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The role of media entertainment in children's and adolescents' ADHD-related behaviors: A reason for concern?

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Publication date

2016

Document Version

Final published version

[Link to publication](#)

Citation for published version (APA):

Nikkelen, S. W. C. (2016). *The role of media entertainment in children's and adolescents' ADHD-related behaviors: A reason for concern?* [Thesis, fully internal, Universiteit van Amsterdam].

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Chapter 1

Media use and ADHD-related behaviors in children and adolescents: A meta-analysis

Abstract

There are several theoretical reasons to believe that media use might be related to attention-deficit/hyperactivity disorder (ADHD) or ADHD-related behaviors (i.e., attention problems, hyperactivity, and impulsivity). Although studies into the media-ADHD relationship have accumulated, they have yielded inconsistent results. Therefore, we still do not know whether children's media use and ADHD-related behaviors are related, and if so, under which conditions. To fill this gap in the literature, we first identified six different hypotheses that may explain why media use in general, and viewing fast-paced or violent media content might be related to one or more ADHD-related behaviors. Subsequently, we conducted a meta-analysis of 45 empirical studies investigating the relationship between media use and ADHD-related behaviors in children and adolescents. Our results indicated a small significant relationship between media use and ADHD-related behaviors ($r^+ = .12$). Finally, we identified several specific gaps in the existing literature and presented five crucial directions for future research.

This chapter is published as:

Nikkelen, S.W.C., Valkenburg, P.M., Huizinga, M., & Bushman, B.J. (2014). Media use and ADHD-related behaviors in children and adolescents: A meta-analysis. *Developmental Psychology, 50*(9), 2228-2241. doi:10.1037/a003731.

In the past four decades, children's media entertainment (e.g., cartoons, TV shows, and computer games) has changed significantly. It has become more fast-paced, violent, and arousing (Allen, Livingstone, & Reiner, 1998; Bushman, Jamieson, Weitz, & Romer, 2013; Koolstra, van Zanten, Lucassen, & Ishaak, 2004), and it has become abundantly accessible to ever younger children. These same four decades have also witnessed a significant increase in the diagnosis rate of attention-deficit/hyperactivity disorder (ADHD; Akinbami, Liu, Pastor, & Reuben, 2011; Kelleher, McInerney, Gardner, Childs, & Wasserman, 2000; Visser et al., 2014). ADHD is a behavioral disorder characterized by a cluster of three symptoms: attention problems, hyperactivity, and impulsivity (*Diagnostic and Statistical Manual of Mental Disorders 5th ed. [DSM-V]*, American Psychiatric Association, 2013). Although ADHD traditionally has been viewed as a qualitatively distinct diagnostic category, nowadays it is often conceptualized as an extreme end on a continuum of behaviors (Larsson, Anckarsater, Råstam, Chang, & Lichtenstein, 2012; Lubke, Hudziak, Derks, van Bijnsterveldt, & Boomsma, 2009). In this article, we use the term *ADHD-related behaviors* to refer to this continuous distribution of attention problems, hyperactivity, and impulsivity among the general population of children and adolescents.

The parallel between changes occurring in children's media environment and ADHD diagnosis rates have led to a concern among some authors that use of media entertainment may influence ADHD-related behaviors (e.g., Christakis, 2009; Jensen et al., 1997; Nigg, 2006; Sigman, 2007). Although studies into the relationship between children's media use and ADHD-related behaviors have accumulated, they have yielded mixed results (also see Kirkorian, Wartella, & Anderson, 2008; Schmidt & Vandewater, 2008). It is essential to gain more understanding of the media-ADHD relationship in order to design adequate prevention and intervention strategies aimed at children displaying behavioral problems. To date, no attempt has been made to integrate the inconsistent findings in the current literature using meta-analysis. To fill this gap, we conducted a meta-analysis of studies investigating the relationship between the use of screen entertainment media (i.e., television viewing and video game playing) and ADHD-related behaviors in children or adolescents under the age of 18.

For this meta-analysis, we systematically collected all cross-sectional, longitudinal, and experimental studies examining the relationship between screen entertainment media use and ADHD-related behaviors. The aim was to calculate an average correlation for the relationship between screen entertainment media use and ADHD-related behaviors. In addition, we examined three factors that might influence the strength of this relation: *media content* (i.e., violent media, fast-paced media, overall media use), *media types* (i.e., television vs. video games),

and *child characteristics* (i.e., age, sex).

Media Content

Several hypotheses have been put forward to explain how media use could induce ADHD-related behaviors. Some of these hypotheses attribute this effect to its violent content (Zimmerman & Christakis, 2007). Other hypotheses attribute this effect to the fast pace of entertainment media (i.e., the frequent use of cuts, edits, and fast character movement; Christakis, 2009; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Geist & Gibson, 2000; Halpern, 1975; Jensen et al., 1997; Landhuis, Poulton, Welch, & Hancox, 2007; Levine & Waite, 2000), or to the overall amount of time children spent consuming media (Christakis, 2009; Zimmerman & Christakis, 2007). Therefore, in this meta-analysis, we included all studies investigating the effect of either violent, fast-paced, or overall screen media use on ADHD-related behaviors. Comparing the strengths of these three relationships allowed us to single out whether a potential media effect on ADHD-related behaviors should be attributed to the overall time spent with media, or to fast-paced or violent media.

Violent content. Television programs, movies, and video games frequently contain acts of physical violence (Wilson et al., 2002). Two hypotheses may explain why media violence may lead to ADHD-related behaviors. A first hypothesis, which we have named the *violence-induced script hypothesis*, argues that because violence is characterized by impulsive behavior (i.e., no inhibition of antisocial behavior), exposure to such violent acts may activate a behavioral script of poor self-control (Anderson & Bushman, 2001; Hummer et al., 2010). Activation of such a script, in turn, may result in attention problems, hyperactivity, or impulsivity, which are assumed to result from poor self-control (Barkley, 1997a).

