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ORIGINAL ARTICLE

Media Violence and Children's ADHD-Related Behaviors: A Genetic Susceptibility Perspective

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This study examined the relationship between media violence exposure and Attention-deficit/hyperactivity disorder (ADHD)-related behaviors. Using survey (parent-reported) and genetic data of 1,612 Dutch children (aged 5 to 9 years), we examined genetic disposition as a possible cause of individual differences in children's use of and susceptibility to media violence. The gene variant of interest was the 5-HTTLPR polymorphism, which has been associated with ADHD-related behaviors in previous research. Results showed that the "long" variant of the gene polymorphism was related to greater violent media use, which in turn was related to more ADHD-related behaviors. The 5-HTTLPR genotype did not moderate the effect of media violence on ADHD-related behaviors. This study provides insight into the role of genetic factors in media effects.

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Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood behavioral disorders, with prevalence estimates ranging from 5 to 6% in Western countries (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). Traditionally, ADHD has been viewed as a discrete disorder, characterized by extreme levels of inattentiveness, hyperactivity, and impulsivity (American Psychiatric Association [DSM-V], 2013). In recent years, a growing number of authors conceive ADHD as the extreme end on a continuum of behaviors (Larsson, Anckarsater, Råstam, Chang, & Lichtenstein, 2012; Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma,

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2009), a perspective that is adopted in this study. We refer to this continuum as ADHD-related behaviors. Children displaying excessive ADHD-related behaviors typically face several other problems, including academic underachievement (Daley & Birchwood, 2010), impaired peer relationships (Diamantopoulou, Henricsson, & Rydell, 2005), aggressiveness (Waschbusch, 2002), and increased risk for later substance abuse (Molina & Pelham, 2003).

There have been recurrent claims in the literature that specific features of entertainment media may cause children's ADHD-related behaviors (e.g., Christakis, 2009; Nigg, 2006). The average time that children spend with entertainment media has increased dramatically in recent decades (Rideout, Foehr, & Roberts, 2010). Moreover, entertainment media have become more fast-paced, arousing, and violent (Carnagey & Anderson, 2004; Gentile & Anderson, 2003), and have been targeting children at an ever younger age. Several scholars have attributed the potential effects of entertainment media on ADHD-related behaviors to their violent nature (Kronenberger et al., 2005a; Levine & Waite, 2000; Zimmerman & Christakis, 2007). These scholars argue that violent media entertainment may (a) negatively affect children's basic arousal level or (b) disturb their development of self-control, which may both lead to attention problems, hyperactivity, and impulsivity (Huizinga, Nikkelen, & Valkenburg, 2013).

Several earlier studies have investigated the relationship between exposure to violent media and ADHD-related behaviors. Most of these studies have yielded positive albeit modest relationships between violent media use and measures of ADHD-related behaviors (Anderson & Maguire, 1978; Hastings et al., 2009; Kronenberger et al., 2005a; Levine & Waite, 2000; Zimmerman & Christakis, 2007). However, although research on the media–ADHD relationship has been burgeoning, little attention has been paid to individual differences between children that may shape this relationship. Children greatly differ in their preference for and susceptibility to media violence (Huesmann & Taylor, 2006; Valkenburg & Cantor, 2000). For example, children who exhibit a high level of trait aggression have stronger preferences for violent media, and are more readily affected by such media (Bushman, 1995; Kronenberger et al., 2005b). To fill this gap in the literature, this study investigated how individual differences predict exposure to media violence and moderate its effect on ADHD-related behaviors.

An important variable that may explain individual differences in the uses and effects of media violence on ADHD-related behaviors is children's genetic disposition. This assumption is based on two earlier research findings. First, the heritability of ADHD-related behaviors is among the highest compared to other behaviors (Bergen, Gardner, & Kendler, 2007), with estimates around 76% (e.g., Faraone et al., 2005; Nikolas & Burt, 2010; Thapar, Harrington, Ross, & McGuffin, 2000). Second, overall media use has also been shown to be partly heritable, with estimates ranging from 7 to 35%, depending on the measure of media use and the employed methods (Kirzinger, Weber, & Johnson, 2012; Plomin, Corley, DeFries, & Fulker, 1990). It is therefore conceivable that violent media use is also partly influenced by genetic factors. Given that both ADHD-related behaviors and media use are partly heritable, it seems reasonable to include genetic factors in media-uses-and-effects models considering ADHD-related behaviors.

