors when examining the efficacy of gaming for direct outcomes (e.g., how learning motivation impacts knowledge acquisition in game-based learning; Tsai et al., 2012), or testing indirect outcomes as moderators of the effects that digital gaming has on direct learning outcomes (e.g., cognitive engagement as a moderator of word reading gains pre- and post digital gaming; Ronimus et al., 2019). This approach allows for greater examination of individual differences in learning from digital gaming rather than examining direct or indirect learning outcomes on their own.

The measurement tools used by researchers to examine linkages between game play and general cognitive mechanisms were predominantly clinical in nature (i.e., centering on cognitive training for neurodiverse children), although we found some examples whereby cognitive training was situated in a regular academic context. Still, nearly all of the studies we reviewed that examined cognitive training focused on executive functions, with only two studies focusing on other cognitive skills (e.g., Fisch et al., 2011; Ricker & Richert, 2021). We see this emphasis as compromising what can be learned about the impacts of digital gaming on these other aspects of cognition that clearly impact learning via game play and more traditional academic tasks. Further, from a developmental science perspective, one might argue that enhancements in general cognitive mechanisms via digital gaming, which warrants examination of more than EF, should transfer to content learning gains. Several studies were poised to examine this transfer as the researchers measured cognitive skills and/or development in concert with measures of content learning. This methodological approach is a promising future direction as it allows researchers to determine how children enhance their skills and acquire knowledge through CCI, such as digital game play.

Among the studies examining the influence of digital games on cognitive skills, the majority focused on measuring direct outcomes, with only a handful considering how indirect outcomes might moderate the results. We contend that these outcomes are better understood when complemented with information about how children play the game. A promising trend we observed within this body of literature was the growing number of studies with innovative approaches to gathering data about children's actions during game play through screen capture videos and recording of children while gaming (e.g., Dovis et al., 2015; Ricker & Richert, 2021), data mining techniques to examine children's gaming log files (e.g., Fisch et al., 2011; Homer et al., 2019), and coordinating data with physiological behaviors such as eye movements (Chukoskie et al., 2018). These approaches were less prevalent in the studies that examined content learning outcomes. The nexus of these approaches to measuring and assessing behavior during game play has ramifications for what is learned about game efficacy and direct outcomes resulting from that play, with respect to cognition and content learning.

4.3. Considerations for research designs

Our review yielded studies with a wide range of research designs employed to examine gaming as a meaningful child–computer interaction for learning and cognition. The decision of what research design to use, is one that must be driven by the research question at hand and the ability of the research team. Many studies utilized non-experimental designs to explore how and what children learn from digital games. These designs allow for feasibility and usability testing before conducting a more carefully controlled experiment and provide an in-depth and nuanced description of the complex relationships between digital gaming, children's cognitive abilities, and learning within the game.

Alternatively, we also reviewed many studies that employed quasi-experimental designs including pre-post-designs with varying control conditions, person by treatment designs using individual difference factors, or within-subjects designs. These studies allowed for the examination of change in content knowledge or cognitive skills, and complementary investigations of the moderators and potential predictors of that change. Finally, there were very few examples of rigorous longitudinal designs or RCTs that could address the causal relationships between gaming and cognition or content learning. The RCT studies that were found tended to include primarily clinical or neuro-diverse samples, limiting the generalizability of their causal findings. This situation could be rectified via the use of within-subjects designs or RCT studies in traditional classroom settings. Continued use of longitudinal designs with multiple data collection points also would enable researchers to examine optimal dosage level of game play and the point at which game play as an intervention may no longer be efficacious (see Dore, Logan, Lin, Purtell, & Justice, 2020).

One notable strength we saw across research designs was the inclusion of individual difference factors (e.g., affective game states, prior game experience or knowledge) to examine changes in learning or cognition. We appreciated this approach as it allowed for clearer conclusions about for whom the games were the most or least beneficial (Blumberg, Flynn, Kleinknecht, & Ricker, 2019). This approach stands in sharp contrast to the "one game fits all" assumption which remains prevalent in a fair number of studies examining game play effects on children's learning. Examining individual difference factors, including those pertinent to developmental differences, also enables researchers to examine the choices that children make while playing and to coordinate those choices with both direct and indirect learning outcomes of game play. This type of examination is what we see as informing decisions that can be communicated to educators and parents about the best type of game to facilitate a given type of learning. In fact, we see these decisions as key to those within the CCI research community.