A second hypothesis, which we have named the *violence-induced arousal-habituation hypothesis*, states that violent media content causes ADHD-related behaviors by its effect on children's arousal system. Violent media content can induce intense arousal in children (Bushman & Huesmann, 2006; Fleming & Rickwood, 2001). However, after repeated exposure, children may get desensitized to media violence, which means that they gradually experience less induced arousal to the same violent media portrayals (Ballard, Hamby, Panee, & Nivens, 2006). As a result of this desensitization process, children may start to experience a state of underarousal in less stimulating environments. Underarousal, in turn, can cause attention problems, hyperactivity, and impulsivity (Nigg, 2006; White, 1999).

Fast pace. The literature has revealed two hypotheses explaining the effects of fast-paced media on the development of ADHD-related behaviors. A first

hypothesis, which we named the *scan-and-shift hypothesis*, states that fast-paced media, by the frequent use of cuts and edits, teach the child an attentional style of scanning and shifting (Jensen et al., 1997). Such an attentional style may hinder the child in tasks that require sustained attention, such as doing schoolwork. A second hypothesis, which we named the *fast-pace arousal-habituation hypothesis*, states that the fast pace of entertainment media may increase arousal by triggering repeated attention shifts in the user (Lang, Zhou, Schwartz, Bolls, & Potter, 2000). After frequent exposure to fast-paced media, children might get habituated to this arousal lift, thereby decreasing their baseline arousal level. As with violent media use, low baseline arousal may cause ADHD-related behaviors.

Overall media use. Two additional hypotheses do not attribute the effect of media use on ADHD-related behaviors to specific features of media but rather to the large amount of time children spend using media. The *displacement hypothesis* states that frequent use of screen entertainment media might displace activities that are thought to stimulate cognitive abilities more than screen entertainment media, such as imaginative play (Christakis, 2009; Zimmerman & Christakis, 2007). A second hypothesis, which we refer to as the *impaired-language development hypothesis*, states that excessive use of screen entertainment media hinders language development because it mainly relies on visual processing, and uses adult-like language that is not attuned to the child's cognitive ability (Nigg, 2006; Zimmerman & Christakis, 2007). Language skills are assumed to facilitate self-regulation in children by allowing for reflection on and directing of their behavior (Beaver, Delisi, Vaughn, Wright, & Boutwell, 2008; Gallagher, 1999). The presumed media-induced lack of language development is assumed to disrupt the consolidation of self-regulation (Jensen et al., 1997), leading to ADHD-related behaviors.

Media Types

Both video game playing and television viewing have been argued to induce ADHD-related behaviors through the mechanisms we described (Acevedo-Polakovich, 2005; Christakis, 2009). These two media activities, however, are quite different in nature, which may lead to differences in the strength of their effects. First, unlike television shows and movies, video games allow for interactivity; the player is in part responsible for the way the game unfolds (Vorderer, 2000). Second, whereas video game playing is typically a primary activity, television viewing is often used as a secondary activity (Carnagey & Anderson, 2004). Finally, identification with a media character, if any, may be higher in video game playing, because the player is in control of the character (Carnagey & Anderson, 2004). To investigate whether the correlation between media use and ADHD-related

behaviors differed between studies measuring television viewing and those measuring video game playing, we included both types of studies in this meta-analysis.

Child Characteristics

Age differences. Compared with older children and adolescents, younger children might be more strongly affected by media use. Children in early childhood have been shown to be particularly susceptible to environmental influences (Knudsen, 2004; Mundkur, 2005; Uylings, 2006), including media influences (Christakis, 2009; Valkenburg & Peter, 2013a). In addition, young children (younger than about age 7) are not yet able to make a clear distinction between fantasy and reality in the media (Valkenburg & Cantor, 2001). As a result, they have difficulty making sense of what they see on the screen and distinguishing it from the “real” world, which may lead to stronger media effects. Moreover, young children are not yet able to reassure themselves effectively when confronted with violent media content (Cantor, 2009), and they are less able than older children to regulate their arousal levels when watching violent and action oriented media (Gross & Thompson, 2007). Inspecting the effect of age was one aim of this meta-analysis. We expected that the correlation between media use and ADHD-related behaviors would decrease with age.

Sex differences. Previous research has shown that, compared with girls, boys more often exhibit ADHD-related behaviors (Gershon & Gershon, 2002; Lavigne, LeBailly, Hopkins, Gouze, & Binns, 2009). Boys also spend more time using media than girls (Rideout, Foehr, & Roberts, 2010), and are more attracted to violent and action-packed media (Cantor, 1998; Olson et al., 2007; Valkenburg & Janssen, 1999). However, these observed sex differences in media preferences and ADHD-related behaviors do not necessarily imply that the effect of media use on ADHD-related behaviors is stronger for boys than for girls. For example, although boys are generally more aggressive than girls (Card, Stucky, Sawalani, & Little, 2008) and have a stronger preference for media violence, one meta-analysis revealed larger media violence effects on aggression in males (Paik & Comstock, 1994), whereas other meta-analyses showed no sex differences (Anderson et al., 2010; Anderson & Bushman, 2001). Sex differences in media-induced effects on ADHD-related behaviors did not receive much attention in earlier research, and to investigate such differences was another aim of the present meta-analysis.

Outcome Variables

The available empirical studies differ in their conceptual and operational definitions of ADHD and ADHD-related behaviors. In this meta-analysis, we

included studies focusing on clinically diagnosed ADHD as well as studies using continuous measures of the three ADHD-related behaviors (i.e., attention problems, hyperactivity, and impulsivity). We define *attention problems* as children's inability to focus their attention (i.e., being easily distracted), which is important for organizing and completing a task. *Hyperactivity* refers to excessive physical activity (i.e., being continuously in motion). *Impulsivity* is defined as the inability to control immediate action (i.e., not thinking before acting; Barkley, 1997b; Nigg, 2006).

Most studies examining the media-ADHD relationship include a composite measure of attention problems, hyperactivity, and impulsivity, without distinguishing among the three behaviors. Although the three behaviors often co-occur, children may also predominantly exhibit one or two of them (American Psychiatric Association, 2013). Moreover, media effects may differ for each of the three ADHD-related behaviors. In this meta-analysis, we therefore focused on the relationship between media use and composite measures of ADHD-related behaviors, as well as on the relationship between media use and attention problems, hyperactivity, and impulsivity separately.