Disposition-content congruency hypothesis

This study is guided by Valkenburg and Peter's (2013) disposition-content congruency hypothesis, which explains why dispositions simultaneously predict children's media use and enhance media effects. Valkenburg and Peter argue that children have a tendency to seek out media that do not diverge too much from their preexisting cognitions, emotions, attitudes, and behavior (Oliver, Kim, & Sanders, 2006). Dispositionally congruent media content is expected to enhance media effects for two reasons. First, it stimulates children's information processing. In comparison to dispositionally incongruent content, processing of congruent media content requires less cognitive effort because it can be related to more existing mental schemata of the media user (Alba & Hutchinson, 1987; Lang, 2009). Because children can allocate more resources while processing dispositionally congruent media content, this content can enhance media effects. Second, dispositionally congruent content is more likely to strengthen children's experience of familiarity with the content or at least their illusion of familiarity (Whittlesea, 1993). This familiarity heightens pleasure while watching, which has in turn been shown to enhance media effects (Goldberg & Gorn, 1987; Mathur & Chattopadhyay, 1991; Owolabi, 2009). This familiarity-pleasure process has been explained with the hedonistic fluency hypothesis (Reber, Schwarz, & Winkielman, 2004).

Hypothesized relationships between genes, media violence, and ADHD-related behaviors

When integrating the propositions of the disposition-content congruency hypothesis with earlier research findings on the heritability of media use and ADHD-related behaviors, four potential hypotheses emerge. These hypotheses are depicted in Figure 1. First, given the established heritability of ADHD (Faraone et al., 2005; Nikolas & Burt, 2010; Thapar et al., 2000), we hypothesize that children with a certain genetic disposition are more susceptible to ADHD-related behaviors compared to children with a different genetic disposition (H1).

Second, we expect that children with a genetic susceptibility to ADHD-related behaviors will use more violent media (H2A). Children who display ADHD-related behaviors typically show low baseline levels of arousal (Beauchaine, Katkin, Strassberg, & Snarr, 2001; Lazzaro et al., 1999). Based on arousal theory (Eysenck, 1997), it is assumed that low baseline arousal leads children to seek out arousal-enhancing activities because low arousal is experienced as an unpleasant physiological state. Violent media use is an activity that can evoke intense arousal and therefore qualifies as a suitable arousal enhancer (Anderson & Bushman, 2001; Fleming & Rickwood, 2001). Our hypothesized relationship between genetic susceptibility and violent media exposure is an example of a phenomenon in the literature that has been named as *gene–environment correlation* (Rutter & Silberg, 2002).

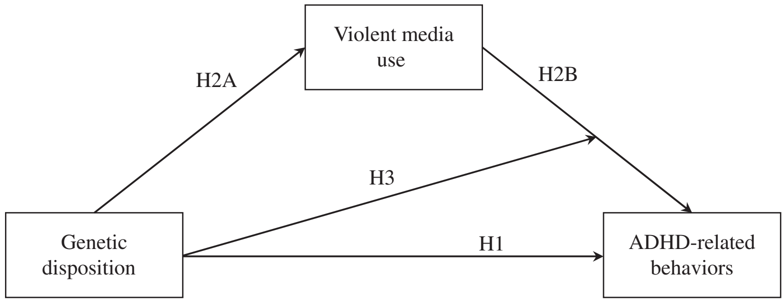

Figure 1 Disposition-content congruency hypothesis predicting the relationships between genetic disposition, violent media use, and ADHD-related behaviors.