5. Limitations and future directions

Our review has some limitations, particularly stemming from the title-keyword search strategy which may have resulted in missing studies relevant to our aims. As developmental psychologists invested in the study of digital game play's impact on cognitive enhancements for children and adolescents, the notable paucity of articles from our own field was surprising. That is, the title keyword search strategy may not have been specific enough to capture all the work that has been done across different disciplines such as our own. For this reason, we cannot make definitive claims about whether a particular design feature or measured outcome (e.g., cognitive skills) is under-represented in the literature. That said, the body of work represented in our review is quite sizable and demonstrates the diversity of CCI research methods. A second limitation stems from our decision to review a broad scope of methods and outcomes rather than focus on directional findings of the research. This decision was aligned with our goal to offer an overview of methodological features currently used to examine game-based learning in middle childhood. There is a need for future systematic reviews or meta-analyses that examine directional findings. We see our narrative review as informing this work.

6. Conclusions

Overall, the purpose of our narrative review was to bring cohesion to the research that has been done across disciplines examining digital games as an important child–computer interaction that may improve academic content learning and cognitive skills in middle childhood. The broad nature of the international literature reviewed here elucidates opportunities for bridging gaps both in terms of the methodologies used and how researchers across disciplines might collaborate to efficiently and comprehensively investigate the impacts of digital gaming on cognitive and academic skills. Researchers should capitalize on these opportunities as digital gaming increasingly becomes an integral part of children's daily activities.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table A.1
Articles reviewed for methods.

Author(s)	Year of publication	Journal of publication
Anderson & Barnett	2013	Journal of Science Education and Technology
Avila-Pesantez et al.	2019	IEEE Access
Bakker et al.	2016	British Journal of Educational Technology
Benzing & Schmidt	2019	Scandinavian Journal of Medicine & Science in Sports
Bergey et al.	2015	Journal of Science Education and Technology
Beserra & Oteo	2019	Journal of Educational Computing Research
Beserra et al.	2014	Computers in Human Behavior
Bigueras	2020	International Journal of Advanced Trends in Computer Science and Engineering
Bikic et al.	2018	European Child & Adolescent Psychiatry
Block et al.	2018	Pediatric Exercise Science
Butler et al.	2014	ELT Journal
Castellar et al.	2015	Computers & Education
Checa-Romero	2016	Games and Culture
Chen et al.	2018	British Journal of Educational Technology
Chu et al.	2019	Educational Technology & Society
Chukoskie et al.	2018	Developmental Neurobiology
Crepaldi et al.	2020	Information
Araújo & de Almondes	2015	Biological Rhythm Research
Deater-Deckard et al.	2014	International Journal of Child-Computer Interaction
Dourda et al.	2014	Electronic Journal of e-Learning
Dovis et al.	2012	Journal of Abnormal Child Psychology
Dovis et al.	2015	PLoS One
Es-Sajjade & Paas	2020	Educational Technology Research and Development
Fisch et al.	2011	Child Development Perspectives
Flynn & Colon	2016	Games for Health Journal
Flynn & Richert	2018	Journal of Cognition and Development
Franceschini et al.	2017	Scientific Reports
Furió et al.	2013	Computers & Education
Gao et al.	2013	American Journal of Preventive Medicine
Garcia-Redondo et al.	2019	International Journal of Environmental Research and Public Health
Goldin et al.	2014	PNAS
Harker-Schuch et al.	2020	Computers & Education
Holbert & Wilensky	2014	Technology, Knowledge and Learning
Homer et al.	2019	Cognitive Development
Hussein et al.	2019	IEEE Access
Hwang et al.	2013	Computers & Education
Hwang et al.	2012	Educational Technology Research and Development
Imlig-Iten & Petko	2018	Simulation & Gaming
Infante et al.	2010	Interactive Learning Environments
Jere-Folotiya et al.	2014	Educational Technology Research and Development
Ke & Im	2014	International Journal of Technology and Design Education
Kourakli et al.	2017	International Journal of Child-Computer Interaction
Kyriakides et al.	2016	Mathematics Education Research Journal
Lee et al.	2014	International Journal of Child-Computer Interaction
Liao et al.	2019	Computers & Education
Lin et al.	2018	Educational Technology & Society
Masek et al.	2017	Journal of Computer Assisted Learning
Mercado et al.	2020	Journal on Multimodal User Interfaces
Moyer-Packenham et al.	2019	Computers in Human Behavior
Murphy & Darrah	2015	IEEE Transactions on Haptics
O'Rourke et al.	2017	Australian Journal of Teacher Education
Pitchford et al.	2019	Developmental Science
Ricker & Richert	2021	Computers in Human Behavior
Ronimus & Lyytinen	2015	Human Technology
Ronimus et al.	2019	Educational Technology Research and Development
Ronimus et al.	2014	Computers & Education
Rosetti et al.	2020	International Journal of Child-Computer Interaction
Sampayo-Vargas et al.	2013	Computers & Education
Serret et al.	2017	Frontiers in Psychology
Silva da Cunha et al.	2016	Psicologia: Reflexão e Crítica
Song & Park	2020	PLoS One
Sun & Gao	2016	Journal of Sport and Health Science
Sung & Hwang	2018	Interactive Learning Environments
Tahiroglu et al.	2010	Journal of Attention Disorders
Tazouti et al.	2019	International Journal of Emerging Technologies in Learning
Tsai et al.	2012	Educational Technology & Society
van den Heuvel-Panhuizen et al.	2013	Educational Studies in Mathematics
Vanbecelaere et al.	2020	Computers & Education
Vasalou et al.	2017	Computers & Education
Weerdmeester et al.	2016	Games for Health Journal
Yang	2017	Interactive Learning Environments
Yang et al.	2019	International Journal of Human-Computer Interaction
Yang et al.	2018	Journal of Computer Assisted Learning