Method

Search Strategies

Relevant studies for this meta-analysis were obtained using a three-step approach. First, we searched the Web of Science and PsycINFO databases using the following search terms: “(*media or TV or television or game**)” and “(*ADHD or attention* or hyperactiv* or impulsiv**).” This search covered journal articles and doctoral dissertations from the year each database started until September 2013. Second, we examined the reference sections of studies related to the subject of media use and ADHD-related behaviors for additional citations. Third, to reduce potential publication bias, we contacted all corresponding authors of included studies to request for additional unpublished data. These three steps generated a sample of 50 studies that met the inclusion criteria described in the following section.

Inclusion and Exclusion Criteria

Studies had to meet three criteria to be included in this meta-analysis. First, they required the inclusion of a measure or a manipulation of media violence, media pacing, or overall media use. Media violence referred to television, movies, or video games containing physical actions that kill or injure living beings. Media pacing pertained to the frequency of use of cuts, edits or scene changes.

Overall media use referred to the overall amount of time spent viewing television (including movies) or playing video games on any platform (e.g., in hours per week). The literature search also yielded several studies that distinguished other categories of media content (e.g., educational and non-educational media, or child-directed and adult-directed media). Because there were too few studies available for these other categorizations to conduct reliable analyses, these were not included in this meta-analysis.

Second, studies had to use a measure of ADHD-related behaviors. A first type of studies included in the meta-analyses consisted of samples in which a group of children who were clinically diagnosed with ADHD was compared with a control group not diagnosed with ADHD. A second type of studies included non-clinical samples, in which measures of media use were related to measures of attention problems, hyperactivity, or impulsivity, or a composite measure of these dimensions (which we refer to as *ADHD composite*). Studies using survey measures or observational measures of ADHD-related behaviors were included when items in the measures were consistent with the diagnostic criteria of ADHD in the *DSM-V*. Studies using survey measures that included items measuring aggressive behavior were excluded from this meta-analysis (Stevens & Mulsow, 2006). For studies using experimental measures (e.g., computerized tasks) that could not be evaluated using these criteria, earlier empirical evidence of an association between the particular measure and the *DSM-V* criteria was required.

Third, we only included studies with child participants younger than 18 years of age. The relation between media use and adult ADHD was beyond the scope of this project. Moreover, although the literature search yielded a handful of studies with adult participants, these were too few to be included in our meta-analysis.

Of the 50 studies that met these three inclusion criteria, four studies were excluded because effect sizes could not be computed due to missing statistics, even after repeated efforts to contact the corresponding author (Barnard, 2009; Ebenegger et al., 2012; Mistry, Minkovitz, Strobino, & Borzekowski, 2007; Valdez et al., 2007). A rationale for exclusion of these studies is available from the first author. Finally, because the results of two studies were derived from the same sample (Christakis et al., 2004; Foster & Watkins, 2010), these studies counted as one study in our sample.¹ Our final sample thus included 45 studies.

¹A study by Christakis, Zimmerman, DiGiuseppe, and McCarthy (2004) was replicated in a 2010 study by Foster and Watkins, using the same dataset. Both studies only reported partial effect sizes. After contacting the authors of both papers, we received raw correlation coefficients of the authors of the 2010 paper. Therefore, this study is listed in Table 2, and not the original 2004 study.

Measures of ADHD-Related Behaviors

The studies that were included in this meta-analysis showed large variability in the way ADHD-related behaviors were conceptualized and measured. Several studies included multiple measures for assessing ADHD-related behaviors, such as parent and self-report. Six studies included children who were clinically diagnosed with ADHD and a control group of children. The majority of the studies included a survey measure of ADHD-related behaviors filled out by one or multiple informants. Parent reports were most common ($k = 28$), followed by teacher reports ($k = 10$) and self-reports ($k = 6$). The most common survey measures were subscales from the Child Behavior Checklist (CBCL; Achenbach, 2009) and the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). A multitude of different survey measures were used in the other studies.

Seven studies in this meta-analysis included measures other than self-, parent-, or teacher-report measures to assess ADHD-related behaviors. One study (Kronenberger et al., 2005) used the Continuous Performance Task (CPT; Conners, 2000), one study (Cooper, Uller, Pettifer, & Stolc, 2009) used the Attentional Networks Test (ANT; Rueda et al., 2004), two studies (Anderson, Levin, & Lorch, 1977; Gadberry, 1980) used the Matching Familiar Figures Test (MFFT; Kagan, Rosman, Day, Albert, & Philips, 1964), and a fifth study included actigraphy to measure the amount of movement displayed by the child during a certain time period (Miller et al., 2007). The two remaining studies used coded observations during free-play (Tower, Singer, Singer, & Biggs, 1979) or during normal class periods (Levine & Waite, 2000) to measure ADHD-related behaviors.

Coding of Studies

The following variables were coded for each study: (a) *outcome* (i.e., attention problems, hyperactivity, impulsivity, or ADHD composite), (b) *measurement type* (i.e., standardized or unstandardized measure of ADHD), (c) *study design* (i.e., cross-sectional, longitudinal, or experimental), (d) *media type* (i.e., television or video games), (e) *media content* (i.e., violent content, fast-paced content, or overall media use), (f) *proportion of girls* in the sample, and (g) *mean age* of the sample (in years; in case of multiple data waves, age was coded as the mean age at the first wave).

Often, authors intended to measure one of the ADHD-related behaviors (e.g., attention problems), but included a scale or items of a scale that also tapped other dimensions (e.g., Landhuis et al., 2007; Swing, Gentile, Anderson, & Walsh, 2010; Zimmerman & Christakis, 2007). Consequently, such a measure does not solely reflect the intended behavior. This problem of conceptual contamination could bias the meta-analytic results. To avoid this potential bias, the first and

third author independently categorized each of the outcome measures used in the included studies into one of four categories: attention problems, hyperactivity, impulsivity, or ADHD composite using the diagnostic criteria of ADHD in the *DSM-V*. A measure covering two or three ADHD-related behaviors as described in the *DSM-V* (e.g., attention problems and hyperactivity), was rated as an ADHD composite measure. This rating process resulted in a satisfactorily inter-coder reliability (Cohen's $\kappa = .76$). The two raters discussed rating disagreements to achieve a single rating for each measure. Studies including samples of children who were clinically diagnosed with ADHD were categorized as ADHD composite.