Given the association between violent media use and ADHD-related behaviors found in earlier studies (Anderson & Maguire, 1978; Hastings et al., 2009; Kronenberger et al., 2005a; Levine & Waite, 2000; Zimmerman & Christakis, 2007), we expect that exposure to media violence may evoke ADHD-related behaviors (H2B). If H2A and H2B are valid, violent media use may act as a mediator between genetic disposition and ADHD-related behaviors, such that genetic disposition indirectly affects ADHD-related behaviors through its effect on violent media use (Hayes, 2009).

Our final hypothesis H3 concerns a moderating effect of children's genetic disposition on the relationship between violent media use and ADHD-related behaviors. Based on the disposition-content congruence hypothesis, we expect that children with a certain genetic disposition will be more vulnerable to influences of media violence compared to children with a different genetic disposition. Such a moderating effect of children's genetic disposition and environmental features (i.e., violent media exposure) is a conceptualization of a gene–environment *interaction* (Rutter & Silberg, 2002). This hypothesized relationship is visualized by path H3 in Figure 1.

In the disposition-content congruency hypothesis, the proposed mediating and moderating effects of dispositional factors are expected to coincide. This implies that children with a genetic susceptibility to ADHD-related behaviors have a preference for violent media, and at the same time process violent media content differently than children without this genetic susceptibility, thereby strengthening its effect on ADHD-related behaviors. Such a model, in which a predictor of variable X is also the moderator of the effect of variable X on variable Y, is a conceptualization of a *moderated mediation* (Preacher, Rucker, & Hayes, 2007). Testing the joint occurrence of a mediating and moderating effect of genetic disposition in the relationship between violent media use and ADHD-related behaviors was the aim of this study.

The 5-HTT gene, violent media use, and ADHD

Although ADHD-related behaviors are highly heritable (e.g., Faraone et al., 2005), little is known about the specific genes that are involved. One gene that has been associated with ADHD is the 5-HTT gene (Manor et al., 2001; Zoroğlu et al., 2002). Previous gene–environment studies have shown a moderating effect of this gene on the relationship between aversive factors in the home environment (e.g., marital conflict) and children's ADHD-related behaviors (for an overview, see Nigg, Nikolas, & Burt, 2010). Given these earlier findings, the 5-HTT gene serves as a suitable candidate for testing our hypothesized model.

The 5-HTT gene plays a crucial role in regulating serotonin transmission in the brain (Greenberg et al., 1999). Serotonin is a neurotransmitter that has an important function in the regulation of emotions and impulses (Gazzaniga & Heatherton, 2006). Serotonin activity has been found to be involved in ADHD-related behaviors (Canli et al., 2005; Gainetdinov et al., 1999; Lucki, 1998). Within the 5-HTT gene, a frequently studied polymorphism (i.e., part of the gene where the DNA code varies between individuals) is the 5-HTT-linked polymorphic region (5-HTTLPR). Traditionally, two alleles (i.e., variants) of this polymorphism are distinguished: a "short" (*s*) and a "long" (*l*) allele (Greenberg et al., 1999). The long allele of this polymorphism is usually found to be associated with ADHD-related behaviors (Manor et al., 2001; Zoroğlu et al., 2002). Therefore, we expect that the presence of the long allele of the 5-HTTLPR polymorphism will be associated with more ADHD-related behaviors (H1), and more violent media use (H2A). In addition, we expect that it will strengthen the relationship between violent media use and ADHD-related behaviors (H3).

Method

Sample

This study was conducted with a subsample of children participating in the 2010/2011 data wave of the *Generation R* study, a prospective longitudinal cohort study conducted in Rotterdam, the Netherlands. This subsample consisted of 1,612 children (51.1% male) aged 5 to 9 years ($M = 6.00$, $SD = 0.38$). Of the children in our sample, 59.6% were first-born children, 31.9% were second-born children, and 8.5% were third- or later-born children.

Our sample solely consisted of children of Dutch ethnicity to reduce possible effect variations of the 5-HTTLPR polymorphism due to ethnic heterogeneity. We defined Dutch ethnicity as having both parents and all four grandparents born in the Netherlands. Of the total group of 6,346 children participating in the 2010/2011 data wave of the Generation R study, 2,903 met this criterion. Of this subsample, 1,169 children were excluded because DNA samples were unavailable. Another 122 children were excluded due to incomplete survey data, resulting in a final sample of 1,612 children.