Note. All 73 articles reviewed for methodology presented here are cited within the manuscript. See Reference Page for the full citation.

Appendix

See Table A.1.

References

Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, *22*(6), 914–926. http://dx.doi.org/10.1007/s10956-013-9438-8.

Araújo, D. D. F., & de Almondes, K. M. (2015). Evaluation of intervention with electronic games upon cognitive processes of elementary school students in a Brazilian state-run school: The role of sleep. *Biological Rhythm Research*, *46*(3), 389–401. http://dx.doi.org/10.1080/09291016.2015.1015234.

Avila-Pesantez, D., Delgadillo, R., & Rivera, L. A. (2019). Proposal of a conceptual model for serious games design: A case study in children with learning disabilities. *IEEE Access*, *7*, 161017–161033. http://dx.doi.org/10.1109/access.2019.2951380.

Bakker, M., van den Heuvel-Panhuizen, M., & Robitzsch, A. (2016). Effects of mathematics computer games on special education students' multiplicative reasoning ability. *British Journal of Educational Technology*, *47*(4), 633–648. http://dx.doi.org/10.1111/bjet.12249.

Benzing, V., & Schmidt, M. (2019). The effect of exergaming on executive functions in children with ADHD: A randomized clinical trial. *Scandinavian Journal of Medicine & Science in Sports*, *29*(8), 1243–1253. http://dx.doi.org/10.1111/sms.13446.

Bergey, B. W., Ketelhut, D. J., Liang, S. F., Natarajan, U., & Karakus, M. (2015). Scientific inquiry self-efficacy and computer game self-efficacy as predictors and outcomes of middle school boys' and girls' performance in a science assessment in a virtual environment. *Journal of Science Education and Technology*, *24*(5), 696–708. http://dx.doi.org/10.1007/s10956-015-9558-4.

Beserra, V., Nussbaum, M., & Oteo, M. (2019). On-task and off-task behavior in the classroom: A study on mathematics learning with educational video games. *Journal of Educational Computing Research*, *56*(8), 1361–1383. http://dx.doi.org/10.1177/0735633117744346.

Beserra, V., Nussbaum, M., Oteo, M., & Martin, R. (2014). Measuring cognitive load in practicing arithmetic using educational video games on a shared display. *Computers in Human Behavior*, *41*, 351–356. http://dx.doi.org/10.1016/j.chb.2014.10.016.

Best, J. R. (2012). Exergaming immediately enhances children's executive function. *Developmental Psychology*, *48*(5), 1501–1510. http://dx.doi.org/10.1037/a0026648.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641–1660. http://dx.doi.org/10.1111/j.1467-8624.2010.01499.x.

Bigueras, R. T. (2020). Design of mobile game-based learning application for children with dyslexia. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*, 322–326. http://dx.doi.org/10.30534/ijatcse/2020/4991.32020.

Bikic, A., Leckman, J. F., Christensen, T. O., Bilenberg, N., & Dalsgaard, S. (2018). Attention and executive functions computer training for attention-deficit/hyperactivity disorder (ADHD): Results from a randomized, controlled trial. *European Child & Adolescent Psychiatry*, *27*(12), 1563–1574. http://dx.doi.org/10.1007/s00787-018-1151-y.

Block, S. S., Tooley, T. R., Nagy, M. R., O'Sullivan, M. P., Robinson, L. E., Colabianchi, N., et al. (2018). Acute effect of intermittent exercise and action-based video game breaks on math performance in preadolescent children. *Pediatric Exercise Science*, *30*(3), 326–334. http://dx.doi.org/10.1123/pes.2017-0183.

Blumberg, F. C., Altschuler, E. A., Almonte, D. E., & Mileaf, M. I. (2013). The impact of recreational video game play on children's and adolescents' cognition. *New Directions for Child and Adolescent Development*, *2013*(139), 41–50. http://dx.doi.org/10.1002/cad.20030.