Computation of Effect Sizes

Four data sets were constructed, one for each outcome variable. All data sets were analyzed using the Comprehensive Meta-Analysis (CMA) software. The effect size estimate used in the analyses was the Pearson product-moment correlation coefficient (r). For studies that did not report correlation coefficients, we used other available statistics (e.g., t tests) that were transformed to r s. In case of missing information (e.g., mean age of the study sample), we contacted the authors via e-mail. In cases where studies reported nonsignificant results without additional statistics available to calculate an effect size and the authors were unable to provide us with the data, we used the common and conservative method of ascribing the study a correlation of zero (Pigott, 1994). This was the case for two of the studies (Anderson & Maguire, 1978; Milich & Lorch, 1994).²

For studies that reported multiple effect sizes (e.g., separate correlations for television viewing and video game playing, or cross-sectional and longitudinal correlations), we used a shifting unit of analysis approach (Cooper, 1989). Each statistical test was coded as if it were an independent event. For example, if a study included separate correlations for overall media use and violent media use for both television and video games, four effect-size estimates were coded (i.e., for overall television viewing, violent television viewing, overall video game playing, and violent video game playing). For the overall effect, however, the four effect-size estimates were averaged so that the study provided only one effect-size estimate. Thus, the shifting unit of analysis retains as much data as possible without violating the independence assumption that underlies the validity of meta-analytic procedures.

² There were 2 studies that reported non-significant results without reporting the actual effect size: one in the 'ADHD composite' dataset and one in the 'impulsivity' dataset. Removal of these studies did not change the meta-analytic results.

Statistical Analyses

The analyses were conducted separately for each of the four outcome variables (i.e., attention problems, hyperactivity, impulsivity, and ADHD composite). Although there is no strict rule about the minimum number of effect sizes to include in a meta-analysis, performing a meta-analysis on a small number effect sizes increases the chance of second-order sampling error (Hunter & Schmidt, 2004). Due to the heterogeneity of the studies included in this meta-analysis, we only performed analyses when there were five or more independent effect size estimates available. All analyses were conducted using a random effects model, which allows for variation between the studies' effect sizes. This method is recommended when the included studies differ on several aspects (e.g., sample characteristics) and it allows one to generalize the result beyond the set of studies included in the meta-analysis (Borenstein, Hedges, Higgins, & Rothstein, 2009; Hunter & Schmidt, 2004).

For each outcome variable, we first examined the general relationship between media use and ADHD-related behaviors, without distinguishing among measurement type, media types, media content, or study design. Before conducting these analyses, we averaged dependent correlations (i.e., correlations that were calculated for the same sample of participants). This is considered a conservative method, resulting in wider confidence intervals upon calculation of the average effect size than if each dependent correlation was used separately in the analysis (Borenstein et al., 2009). Fisher z -transformation was applied to each correlation coefficient to normalize its distribution (Silver & Dunlap, 1987). Next, we calculated the average effect size for each outcome, which was transformed back to Pearson's r for interpretative purposes. This pooled estimate of r is denoted as r_p . Finally, we performed a Q -test (which has a chi-square distribution) for heterogeneity to examine differences between outcomes (Borenstein et al., 2009).

In a second step, we used multiple regression analysis to analyze all study characteristics simultaneously to account for possible covariance between studies. Age (i.e., mean age of the sample in years) and sex (i.e., proportion of girls in the sample) were entered as continuous variables. Measurement type (0 = *unstandardized*, 1 = *standardized*), media type (0 = *television*, 1 = *video games*), media content (0 = *overall*, 1 = *violent*) and study design (0 = *cross-sectional*, 1 = *longitudinal*) were entered as dichotomous variables. We excluded the categories "fast-paced" and "experimental" because, as we demonstrate later, too few independent effect sizes were available for these categories. The model was tested using restricted maximum likelihood. Again, Fisher z -transformation was first applied to each correlation coefficient.

In each analysis, we examined the presence of outliers by standardizing all effect sizes. An effect size was considered an outlier when the absolute value of its standardized score (i.e., z value) was 2 or higher. In the multiple regression analysis, we used the Studentized residuals to detect outliers, again using the criterion $z \geq 2$. Outliers were removed step by step in each analysis. We conducted a sensitivity analysis to determine whether the meta-analytic results changed upon removal of these outliers.

Publication Bias Analyses

To test for potential publication bias, we included four publication bias tests: (a) Orwin's fail-safe N test, (b) Begg and Mazumdar's rank correlation test, (c) Egger's regression test, and (d) Duval and Tweedie's trim and fill procedure. Orwin's fail-safe N test calculates the number of additional (i.e., unpublished) studies with a certain mean effect size that would result in an average effect size below a threshold that is deemed trivial (Orwin, 1983). Because a small effect equals $r = .1$ (Cohen, 1988), we set this threshold to $r = .05$ and the mean effect size to 0. Publication bias may be present when the Orwin's fail safe N is lower than the number of independent effect sizes. The rank correlation test, Egger's regression test, and Duval and Tweedie's trim and fill procedure all rely on the assumption that in the absence of publication bias, effect sizes of individual studies are symmetrically distributed around the average effect. However, small studies (i.e., in terms of N) with low effect sizes often fail to reach significance and as such are less likely to be published. Thus in the presence of publication bias, the meta-analysis includes a disproportional amount of small sample studies with large effect sizes.

The rank correlation test and Egger's regression test formally test whether small sample studies in a meta-analysis tend to have larger effect sizes than expected, the former using rank orders and the latter using the actual effect sizes (Begg & Mazumdar, 1994; Egger, Smith, Schneider, & Minder, 1997). Significance of these tests indicates presence of publication bias. We used Stata software (version 12) to conduct the Begg and Mazumdar's rank correlation test and the Egger's regression test with the standard errors from the random effects model. Duval and Tweedie's trim and fill procedure imputes the unpublished studies that would have to be added for a more even distribution of studies around the average effect and recalculates the average effect size using these imputed studies (Duval & Tweedie, 2000), which is assumed to be a better estimation of the unbiased average effect size. As suggested by Peters, Sutton, Jones, Abrams, and Rushton (2007) we used a fixed effects model to 'trim' and a random effects model to 'fill' the results.