Procedure

The Generation R study was designed to identify genetic and environmental factors contributing to the growth, health, and development of children, by following a large birth cohort from fetal life onwards (Jaddoe et al., 2012). Prenatal and postnatal assessment consisted of frequent physical examinations at child health centers and surveys filled out by the children's parents. Regular assessment of the subjects continues until children reach young adulthood. The data for this study were obtained from DNA samples collected at birth and cross-sectional survey data collected at the 2010/2011 data wave. We tested our model using the most recent data wave of the Generation R study (the 2010/2011 wave), which is to date the only wave in which our measure of violent media use has been included. Surveys were filled out by the children's primary caregiver (85.1% mother). The Generation R study has been approved by the Medical Ethical Committee of the Erasmus Medical Center, Rotterdam.

Measures

Genotyping

DNA was extracted from umbilical cord blood samples collected at birth. Determination of the 5-HTTLPR polymorphism was carried out in a laboratory using common procedures.[1] The frequencies of the short (*s*) and long (*l*) alleles were 43.5 and 56.5%, respectively, indicating that the short variant was less frequently present in our sample than the long variant. This finding is in line with observations in other Caucasian samples (Brummett et al., 2008; Stein, Schork, & Gelernter, 2008). Each child had two copies of the 5-HTTLPR polymorphism (one copy from each parent), which combination is referred to as the child's genotype. Children's genotype could thus either consist of two *s* alleles (*s/s*), two *l* alleles (*l/l*), or one *s* and one *l* allele (*s/l*). To test for genotyping errors, we checked the distribution of the genotype frequencies in our sample (19.0% *s/s*, 49.0% *s/l*, and 32.1% *l/l*) against the Hardy-Weinberg equilibrium (HWE; Wigginton, Cutler, & Abecasis, 2005). The HWE is a principle predicting population genotype frequencies. Deviation from HWE might indicate problems in the genotyping process. The genotyping frequencies in our sample did not deviate from HWE, $\chi^2(1) = .00$, $p = .969$, indicating that the genotyping process was successful.

Besides distinguishing between the *s* and *l* allele, two subvariants of the long allele were distinguished, denoted by l_a and l_g (Nakamura, Ueno, Sano, & Tanabe, 2000). The frequencies of the l_a and l_g alleles were 49.4% and 7.3% respectively. Because serotonin functioning of the l_g variant is comparable to that of the *s* allele (Nakamura et al., 2000), the *s* and l_g alleles were grouped together (denoted by s'). This resulted in a frequency distribution of 25.2% s'/s', 51.1% s'/l_a, and 23.8% l_a/l_a. The 5-HTTLPR genotype was coded $0 = s'/s'$, $1 = s'/l_a$, $2 = l_a/l_a$. The l_a allele indicates genetic susceptibility to ADHD-related behaviors (Manor et al., 2001; Zoroğlu et al., 2002).

ADHD-related behaviors

ADHD-related behaviors were measured using the DSM-ADHD subscale of the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000).[2] This subscale has been especially constructed to be consistent with the diagnostic criteria of ADHD described in the DSM-IV. The subscale consists of six problem items, which mothers rated on a 3-point scale with 0 = *not true*, 1 = *somewhat or sometimes true*, 2 = *very true* of the child. Research has shown good convergent validity of this parent-report scale with clinician's ratings of ADHD (Nakamura, Ebesutani, Bernstein, & Chorpita, 2009). However, the CBCL's ADHD scale is not designed to diagnose ADHD, nor does a high score on this scale necessarily indicate ADHD. Rather, it can be used as a continuous measure of the problem behaviors that are characteristic of ADHD, which is the aim of this study. The Dutch version of the CBCL has displayed good psychometric properties (Tick, van der Ende, Koot, & Verhulst, 2007). In our sample, Cronbach's alpha for this scale was .79 ($M = 2.72$, $SD = 2.48$).