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

Blumberg, F. C., Flynn, R. M., Kleinknecht, E., & Ricker, A. A. (2019). Cognitive development and gaming in the digital age. *Ubiquitous Learning: An International Journal*, *12*(2), 39–50. http://dx.doi.org/10.18848/1835-9795/CGP/v12i02/39-50.

Blumberg, F. C., & Randall, J. D. (2013). What do children and adolescents say they do during video game play? *Journal of Applied Developmental Psychology*, *34*(2), 82–88. http://dx.doi.org/10.1016/j.appdev.2012.11.004.

Butler, Y. G., Someya, Y., & Fukuhara, E. (2014). Online games for young learners' foreign language learning. *ELT Journal*, *68*, 265–275. http://dx.doi.org/10.1093/elt/ccu008.

Calvert, S. L., Appelbaum, M., Dodge, K. A., Graham, S., Nagayama Hall, G. C., Hamby, S., et al. (2017). The American Psychological Association Task Force assessment of violent video games: Science in the service of public interest. *American Psychologist*, *72*(2), 126–143. http://dx.doi.org/10.1037/a0040413.

Calvert, S. L., Putnam, M. M., Aguiar, N. R., Ryan, R. M., Wright, C. A., Liu, Y. H. A., et al. (2019). Young children's mathematical learning from intelligent characters. *Child Development*, http://dx.doi.org/10.1111/cdev.13341.

Castellar, E. N., All, A., de Marez, L., & Van Looy, J. (2015). Cognitive abilities, digital games and arithmetic performance enhancement: A study comparing the effects of a math game and paper exercises. *Computers & Education*, *85*, 123–133. http://dx.doi.org/10.1016/j.compedu.2014.12.021.

Checa-Romero, M. (2016). Developing skills in digital contexts: Video games and films as learning tools at primary school. *Games and Culture*, *11*(5), 463–488. http://dx.doi.org/10.1177/1555412015569248.

Chu, H. C., Wang, C. C., & Wang, L. (2019). Impacts of concept map-based collaborative mobile gaming on English grammar learning performance and behaviors. *Educational Technology & Society*, *22*(2), 86–100. http://dx.doi.org/10.2307/26819619.

Chukoskie, L., Westerfield, M., & Townsend, J. (2018). A novel approach to training attention and gaze in ASD: A feasibility and efficacy pilot study. *Developmental Neurobiology*, *78*(5), 546–554. http://dx.doi.org/10.1002/dneu.22563.

Crepaldi, M., Colombo, V., Mottura, S., Baldassini, D., Sacco, M., Cancer, A., et al. (2020). Antonyms: A computer game to improve inhibitory control of impulsivity in children with Attention Deficit/Hyperactivity Disorder (ADHD). *Information*, *11*(4), http://dx.doi.org/10.3390/info11040230, Article 230.

Deater-Deckard, K., El Mallah, S., Chang, M., Evans, M. A., & Norton, A. (2014). Student behavioral engagement during mathematics educational video game instruction with 11–14 year olds. *International Journal of Child-Computer Interaction*, *2*(3), 101–108. http://dx.doi.org/10.1016/j.ijcci.2014.08.001.

Dore, R. A., Logan, J., Lin, T.-J., Purtell, K. M., & Justice, L. M. (2020). Associations between children's media use and language and literacy skills. *Frontiers in Psychology*, *11*, 1734. http://dx.doi.org/10.3389/fpsyg.2020.01734.

Dourda, K., Bratitsis, T., Griva, E., & Papadopoulou, P. (2014). Content and language integrated learning through an online game in primary school: A case study. *Electronic Journal of e-Learning*, *12*(3), 243–258, https://files.eric.ed.gov/fulltext/EJ1035666.pdf.

Dovis, S., Van der Oord, S., Wiers, R. W., & Prins, P. J. (2012). Can motivation normalize working memory and task persistence in children with attention-deficit/hyperactivity disorder? The effects of money and computer-gaming. *Journal of Abnormal Child Psychology*, *40*(5), 669–681. http://dx.doi.org/10.1007/s10802-011-9601-8.

Dovis, S., Van der Oord, S., Wiers, R. W., & Prins, P. J. (2015). Improving executive functioning in children with ADHD: Training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial. *PLoS One*, *10*(4), Article e0121651. http://dx.doi.org/10.1371/journal.pone.0121651.

Dubé, A. K., & Dubé, N. J. (2020). Policies to guide the adoption of educational games into classrooms. *Educational Technology Research and Development*, http://dx.doi.org/10.1007/s11423-020-09835-9.