Results

Descriptive Statistics

Our meta-analysis consisted of 29 cross-sectional studies, 12 longitudinal studies, and four experimental studies. Tables 1, 2, and 3 present summaries of the study characteristics of the included studies. The first author can be contacted to provide individual study-level effect sizes. Our sample of studies together included over 155,000 participants, ranging in age from 0 to 18 years. Of the 45 studies, 38 included a measure or manipulation of television viewing, and 17 included a measure or manipulation of video game playing. Most studies ($k = 40$) included a measure of overall amount of television viewing or video game playing. Twelve studies examined violent media content, and three studies examined pacing of media content.

The rating process of the outcome measures revealed that only few studies included a measure that purely reflected one of the three ADHD-related behaviors. Consequently, there were only seven independent effect size estimates available for the outcome variable attention problems, one for hyperactivity, and seven for impulsivity. As a result, we were not able to perform a meta-analysis for the outcome variable hyperactivity. The study measuring hyperactivity reported a positive correlation ($r = .20$) between media use and hyperactivity (Miller et al., 2007). Because there were seven independent effect sizes available for the outcome variables of attention problems and impulsivity, we could calculate an average correlation coefficient but were unable to conduct additional moderator analyses for these outcomes. For the outcome variable ADHD composite, 43 independent effect size estimates were available. Therefore, in addition to calculating an average correlation coefficient for the relationship between media use and ADHD composite measures, we were able to conduct a multiple regression analysis examining the effects of measurement type, media type, media content, study design, age, and sex.

Overall Meta-Analytic Results

The meta-analyses revealed significant positive relationships between media use and ADHD composite measures, $r_+ = .12$, 95% confidence interval (CI) [.09, .14], $k = 43$, attention problems, $r_+ = .32$, 95% CI [.11, .50], $k = 7$, and impulsivity, $r_+ = .11$, 95% CI [.00, .22], $k = 7$. A heterogeneity analysis revealed a significant difference between ADHD composite and attention problems, $Q(1) = 44.64$, $p < .001$, a nonsignificant difference between ADHD composite and impulsivity, $Q(1) = 0.12$, $p = .726$, and a marginally significant difference between impulsivity and attention problems, $Q(1) = 3.25$, $p = .072$. Because the average correlation between

Table 1 Characteristics of Cross-sectional Studies Included in This Meta-Analysis

Study	N	% girls	Age (in years)		Outcome ^a	Media type ^b	Media content ^c
			Mean	Range			
Acevedo-Polakovich et al. (2006) ^d	165	37%	7.2	n/a	C	TV	O
Acevedo-Polakovich et al. (2007)	81	32%	n/a	4-6	C	TV	O
	107	32%	n/a	7-9	C	TV	O
C. C. Anderson & Maguire (1978)	102	46%	n/a	8-10	I	TV	O; V
	198	51%	n/a	10-12	I	TV	O; V
Bioulac et al. (2008)	50	12%	11.3	6-16	C	VG	O
Chan & Rabinowitz (2006)	72	57%	15.3	14-16	C; A	TV;VG	O
Connors-Burrow et al. (2011)	92	50%	5.2	4-6	C	TV	O
De Sousa (2011)	315	0%	14.3	n/a	C; A	VG	O
Erdogan et al. (2006)	356	51%	6.0	5-7	C	TV	O
Ferguson (2011)	603	49%	12.4	10-14	C	TV;VG	O; V
Ferguson & Olson (2013)	1,254	53%	12.9	12-14	C	VG	O; V
Greenwood & Lillard (2011)	48	50%	4.5	3-5	C	TV	O
Hastings et al. (2009)	70	50%	7.8	6-10	C	VG	O; V
Kim et al. (2011)	66,707	49%	11.9	6-17	C	TV+VG	O
Knezevic (2009)	33	58%	3.9	3-4	C	TV	O; V
Kronenberger et al. (2005)	54	22%	14.3	13-17	C; A	TV+VG	V
Levine & Waite (2000)	70	47%	10.3	8-11	C	TV	O; V
Lillard & Peterson (2011) ^d	60	47%	4.6	4-4	C	TV	O
Lin & Lepper (1987)	189	42%	n/a	9-12	I	VG	O
Lingineni et al. (2012)	59,880	48%	11.6	5-17	C	TV	O
Maaß, Hahlweg, Heinrichs et al. (2010)	708	41%	4.3	2-6	C	TV;VG	O
Mazurek & Engelhardt (2013)	141	0%	11.7	8-18	C; A	VG	O; V
Milich & Lorch (1994)	40	0%	n/a	7-12	C	TV	O; V
Miller et al. (2007)	170	38%	4.3	2-5	C; H	TV	O
Nikkelen et al. (2014)	1,612	49%	6.0	5-9	C	TV+VG	V
Özmert et al. (2002)	689	50%	8.0	7-9	C	TV	O
Özmert et al. (2011)	581	59%	13.5	12-16	C	TV	O
Schittenhelm et al. (2010)	60	50%	9.8	8-11	C; A	TV	O
Shin (2004)	1,203	50%	9.0	6-13	C	TV	O
van Egmond-Fröhlich et al. (2012)	9,428	48%	11.7	6-17	C	TV	O

Note. ^aC = attention-deficit/hyperactivity disorder (ADHD) composite; A = attention problems; H = hyperactivity; I = impulsivity. ^bTV = television viewing; VG = video game playing; The plus sign (+) indicates a combined measure of television viewing and video game playing. ^cO = overall media use; V = violent media use; ^dStudy has a longitudinal design, but the media-ADHD effect size data was considered cross-sectional.