Violent media use

Violent media use was measured using a scale specifically created for this study. This scale was based on commonly used time estimate measures of media use (Vandewater & Lee, 2009). Mothers indicated how often their child watched (a) television, (b) DVDs, and (c) videos and computer games in which violence occurs. Violence was defined as "all the violence (for example, fighting, shooting) that living beings (for example, people, monsters) do to each other." Response options were 1 = *never*, 2 = *one day a month*, 3 = *two days a month*, 4 = *three days a month*, 5 = *one day a week*, 6 = *two days a week*, 7 = *three days a week*, 8 = *four days a week*, 9 = *five days a week*, 10 = *six days a week*, and 11 = *every day*. Scores on the three items were summed to create a total violent media use score ($M = 3.40$, $SD = 4.71$).

Covariates

On the basis of previous studies, we included age (Valkenburg & Cantor, 2000), gender (Polanczyk et al., 2007), birth order (D'Onofrio et al., 2009; Satake, Yoshida, Yamashita, Kinukawa, & Takagishi, 2003), and socioeconomic status (SES; Zwirs et al., 2011) as covariates in our analyses. Children's age was measured in months. Gender was dichotomously scored as 0 = *male*, 1 = *female*. Birth order referred to the rank of the child by age amongst his or her older siblings, if any (0 = *first born*, 1 = *second born*, etc.). SES was a composite measure of mother's educational level, partner's educational level, and household income. Mother's and partner's educational level referred to the highest educational level they had finished, if any (0 = *no education finished*, 1 = *elementary education*, 2 = *lower secondary education*, 3 = *general or higher secondary education*, 4 = *vocational education*, 5 = *higher education*). Household income referred to the net income of the household per month, hence mother's income plus that of their partner, if any (1 = *less than 800 euros*, 2 = *800–1200 euros*, 3 = *1200–1600 euros*, 4 = *1600–2000 euros*, 7 = *2000–2400 euros*, 8 = *2400–3200 euros*, 9 = *3200–4000 euros*, 10 = *4800–5600 euros*, 11 = *more than 5600 euros*). Composite SES was calculated by averaging the standardized scores of mother's educational level, partner's educational level, and household income.

Table 1 Correlations Among Violent Media Use, ADHD-Related Behaviors, the 5-HTTLPR Genotype, and Covariates

	Violent Media Use	ADHD-Related Behaviors
Main variables		
Violent media use		
ADHD-related behaviors	.08**	
5-HTTLPR genotype[a]	.07**	.00
Covariates		
Age	.09***	.01
Gender[b]	−.26***	−.10***
Birth order	.12***	−.15***
SES	−.01	−.23***

[a]$0 = s'/s'$, $1 = s'/l_a$, $2 = l_a/l_a$. [b]0 = boy, 1 = girl.
**$p < .01$; ***$p < .001$.

Statistical analysis

Our hypothesized model (Figure 1) was tested using the PROCESS SPSS macro developed by Hayes (2012). This macro uses linear regression analysis to test individual paths as well as indirect and moderated paths and produces bootstrap confidence intervals for testing the indirect effect. The bootstrap method has been described in detail elsewhere (Bollen & Stine, 1990). One of the advantages of using the bootstrapping technique is that it does not require the normality assumption to be met. It is therefore an appropriate method of testing effects in the presence of skewed data (Russel & Dean, 2000) as is the case with the data for this study. Five thousand bootstrap samples were drawn to generate bias-corrected and accelerated 95% confidence intervals (BCa 95% CI). All analyses controlled for gender, age, birth order, and SES.

Results

Zero-order correlations

Table 1 presents the zero-order correlations among the variables in our model. The correlations demonstrate that presence of the l_a allele of the 5-HTTLPR polymorphism was positively related to violent media exposure. Violent media exposure, in turn, was positively related to ADHD-related behaviors.