Es-Sajjade, A., & Paas, F. (2020). Educational theories and computer game design: Lessons from an experiment in elementary mathematics education. *Educational Technology Research and Development*, http://dx.doi.org/10.1007/s11423-020-09799-w.

ESA (2020). Essential facts about the video game industry. https://www.theesa.com/esa-research/2020-essential-facts-about-the-video-game-industry.

Fisch, S. M., Lesh, R., Motoki, E., Crespo, S., & Melfi, V. (2011). Children's mathematical reasoning in online games: Can data mining reveal strategic thinking? *Child Development Perspectives*, *5*(2), 88–92. http://dx.doi.org/10.1111/j.1750-8606.2011.00161.x.

Flynn, R. M., & Colon, N. (2016). Solitary active videogame play improves executive functioning more than collaborative play for children with special needs. *Games for Health Journal*, *5*(6), 398–404. http://dx.doi.org/10.1089/g4h.2016.0053.

Flynn, R. M., & Richert, R. A. (2018). Cognitive, not physical, engagement in video gaming influences executive functioning. *Journal of Cognition and Development*, *19*(1), 1–20. http://dx.doi.org/10.1080/15248372.2017.1419246.

Flynn, R. M., Richert, R. A., Staiano, A. E., Wartella, E., & Calvert, S. L. (2014). Effects of exergame play on EF in children and adolescents at a summer camp for low income youth. *Journal of Educational and Developmental Psychology*, *4*(1), http://dx.doi.org/10.5539/jedp.v4n1p209.

Franceschini, S., Trevisan, P., Ronconi, L., Bertoni, S., Colmar, S., Double, K., et al. (2017). Action video games improve reading abilities and visual-to-auditory attentional shifting in English-speaking children with dyslexia. *Scientific Reports*, *7*(1), 5863. http://dx.doi.org/10.1038/s41598-017-05826-8.

Furió, D., González-Gancedo, S., Juan, M. C., Seguí, I., & Rando, N. (2013). Evaluation of learning outcomes using an educational iPhone game vs. traditional game. *Computers & Education*, *64*, 1–23. http://dx.doi.org/10.1016/j.compedu.2012.12.001.

GameTrack (2019). In-game spending by children & parental control tools 2019: GameTrack Survey. https://www.isfe.eu/wp-content/uploads/2020/11/GameTrack-In-Game-Spending-2019.pdf.

Gao, Z., Hannan, P., Xiang, P., Stodden, D. F., & Valdez, V. E. (2013). Video game-based exercise, Latino children's physical health, and academic achievement. *American Journal of Preventative Medicine*, *44*(3 Suppl. 3), S240–246. http://dx.doi.org/10.1016/j.amepre.2012.11.023.

Garcia-Redondo, P., Garcia, T., Areces, D., Nunez, J. C., & Rodriguez, C. (2019). Serious games and their effect improving attention in students with learning disabilities. *International Journal of Environmental Research & Public Health*, *16*(14), http://dx.doi.org/10.3390/ijerph16142480.

Gentile, D. A., Lynch, P. J., Linder, J. R., & Walsh, D. A. (2004). The effects of violent video game habits on adolescent hostility, aggressive behaviors, and school performance. *Journal of Adolescence*, *27*(1), 5–22. http://dx.doi.org/10.1016/j.adolescence.2003.10.002.

Goldin, A. P., Hermida, M. J., Shalom, D. E., Elias Costa, M., Lopez-Rosenfeld, M., Segretin, M. S., et al. (2014). Far transfer to language and math of a short software-based gaming intervention. *Proceedings from the National Academy of Science USA*, *111*(17), 6443–6448. http://dx.doi.org/10.1073/pnas.1320217111.

Harker-Schuch, I. E. P., Mills, F. P., Lade, S. J., & Colvin, R. M. (2020). CO_2peration-structuring a 3D interactive digital game to improve climate literacy in the 12–13-year-old age group. *Computers & Education*, *144*, http://dx.doi.org/10.1016/j.compedu.2019.103705.

van den Heuvel-Panhuizen, M., Kolovou, A., & Robitzsch, A. (2013). Primary school students' strategies in early algebra problem solving supported by an online game. *Educational Studies in Mathematics*, *84*(3), 281–307. http://dx.doi.org/10.1007/s10649-013-9483-5.

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. http://dx.doi.org/10.1177/1529100615569721.

Holbert, N. R., & Wilensky, U. (2014). Constructible authentic representations: Designing video games that enable players to utilize knowledge developed in-game to reason about science. *Technology, Knowledge and Learning*, *19*(1–2), 53–79. http://dx.doi.org/10.1007/s10758-014-9214-8.