Table 2 Characteristics of Longitudinal Studies Included in This Meta-Analysis

Study	N	% girls	Age (in years) ^a		Outcome ^b	Media type ^c	Media content ^d
			Mean	Range			
Cheng et al. (2010)	302	49%	1.5	n/a	C	TV	O
Foster & Watkins (2010)	1,159	50%	1.8	1-1	C	TV	O
Gentile et al. (2012)	3,034	28%	11.2	8-17	C	VG	O; V
Johnson et al. (2007)	678	50%	13.7	n/a	C	TV	O
Landhuis et al. (2007)	980	48%	n/a	5	C	TV	O
Maaß, Hahlweg, Naumann et al. (2010)	262	48%	3.8	2-5	A; C	TV; VG	O
Obel et al. (2004)	1,349	n/a	3.5	n/a	C	TV	O
Parkes et al. (2013)	10,500	51%	5.2	5	C	TV; VG	O
Stevens et al. (2009)	2,717	48%	n/a	4	C	TV	O
Swing et al. (2010)	1,323	53%	9.6	6-12	C	TV;VG	O
Tomopoulos et al. (2007)	96	38%	1.8	n/a	C	TV+VG	O
Zimmerman & Christakis (2007)	542	49%	1.6	0-3	C	TV	O; V
	391	44%	5.0	4-6	C	TV	O; V

Note. ^aThe mean age and -range represent the age at the first wave of data collection. ^bC = attention-deficit/hyperactivity disorder (ADHD) composite; A = attention problems. ^cTV = television viewing; VG = video game playing; The plus sign (+) indicates a combined measure of television viewing and video game playing. ^dO = overall media use; V = violent media use.

Table 3 Characteristics of Experimental Studies Included in This Meta-Analysis

Study	N	% girls	Age (in years)		Outcome ^a	Media type ^b	Media content ^c
			Mean	Range			
Anderson et al. (1977)	48	50%	n/a	4	I	TV	F
Cooper et al. (2009)	37	51%	5.2	4-7	A; I	TV	F
Gadberry (1980)	27	56%	6.5	n/a	I	TV	O
Tower et al. (1979)	42	48%	4.1	n/a	C	TV	F

Note. ^aC = attention-deficit/hyperactivity disorder (ADHD) composite; A = attention problems; I = impulsivity. ^bTV = television viewing. ^cO = overall media use; F = fast-paced media use.

composite ADHD and impulsivity did not differ, we combined these studies in subsequent analyses. Step by step removal of outliers in the combined ADHD composite/impulsivity sample resulted in five studies being removed, which only slightly decreased the average correlation coefficient, $r_s = .10$, 95% CI [.08, .12], thus we retained these studies in subsequent analyses. There were no outliers in the attention problems data set.

Moderator Analyses for ADHD Composite/Impulsivity Combined

The multiple regression analysis revealed a significant model overall, $F(6,54) = 5.16$, $p < .001$, $R^2 = .51$. Regarding the six individual predictors (i.e., age, sex, measurement type, media type, media content, study design), we found that the effect of sex was significant, such that the proportion of girls in each of the studies' samples was negatively related to the studies' effect size, $b = -0.50$, $SE = 0.11$, $t(54) = -4.50$, $p < .001$, 95% CI [-0.72, -0.28]. The effect of measurement type was also significant, such that standardized measures had lower effect sizes, $b = -0.10$, $SE = 0.03$, $t(54) = -3.08$, $p = .003$, 95% CI [-0.16, -0.03]. Because the effect of measurement type was significant, we performed a heterogeneity test to examine the average correlations for the two individual categories (i.e., standardized and unstandardized). This analysis showed that the average correlation coefficients for both categories were statistically significant - standardized: $r_s = .11$, 95% CI [.08, .14], $k = 41$; and unstandardized: $r_s = .12$, 95% CI [.06, .18], $k = 9$. The other predictors (i.e., age, media type, media content, study design) were not significant in the initial multiple regression model. After the step by step removal of nine outliers, the model remained significant, $F(6,45) = 17.70$, $p < .001$, $R^2 = .88$. Again, the effects of measurement type ($b = -0.14$, $SE = 0.02$, $t(45) = -7.81$, $p < .001$, 95% CI [-0.18, -0.10]) and sex ($b = -0.60$, $SE = 0.08$, $t(45) = -7.34$, $p < .001$, 95% CI [-0.77, -0.44]) were significant, as well as the effect of study design ($b = -0.03$, $SE = 0.01$, $t(45) = -2.42$, $p = .020$, 95% CI [-0.06, -0.01]) such that effects sizes of longitudinal studies were lower than effect sizes of cross-sectional studies. A heterogeneity test showed that the average correlation coefficients for both categories were statistically significant - cross-sectional: $r_s = .13$, 95% CI [.10, .16], $k = 42$; and longitudinal: $r_s = .10$, 95% CI [.06, .14], $k = 13$.

Publication Bias

ADHD composite/impulsivity combined. Both the rank correlation test ($z = 0.19$, $p = .847$) and the Egger's regression test ($t = 0.39$, $p = .695$) were nonsignificant. Orwin's fail-safe N test resulted in higher number of missing studies ($k = 66$) that would lead to a trivial effect size than the number of included effect sizes. Finally, Duval and Tweedie's trim and fill procedure resulted in six imputed studies on

the left side of the mean. Imputation of these studies lead to an adjusted average correlation coefficient of .09. Generally, these tests indicate that publication bias is not likely to be present.

Attention Problems. Orwin's fail-safe N test resulted in a higher number of missing studies ($k = 40$) that would lead to a trivial effect size than the number of included studies. Both the rank correlation test ($z = 0.60, p = .548$) and the Egger's regression test ($t = -0.70, p = .515$) were non-significant. Finally, Duval and Tweedie's trim and fill procedure resulted in two imputed studies on the right side of the mean. Imputation of these studies led to an adjusted average correlation coefficient of .40. Overall, these results did not indicate a problem of publication bias.

Discussion

In this meta-analysis we aimed to summarize the findings in the empirical literature on the relationship between media use and ADHD-related behaviors in children and adolescents. We analyzed the relations between media use and four outcomes based on the *DSM-V*: attention problems, hyperactivity, impulsivity, and ADHD as a composite of these three behaviors. Furthermore, we examined differences in these relationships for measurement type (i.e., standardized vs. unstandardized measures of ADHD), media type (i.e., television vs. video games), media content (i.e., overall media use, media violence, and media pacing), study design (correlational, longitudinal, and experimental), age, and sex.