Testing the model

The test of our model (Figure 1) revealed no relationship between the 5-HTTLPR genotype and ADHD-related behaviors, $b = -0.00$, $SE = 0.09$, $t = -0.03$, $p = .978$, rejecting H1. We did find a significant relationship between the 5-HTTLPR genotype and violent media use, $b = 0.46$, $SE = 0.16$, $t = 2.87$, $p = .004$, supporting H2A. The relationship between violent media use and ADHD-related behaviors was

Table 2 Multiple Regression Analyses Predicting Violent Media Use and ADHD-Related Behaviors

	Violent Media Use		ADHD-Related Behaviors	
	b	*SE b*	*b*	*SE b*
Age	0.08***	0.02	−0.01	0.01
Gender[a]	−2.53***	0.22	−0.37**	0.12
Birth order	0.84***	0.16	−0.48***	0.09
SES	−0.08	0.13	−0.64***	0.07
5-HTTLPR[b]	0.46**	0.16	−0.00	0.09
Violent media use			0.04**	0.01
F	34.82***		24.04***	
R^2	0.10		0.08	

[a]0 = boy, 1 = girl. [b]$0 = s'/s'$, $1 = s'/l_a$, $2 = l_a/l_a$.
**$p < .01$; ***$p < .001$.

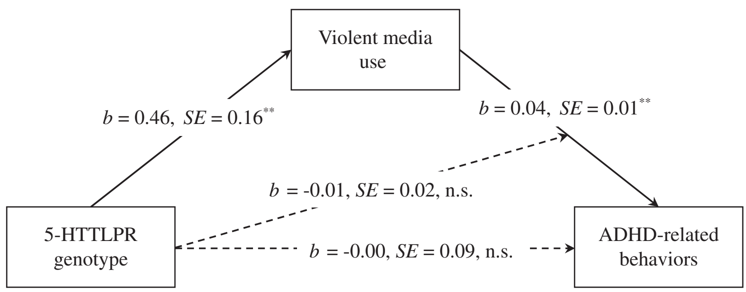

Figure 2 Linear regression results of the relationships between 5-HTTLPR genotype, violent media use, and ADHD-related behaviors. ** $p < .01$.

also statistically significant, $b = 0.04$, $SE = 0.01$, $t = 2.81$, $p = .005$, confirming H2B. Bootstrapping revealed that the indirect effect of the 5-HTTLPR genotype on the ADHD composite score through violent media use was statistically significant, with a standardized point estimate of .005 and a bias-corrected and accelerated 95% confidence interval (BCa 95% CI) of .001 to .011. Table 2 presents the results of the linear regression analyses without the interaction term. Inclusion of the interaction term revealed no moderating effect of the 5-HTTLPR genotype on the relationship between violent media use and ADHD-related behaviors, $b = -0.01$, $SE = 0.02$, $t = -0.61$, $p = .544$. Therefore, H3 was not supported. Results of the analyses including the interaction term are graphically presented in Figure 2.[3]

Discussion

The main aim of this study was to extend previous research focusing on the relationship between violent media use and ADHD-related behaviors in children.

Inspired by the disposition-content congruency model (Valkenburg & Peter, 2013), we investigated the role of genetic disposition (i.e., the 5-HTTLPR genotype) in the relationship between violent media use and ADHD-related behaviors. The model we tested is a conditional rather than a universal media effects model. It assumes that media effects do not equally hold for all children. It assumes that genetics play a role in both children's preference for violent media and their reaction to this content.

In H1, we predicted a direct association between the long allele of the 5-HTTLPR polymorphism and ADHD-related behaviors. This hypothesis could not be confirmed by our findings. Some previous studies, however, also failed to find such an association (Langley et al., 2003; Wigg et al., 2006). A possible explanation for this null-relationship may lie in our sampling methods. Many of the studies examining a direct relationship between specific gene variants and ADHD-related behaviors compared children clinically diagnosed with ADHD to "super-healthy" individuals (Kent et al., 2002; Manor et al., 2001; Seeger, Schloss, & Schmidt, 2001; Zoroğlu et al., 2002). In contrast, we studied a general population sample and measured ADHD-related behaviors as a continuous trait. Because the effects of single genes are typically very small (Plomin & Davis, 2009) they may only become significant when extreme groups are compared.