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. http://dx.doi.org/10.1016/j.cogdev.2018.11.005.

Hourcade, J. P. (2015). Child-computer interaction. Self, Iowa City, Iowa.

Hussein, M. H., Ow, S. H., Cheong, L. S., & Thong, M. K. (2019). A digital game-based learning method to improve students' critical thinking skills in elementary science. *IEEE Access*, *7*, 96309–96318. http://dx.doi.org/10.1109/Access.2019.2929089, Article 8764331.

Hussein, M. H., Ow, S. H., Cheong, L. S., Thong, M. K., & Ebrahim, N. A. (2019). Effects of digital game-based learning on elementary science learning: A systematic review. *IEEE Access*, *7*, 62465–62478. http://dx.doi.org/10.1109/Access.2019.2916324, Article 8713478.

Hwang, G. J., Sung, H. Y., Hung, C. M., Huang, I., & Tsai, C. C. (2012). Development of a personalized educational computer game based on students' learning styles. *Educational Technology Research & Development*, *60*(4), 623–638. http://dx.doi.org/10.1007/s11423-012-9241-x.

Hwang, G. J., Yang, L. H., & Wang, S. Y. (2013). A concept map-embedded educational computer game for improving students' learning performance in natural science courses. *Computers & Education*, *69*, 121–130. http://dx.doi.org/10.1016/j.compedu.2013.07.008.

Imlig-Iten, N., & Petko, D. (2018). Comparing serious games and educational simulations: Effects on enjoyment, deep thinking, interest and cognitive learning gains. *Simulation & Gaming*, *49*, 401–422. http://dx.doi.org/10.1177/1046878118779088.

Infante, C., Weitz, J., Reyes, T., Nussbaum, M., Gomez, F., & Radovic, D. (2010). Co-located collaborative learning video game with single display groupware. *Interactive Learning Environments*, *18*(2), 177–195. http://dx.doi.org/10.1080/10494820802489339.

Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J. C., Sampa, F., Yalukanda, C., Westerholm, J., et al. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. *Educational Technology Research and Development*, *62*(4), 417–436. http://dx.doi.org/10.1007/s11423-014-9342-9.

Ke, F. (2016). Designing and integrating purposeful learning in game play: A systematic review. *Educational Technology Research and Development*, *64*(2), 219–244. http://dx.doi.org/10.1007/s11423-015-9418-1.

Ke, F. F., & Im, T. (2014). A case study on collective cognition and operation in team-based computer game design by middle-school children. *International Journal of Technology and Design Education*, *24*(2), 187–201. http://dx.doi.org/10.1007/s10798-013-9248-6.

Kirkorian, H. L. (2018). When and how do interactive digital media help children connect what they see on and off the screen? *Child Development Perspectives*, *12*(3), 210–214. http://dx.doi.org/10.1111/cdep.12290.

Kourakli, M., Altanis, I., Retalis, S., Boloudakis, M., Zbainos, D., & Antonopoulou, K. (2017). Towards the improvement of the cognitive, motoric and academic skills of students with special educational needs using kinect learning games. *International Journal of Child-Computer Interaction*, *11*, 28–39. http://dx.doi.org/10.1016/j.ijcci.2016.10.009.

Kyriakides, A. O., Meletiou-Mavrotheris, M., & Prodromou, T. (2016). Mobile technologies in the service of students' learning of mathematics: The example of game application A.L.E.X. in the context of a primary school in Cyprus. *Mathematics Education Research Journal*, *28*(1), 53–78. http://dx.doi.org/10.1007/s13394-015-0163-x.

Lee, T. Y., Mauriello, M. L., Ahn, J., & Bederson, B. B. (2014). Ctarcade: Computational thinking with games in school age children. *International Journal of Child-Computer Interaction*, *2*, 26–33. http://dx.doi.org/10.1016/j.ijcci.2014.06.003.

Liao, C. W., Chen, C. H., & Shih, S. J. (2019). The interactivity of video and collaboration for learning achievement, intrinsic motivation, cognitive load, and behavior patterns in a digital game-based learning environment. *Computers & Education*, *133*, 43–55. http://dx.doi.org/10.1016/j.compedu.2019.01.013.

Lin, Y. T., Tseng, Y. M., Lee, Y. S., Wang, T. C., Tsai, S. I., & Yi, Y. J. (2018). Development of a solomo game-based application for supporting local cultural learning in Taiwan. *Educational Technology & Society*, *21*(4), 115–128, Retrieved from https://www.jstor.org/stable/26511543.

Liu, G. Z., Wu, N. W., & Chen, Y. W. (2013). Identifying emerging trends for implementing learning technology in special education: A state-of-the-art review of selected articles published in 2008–2012. *Research in Developmental Disabilities*, *34*(10), 3618–3628. http://dx.doi.org/10.1016/j.ridd.2013.07.007.