We found that only few of the included studies used a measure that exclusively focused on attention problems, hyperactivity, or impulsivity. Because there was only one study that measured hyperactivity, no meta-analysis could be performed for this outcome. For attention problems, the meta-analysis revealed a moderate correlation with combined measures of media use ($r_+ = .32$). As for impulsivity, the meta-analysis revealed a small, but significant positive correlation ($r_+ = .11$). Although media use was more strongly related to attention problems than to impulsivity, the difference was only marginally significant. Moreover, the results for these two outcomes should be interpreted with caution because the number of studies is low and studies are heterogeneous; that is, individual studies differ greatly in their study designs and samples (i.e., children's age and sex distribution).

Results for ADHD Composite/Impulsivity Combined

The vast majority of studies included in our meta-analysis used composite measures of ADHD-related behaviors. Our meta-analysis of these studies revealed a positive relationship between all three measures of media use and

composite ADHD-related behaviors ($r_c = .12$). This correlation coefficient did not significantly differ from the correlation coefficient of the studies measuring impulsivity, which were therefore combined in subsequent moderator analyses. When simultaneously examining these moderator variables, we found that the effect sizes for studies that included standardized measures of ADHD were lower than those including unstandardized measures of ADHD, although both type of measures led to significant mean correlations.

We found no difference in the strength of the correlation between television viewing and video game playing, or between overall media use and violent media use. This finding is consistent with the arguments that overall media use (Nigg, 2006; Zimmerman & Christakis, 2007) and violent media use (Christakis, 2009; Kronenberger et al., 2005; Zimmerman & Christakis, 2007) could affect ADHD-related behaviors, although probably through different mechanisms. Too few studies focused on use of fast-paced media to reliably calculate an average meta-analytic correlation.

The effect sizes of cross-sectional studies were higher than those of longitudinal studies, but only after the removal of some outliers. Contrary to our expectations, we found no effect of age on the strength of the media-ADHD correlations. However, we were unable to directly compare effects sizes for different age groups because the great majority of empirical studies reported only one effect size for their entire sample, which often comprised a large age range. Therefore, we could only examine the moderating effect of age in a meta-regression analysis using the mean age of the studies' sample as a predictor of the studies' effect sizes. Although this is a commonly used method in meta-analysis, it is less sensitive. Therefore, our lack of finding age differences in the media-ADHD relationship should not be considered decisive. It is conceivable and in line with other meta-analytic results (e.g., Paik & Comstock, 1994) and theoretical accounts (e.g., Nigg, 2006) that children in early childhood are more vulnerable to violent and fast-paced media than older ones. Future empirical research should be conducted to investigate differences among different age group and fill this important gap in the literature.

Our multiple regression analysis suggests that the relationship between media use and ADHD-related behaviors is stronger for boys than for girls. This finding is consistent with the meta-analysis on violent media use and aggression by Paik and Comstock (1994), but not with two other meta-analyses that found null effects for sex (Anderson & Bushman, 2001; Anderson et al., 2010). Our result, however, should be interpreted with some caution. Again, we were unable to directly compare groups based on participant sex because, remarkably, of all 45 empirical studies, only two studies reported separate effect sizes for boys and

girls (Kim, Mutyala, Agiovlasitis, & Fernhall, 2011; Lin & Lepper, 1987). Because it is theoretically plausible that the relationship between media use and ADHD-related behaviors is different for boys and girls, future research examining sex differences is needed.

Gaps in the Literature and Directions for Future Research

Our meta-analysis was limited by the low number of available effects sizes for the three separate ADHD-related behaviors and for some of our moderators. As a result, several important analyses could not be conducted. Moreover, although it is common practice to use the bivariate r in meta-analyses, it does not control for other potentially influencing factors. Because the type and number of included covariates differed substantially between studies, we were not able to conduct sub-analyses using partial effect sizes. However, we see our meta-analysis as an important motivator of future research because it points out the gaps in the empirical literature and provides researchers with clear working hypotheses for future research. This is important because the study of the relationship between television and ADHD-related behaviors has been characterized by an ephemeral research interest. Researchers contributed with at most one or two studies, after which they disappeared from the field again. This could be the reason that the empirical studies have typically not been guided by explicit theoretical models. In the remainder of this article, we identify some gaps in the literature and present five crucial directions for future research.

1. Conceptualizing and Disentangling the Three Outcome Measures

We observed that very few of the included studies in our meta-analysis used outcome measures that purely reflected one of the ADHD-related behaviors (i.e., attention problems, hyperactivity, or impulsivity). Although several authors claimed to have measured one of these behaviors (e.g., attention problems) the scales that they used often also included several items measuring one or two other ADHD-related behaviors. Due to this mix-up of items and scales in the empirical studies, we had to code most outcome measures included in our meta-analysis as an ADHD-composite measure. As a result, the samples of studies measuring individual outcomes were limited and impeded subsequent moderator analyses for the separate outcomes.

This confound in the conceptualization and operationalization of the three ADHD-related behaviors is a serious gap in the literature. It is conceivable that media effects differ for each of these three different ADHD-related behaviors. For example, due to a lack of studies, we were not able to assess the effect of violent media use on the outcomes attention problems, hyperactivity and impulsivity.

However, it is conceivable that violent media use is more strongly related to impulsivity than to attention problems and hyperactivity. One of the main characteristics of aggression is the inability to inhibit inappropriate behaviors, thus to act impulsive (Anderson & Bushman, 2002). Several meta-analyses have shown that violent media content is associated with aggressive behavior (Anderson et al., 2010; Ferguson & Kilburn, 2010; Paik & Comstock, 1994; Sherry, 2001; but see the discussion among Bushman, Rothstein, & Anderson, 2010; Ferguson & Kilburn, 2010; and Huesmann, 2010 about the most recent meta-analyses). It is conceivable, therefore, that media violence may more easily elicit impulsivity rather than attention problems or hyperactivity. However, if the relationship between violent media use and the ADHD composite measures could only be attributed to impulsivity (and either less –or not at all- to attention problems and hyperactivity) the reported media violence ADHD-composite relationships could be spurious. Therefore, there is a vital need for future research disentangling the separate ADHD-related behaviors to single out which specific ADHD-related behaviors are more or less affected by which specific aspects of media use.