In H2A, we predicted a direct relationship between the 5-HTTLPR genotype and violent media use. The analyses supported our expectation. The presence of the l_a variant was associated with more violent media use, indicating a gene–environment correlation. This finding extends previous studies that showed that overall media use is partly heritable (Kirzinger et al., 2012; Plomin et al., 1990) by showing a relationship between a specific gene and violent media use. As theorized by the disposition-content congruency hypothesis, our findings suggest that children, due to their genetic disposition, may *actively* seek specific media content (Harden, Hill, Turkheimer, & Emery, 2008; Rose, 2002), for example because they seek out arousing activities (Eysenck, 1997). However, an additional, *passive* process may also be in effect here. Parents share 50% of their DNA with their children and also shape the environment their children grow up in. Therefore, the association between children's genetic disposition and violent media use may also reflect the relationship between parents' genetic disposition and the environment they create for their children (Rutter & Silberg, 2002). Future research including genetic data from parents can help identify whether this association between genetic disposition and violent media exposure reflects active, passive, or both active and passive gene–environment correlations.

H2B concerned the relationship between violent media use and ADHD-related behaviors. We expected that children who were exposed to more media violence would display more ADHD-related behaviors compared to children who were exposed to less media violence. This expectation was confirmed by our findings. Although the effect was small, it does support findings from previous studies showing a positive relationship between violent media use and ADHD-related behaviors (Anderson & Maguire, 1978; Hastings et al., 2009; Kronenberger et al., 2005a; Levine & Waite, 2000; Zimmerman & Christakis, 2007).

Concerning the results of H1, H2A, and H2B, we performed an analysis to test for the indirect effect of the 5-HTTLPR genotype on ADHD-related behaviors. This analysis demonstrated that violent media use acted as a mediator within the relationship between the genotype and ADHD-related behaviors. Thus, in our sample, the 5-HTTLPR genotype did affect ADHD-related behaviors but only through its effect on violent media use. Especially in the absence of the direct effect of the genotype on ADHD-related behaviors (H1), this indirect relationship underlines the important role of violent media use in ADHD-related behaviors. Several earlier media-effects models, most notably the General Aggression Model (Anderson & Bushman, 2002) and the Reinforcing Spiral Model (Slater, 2007), have argued that media use should be seen as an endogenous variable, that is, the result of causally prior variables, including one's predisposition. These theories also argue that even when controlled for these prior variables, media use can change one's beliefs, attitudes, behavior, and personality characteristics (Anderson & Bushman, 2002; Slater, 2007; Valkenburg & Peter, 2013). Our study has provided the first evidence for the proposition that violent media use should be conceptualized as a mediator between genetic disposition and AHDH-related behavior.

In our final hypothesis H3, we expected that the association between violent media use and ADHD-related behaviors would be dependent on children's 5-HTTLPR genotype. However, our results showed that the strength of the relationship between violent media use and ADHD-related behaviors did not vary between children as a function of their 5-HTTLPR genotype. Hence, there was no evidence of a gene–environment interaction between the child's genotype and violent media use, rejecting H3. Rutter and Silberg (2002) pose several explanations for why it is difficult to find such a gene–environment interaction effect. One explanation is that genes that moderate the effect of environmental factors (e.g., media violence) are not necessarily the same as the genes that have a main effect on behavior. In other words, susceptibility to media violence may be influenced by other genes than the 5-HTT gene. Another explanation is that finding a gene–environment interaction in the presence of gene–environment correlation may be problematic. Genetic and environmental factors are not independent, that is, genes may influence the environment. Therefore, it is difficult to entangle the interacting effect of the gene and the environment on behavior from the main effect of the gene (Rutter & Silberg, 2002).

Limitations and future research

The results of this study are preliminary and require further validation. This study is the first to find an association between children's 5-HTTLPR genotype and violent media exposure, and, therefore, replication is needed. The data available in the Generation R study provided us with a unique opportunity to report on the relationship between the 5-HTT gene and the use and effects of media violence. However, the dataset did not allow us to test the cognitive or emotional processes that may underlie the relationship between violent media and ADHD-related behaviors.