Masek, M., Boston, J., Lam, C. P., & Corcoran, S. (2017). Improving mastery of fractions by blending video games into the math classroom. *Journal of Computer Assisted Learning*, *33*, 486–499. http://dx.doi.org/10.1111/jcal.12194.

Mayer, R. E., Parong, J., & Bainbridge, K. (2019). Young adults learning executive function skills by playing focused video games. *Cognitive Development*, *49*, 43–50. http://dx.doi.org/10.1016/j.cogdev.2018.11.002.

Mercado, J., Escobedo, L., & Tentori, M. (2020). A BCI video game using neurofeedback improves the attention of children with autism. *Journal on Multimodal User Interfaces*, http://dx.doi.org/10.1007/s12193-020-00339-7.

Mills, A. J., Durepos, G., & Wiebe, E. (Eds.), (2010). *Collective case study*. Sage Publications Inc, http://dx.doi.org/10.4135/9781412957397.n59.

Moyer-Packenham, P. S., Lommatsch, C. W., Litster, K., Ashby, J., Bullock, E. K., Roxburgh, A. L., et al. (2019). How design features in digital math games support learning and mathematics connections. *Computers in Human Behavior*, *91*, 316–332. http://dx.doi.org/10.1016/j.chb.2018.09.036.

Murphy, K., & Darrah, M. (2015). Haptics-based apps for middle school students with visual impairments. *IEEE Transactions on Haptics*, *8*(3), 318–326. http://dx.doi.org/10.1109/TOH.2015.2401832.

O'Rourke, J., Main, S., & Hill, S. (2017). Commercially available digital game technology in the classroom: Improving automaticity in mental-maths in primary-aged students. *Australian Journal of Teacher Education*, *42*(10), 50–70. http://dx.doi.org/10.14221/ajte.2017v42n10.4.

Peng, P., & Kievit, R. A. (2020). The development of academic achievement and cognitive abilities: A bidirectional perspective. *Child Development Perspectives*, *14*(1), 15–20. http://dx.doi.org/10.1111/cdep.12352.

Pitchford, N. J., Chigeda, A., & Hubber, P. J. (2019). Interactive apps prevent gender discrepancies in early-grade mathematics in a low-income country in sub-Sahara Africa. *Developmental Science*, *22*, Article e12864. http://dx.doi.org/10.1111/desc.12864.

Ratan, R. A., & Ritterfeld, U. (2009). Classifying serious games. In U. Ritterfeld, M. Cody, & P. Vordere (Eds.), *Serious games: Mechanisms and effects* (pp. 10–24). Routledge, http://dx.doi.org/10.4324/9780203891650-10.

Ricker, A. A., & Richert, R. A. (2021). Digital gaming and metacognition in middle childhood. *Computers in Human Behavior*, *115*, Article 106593. http://dx.doi.org/10.1016/j.chb.2020.106593.

Ronimus, M., Eklund, K., Pesu, L., & Lyytinen, H. (2019). Supporting struggling readers with digital game-based learning. *Educational Technology Research & Development*, *67*(3), 639–663. http://dx.doi.org/10.1007/s11423-019-09658-3.

Ronimus, M., Kujala, J., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers & Education*, *71*, 237–246. http://dx.doi.org/10.1016/j.compedu.2013.10.008.

Ronimus, M., & Lyytinen, H. (2015). Is school a better environment than home for digital game-based learning? The case of GraphoGame. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *11*(2), 123–147. http://dx.doi.org/10.17011/ht/urn.201511113637.

Rosetti, M. F., Gómez-Tello, M. F., Maya, C., & Apiquian, R. (2020). Feasibility of TOWI as a cognitive training video game for children. *International Journal of Child-Computer Interaction*, *25*, Article 100172. http://dx.doi.org/10.1016/j.ijcci.2020.100172.

Sampayo-Vargas, S., Cope, C. J., He, Z., & Byrne, G. J. (2013). The effectiveness of adaptive difficulty adjustments on students' motivation and learning in an educational computer game. *Computers & Education*, *69*, 452–462. http://dx.doi.org/10.1016/j.compedu.2013.07.004.

Serret, S., Hun, S., Thummler, S., Pierron, P., Santos, A., Bourgeois, J., et al. (2017). Teaching literacy skills to French minimally verbal school-aged children with Autism Spectrum Disorders with the serious game SEMA-TIC: An exploratory study. *Frontiers in Psychology*, *8*, 1523. http://dx.doi.org/10.3389/fpsyg.2017.01523.