2. Including Theory-Based Media Use Measures

Hardly any study in our meta-analysis has focused on the effects of fast-paced media on ADHD-related behaviors. This is surprising because the fast pace of contemporary entertainment media is the very feature that is most often claimed to induce ADHD-related behaviors (e.g., Christakis, 2009; Jensen et al., 1997; Lang et al., 2000). There is a remarkable discrepancy in most studies between their conceptualization and operationalization of fast-paced media use. Whereas most authors theorized that the relationship between media use and ADHD-related behaviors should be attributed to the fast pace of media, they typically investigate the relationship between overall media use and ADHD-related behaviors. This is a serious omission in the literature. Not only are there large differences in the pacing of media entertainment (McCollum & Bryant, 2003), but children also differ greatly in their preferences for fast-paced and arousing media entertainment. Some children like fast-paced and arousing media entertainment, whereas others do not. Lumping together these different children into one crude overall media use measure could easily lead to unreliable and even invalid relationships between media use and ADHD-related behaviors. Therefore, there is a vital need for studies that directly measure or manipulate pacing of media content (e.g., the number of cuts, edits, and scene changes) and that examine the separate effects of pacing on attention problems, hyperactivity, or impulsivity.

3. Recognizing Transactional Effects

Most of the literature on which this meta-analysis is based employed cross-sectional designs or longitudinal designs examining the effect of media use at Time 1 on ADHD-related behaviors at Time 2. Only three of the included longitudinal studies (Gentile, Swing, Lim, & Khoo, 2012; Johnson, Cohen, Kasen & Brook, 2007; Stevens, Barnard-Brak, & To, 2009) have attempted to investigate the reversed causal effects of ADHD-related behaviors on media use. Although it is often assumed that media use causes ADHD-related behaviors, several arguments have been put forward to explain why children who display ADHD-related behaviors might use more and different media compared with typically developing children (Acevedo-Polakovich, 2005; Acevedo-Polakovich, Lorch, & Milich, 2007; Durkin, 2010). First, children with ADHD-related behaviors typically face peer difficulties (Hoza, 2007; Hoza et al., 2005), and as a result, they may often engage in more solitary play activities, such as watching television and playing video games. In addition, ADHD-related behaviors are often associated with parent-child conflict and parenting stress (DuPaul, McGoey, Eckert, & VanBrakle, 2001; Gupta, 2007; Pimentel, Vieira-Santos, Santos, & Vale, 2011), and media use is an activity where parents can enjoy some conflict-free time with their children. Alternatively, children may escape parents by turning to the media, or some parents may use the media to “baby sit” their children.

Finally, because ADHD-related behaviors are associated with low baseline arousal level (Beauchaine, Katkin, Strassberg, & Snarr, 2001; Lazzaro et al., 1999), children with ADHD-related behaviors often show a tendency to engage in arousing activities to compensate for this low baseline arousal (Roberti, 2004). Use of violent or fast-paced media may serve as such an activity. Thus, although media use may induce ADHD-related behaviors, these behaviors, in turn, may also enhance or change media use. Therefore, there is a vital need for comprehensive longitudinal studies, which may not only provide stronger evidence of causality in the relationship between media use and ADHD-related behaviors, but may also identify potential transactional media effects.

4. Recognizing Differential Susceptibility to Media Effects

The media-ADHD literature is characterized by a universal media effects perspective, which presumes that media effects are equal to all individuals. Such an approach is inconsistent with modern media-effects theories (e.g., Slater, 2007; Valkenburg & Peter, 2013b). Most studies in our meta-analysis ignored the moderating role of even the most straightforward individual difference variables, such as age and sex. This is surprising, because there is increasing consensus that children’s susceptibility to media effects depends on a host of person-based (e.g.,

age, sex, temperament) and social (e.g., family environment, peers; Valkenburg & Peter, 2013a) factors. In related research on the effects of violent media on aggression, it has been found, for example, that the effect of violent media on aggression is stronger for aggressive children (Bushman, 1995; Kronenberger et al., 2005) and for children who grow up in aggressive families (Fikkers, Piotrowski, Weeda, Vossen, & Valkenburg, 2013).

It is conceivable that the effect sizes in the present meta-analysis are small because they are “diluted” across too many different children. It is likely that the effects of media use on ADHD-related behaviors hold particularly for a small group of susceptible children. For these children and their families, the effects that we found for the whole population may be stronger. In the future, researchers on the media-ADHD relationship can no longer ignore potential factors that may differentiate the subtle universal effects reported in this meta-analysis. Potential differential susceptibility variables that are worthwhile to include in future studies, besides age and sex (Anderson & Bushman, 2002), are temperament (Valkenburg & Peter, 2013a), adversities in the home environment (e.g., family conflict, marital discord; Biederman, 2005; Nigg, Nikolas, & Burt, 2010), and prenatal adversities (e.g., prenatal alcohol exposure; Nigg et al., 2010).

5. More Targeted Theory Testing

The media-ADHD literature is characterized by an input-output approach. Several hypotheses in the literature have addressed specific mechanisms that might underlie the relations between media use and ADHD-related behaviors, such as arousal, executive functioning, and self-control. However, none of the included studies in our meta-analysis has operationalized the mechanisms to investigate particular explanatory hypotheses. Some of these hypotheses, such as the language development hypothesis and script theory have received criticisms (e.g., Ferguson & Donnellan, 2013; Ferguson & Dyck, 2012). It is therefore even more important to particularly investigate the proposed mechanisms of the relationship between media use and ADHD-related behaviors. Until now, it remains unclear how and why structural (e.g., pace) and content (e.g., violence) features of media may lead to one or more ADHD-related behaviors. Knowledge of the validity of these processes is of great importance, because it may help researchers to develop interventions aimed at reducing media effects on children’s ADHD-related behaviors. Therefore, there is an urgent need for future research that systematically investigates the hypothesized explanatory mechanisms and that singles out which mechanisms are involved for different types of media use and different types of ADHD-related behaviors.

Conclusion

In our meta-analysis, we found a positive relationship between media use and ADHD-related behaviors. More important, the meta-analysis clearly revealed some important gaps in the media-ADHD literature. There is a vital need for empirical research on the effects of fast-paced and violent media on each of the three separate ADHD-related behaviors. Only if future studies are able to address the questions of causality, individual susceptibility, and the underlying mechanisms of the media-ADHD relationship can researchers draw more decisive conclusions about the role of media use in ADHD-related behaviors.

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