It is therefore an important goal of future research to investigate such underlying mechanisms, to be better able to explain the media–ADHD relationship.

In addition, because of its correlational nature, our study does not permit a conclusion about the direction of the relationship between violent media use and ADHD-related behaviors. Although it is often hypothesized that violent media cause ADHD-related behaviors in children, these children may also be more inclined to use violent media (Acevedo-Polakovich, Lorch, & Milich, 2007; Durkin, 2010). Future studies should thus examine the potential reciprocal relationship between violent media use and ADHD-related behaviors.

Finally, although little is known about the genetic structure of ADHD, several studies have identified other candidate genes that are linked to ADHD-related behaviors that could play a role in its relationship with media violence (Brookes et al., 2006; Gizer, 2009; Li, Sham, Owen, & He, 2006). One, for example, is the DRD4 gene, which is important in the functioning of the dopaminergic system. We also tested our model for the 7-repeat allele of the DRD4 gene, but found no significant effect in the relationship between violent media use and ADHD-related behaviors. Additional research on different genotypes is needed to establish reliable conclusions about the role of genes in the media-ADHD relationship.

Conclusion

The results of this study provide some first insights into the disposition-content congruency hypothesis (Valkenburg & Peter, 2013). Although part of this hypothesis was rejected by our results (i.e., we did not find an interaction effect for the included genotype), our study can be an important starting point for media-effect researchers. It is often theorized that individual difference variables are important to include in models explaining media preferences and effects. However, such variables are still too often ignored, at least in the media-ADHD literature (Huizinga et al., 2013). The model we have tested in this study may not only be applied to genes but also to other individual difference variables in future research. In addition to dispositional variables, important individual difference variables may include developmental (e.g., cognitive level) and social variables (e.g., parents and peers; see Valkenburg & Peter, 2013).

The relationship between the 5-HTTLPR genotype and violent media use turned out to be small ($r = .07$); even smaller than the effects sizes of media use on outcome variables typically found in media-effects research. Small genetic effects are not uncommon. Geneticists generally acknowledge that single-gene variants explain less than 1% of the variance in individual behavior (e.g., Comings et al., 2000). Such small effect sizes raise the question to what extent the inclusion of genetic data can enhance our understanding of media uses and effects. This is important to consider given that the inclusion of genetic data is costly. In our view, it is still important to pursue this new line of research. The developments in genetics are currently revolutionary, and the explanatory power of genetic predisposition is expected to increase significantly in the coming years. These developments may enhance our understanding of individual differences in the processing of environmental stimuli, including those encountered in the media. Several scholars have argued that we need to open up new horizons to understand how media affect their users (e.g., Nabi & Oliver, 2009; Sherry, 2004). In order to get a more elaborate understanding of media use, media processing, and media effects, future research may benefit from incorporating insights from disciplines such as genetics and neurosciences. We hope that our study may form a first starting point for a more integrative approach to media effects research.

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Notes

1 DNA was amplified by a standard polymerase chain reaction (PCR) procedure. Genotyping of the 5-HTTLPR polymorphism was done using Taqman allelic discrimination assay and genotyping master mix (Applied Biosystems, Foster City, CA). Two-step PCR using the GeneAmpR PCR system 9600 consisted of 10 minutes denaturation at 95°C, following 40 cycles of 15-second denaturation at 96°C and 90-second annealing-elongation at 62.5°C. Signals were detected on the 7900HT Fast Real-Time PCR System (Applied Biosystems), and individual genotypes were determined using sequence detection system (SDS) software (version 2.3, Applied Biosystems).

2 We also ran the analyses with the "inattention" subscale of the CBCL and found the same results.

3 We also tested our hypothesized model for the 7-repeat allele of the DRD4 gene, a gene important in the functioning of the dopaminergic system. No significant associations were found between the 7-repeat allele and violent media use or ADHD-related behaviors, rejecting our model for this gene.

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