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology*, *70*, 747–770. http://dx.doi.org/10.1146/annurev-psych-010418-102803.

Silva da Cunha, S. N., Travassos Junior, X. L., Guizzo, R., & de Sousa Pereira-Guizzo, C. (2016). The digital memory game: An assistive technology resource evaluated by children with cerebral palsy. *Psicologia: Reflexão e Crítica*, *29*(1), http://dx.doi.org/10.1186/s41155-016-0009-9, Article 5.

Song, H., Yi, D. J., & Park, H. J. (2020). Validation of a mobile game-based assessment of cognitive control among children and adolescents. *PLoS One*, *15*, Article e0230498. http://dx.doi.org/10.1371/journal.pone.0230498.

Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives*, *5*(2), 93–98. http://dx.doi.org/10.1111/j.1750-8606.2011.00162.x.

Sun, H., & Gao, Y. (2016). Impact of an active educational video game on children's motivation, science knowledge, and physical activity. *Journal of Sport & Health Science*, *5*(2), 239–245. http://dx.doi.org/10.1016/j.jshs.2014.12.004.

Sung, H. Y., & Hwang, G. J. (2018). Facilitating effective digital game-based learning behaviors and learning performances of students based on a collaborative knowledge construction strategy. *Interactive Learning Environments*, *26*(1), 118–134. http://dx.doi.org/10.1080/10494820.2017.1283334.

Tahiroglu, A. Y., Celik, G. G., Avci, A., Seydaoglu, G., Uzel, M., & Altunbas, H. (2010). Short-term effects of playing computer games on attention. *Journal of Attention Disorders*, *13*(6), 668–676. http://dx.doi.org/10.1177/1087054709347205.

Tazouti, Y., Boulaknadel, S., & Fakhri, Y. (2019). JeuTICE: An arabic serious game to enhance mathematics skills of young children. *International Journal of Emerging Technologies in Learning*, *14*, 252–265. http://dx.doi.org/10.3991/ijet.v14i22.11119.

Tsai, Y. L., & Tsai, C. C. (2018). Digital game-based second-language vocabulary learning and conditions of research designs: A meta-analysis study. *Computers & Education*, *125*, 345–357. http://dx.doi.org/10.1016/j.compedu.2018.06.020.

Tsai, F. H., Yu, K. C., & Hsiao, H. S. (2012). Exploring the factors influencing learning effectiveness in digital game-based learning. *Educational Technology & Society*, *15*(3), 240–250. http://dx.doi.org/10.2307/jeductechsoci.15.3.240.

Vanbecelaere, S., Van den Berghe, K., Cornillie, F., Sasanguie, D., Reynvoet, B., & Depaepe, F. (2020). The effects of two digital educational games on cognitive and non-cognitive math and reading outcomes. *Computers & Education*, *143*, http://dx.doi.org/10.1016/j.compedu.2019.103680.

Vandeventer, S. S., & White, J. A. (2002). Expert behavior in children's video game play. *Simulation & Gaming*, *33*(1), 28–48. http://dx.doi.org/10.1177/1046878102033001002.

Vasalou, A., Khaled, R., Holmes, W., & Gooch, D. (2017). Digital games-based learning for children with dyslexia: A social constructivist perspective on engagement and learning during group game-play. *Computers & Education*, *114*, 175–192. http://dx.doi.org/10.1016/j.compedu.2017.06.009.

Vega, V., & Robb, M. (2019). *The common sense census: Inside the 21st-century classroom*. San Francisco, CA: Common Sense Media.

Weerdmeester, J., Cima, M., Granic, I., Hashemian, Y., & Gotsis, M. (2016). A feasibility study on the effectiveness of a full-body videogame intervention for decreasing Attention Deficit Hyperactivity Disorder symptoms. *Games for Health Journal*, *5*(4), 258–269. http://dx.doi.org/10.1089/g4h.2015.0103.

Yang, K. H. (2017). Learning behavior and achievement analysis of a digital game-based learning approach integrating mastery learning theory and different feedback models. *Interactive Learning Environments*, *25*(2), 235–248. http://dx.doi.org/10.1080/10494820.2017.1286099.

Yang, J. C., Lin, M. Y. D., & Chen, S. Y. (2018). Effects of anxiety levels on learning performance and gaming performance in digital game-based learning. *Journal of Computer Assisted Learning*, *34*(3), 324–334. http://dx.doi.org/10.1111/jcal.12245.

Yang, J. C., Quadir, B., & Chen, N. S. (2019). Effects of children's trait emotional intelligence on digital game-based learning. *International Journal of Human-Computer Interaction*, *35*(4–5), 374–383. http://dx.doi.org/10.1080/10447318.2018.1543088.