**Game Violence, Game Mechanics, and 2D:4D Digit Ratio as Predictors of Aggressive Behavior**

Media shapes the world. In the absence of media, people’s perceived worlds would be limited to only that fraction of the world which they personally experience. Through media, however, people develop ideas, attitudes, and schema about people they’ve never met, experiences they’ve never had, and concepts they’ve never personally explored. Because these ideas, attitudes, and schema are the basis of behavior, media messages promise to influence human psychology and behavior.

One of the newest and most popular forms of media is video games. Compared to traditional media such as books, movies, and film, video games are highly interactive; the player controls, to at least some degree, the game character. Moreover, video games are generally highly motivating and engaging and can be played for many hours at a time. These properties have inspired research that investigates whether video games are an effective way to teach skills and behaviors (Green & Bavelier, 2003).

However, not all learned skills and behaviors are desirable. While video games are a broad and heterogeneous form of media, many of the most popular video games contain violent content. Violent content ranges from the mild, fantastic, and cheerful (e.g., *Super Mario Galaxy*) to the graphic, realistic, and morally deviant (e.g., *Grand Theft Auto 3, Manhunt, Mortal Kombat*). Exposure to this violent content is expected to teach players aggressive behaviors and schema. It is further supposed that media effects of video games are more potent than those of other forms of media because the player is an active participant in the violent content, rather than a passive viewer.

**Psychological theories of aggressive behavior**

Like most psychological and behavioral phenomena, aggressive and violent behavior is thought to be complex and multiply determined, with no single clear cause. However, a variety of theories have emerged to describe the diverse possible causal pathways from stimuli to aggression.

**Social learning theory.** Research of media effects on behavior began with Bandura’s social learning theory (Bandura & McClelland, 1977). In contrast to behaviorist theories, which proposed that individuals learn through experienced rewards and punishments for behaviors, social learning theory suggested that behavior also could be shaped through observational learning. Instead of having to experience a reward or punishment firsthand, a person could learn behavior through observing others’ behaviors and the rewards or punishments those others received.

An early study examined the possibility of such a learning process. Children were randomly assigned to watch a version of a video of a lab assistant in a room full of toys. Among the toys in the room is a “bobo doll”, an inflatable, durable doll with a weighted base, such that it springs upright when pushed over. In one version of the video, the lab assistant ignores the doll and plays with the other toys in the room. In another version, the lab assistant repeatedly attacks the doll, hitting it with a mallet, throwing it into the air, or sitting on it and punching it repeatedly. Children who watched this version of the video were more likely to engage in aggressive play with the doll or with other toys, imitating behaviors learned from watching the assistant’s behavior (Bandura, Ross, & Ross, 1961).

This theory had alarming implications for the possible effects of violent media. If behavior is easily and readily shaped by observing others, then watching media in which violent behaviors are justified and rewarded could teach people to use violence. Future research attempted to test Social Learning Theory models of violent media and aggressive behavior with more externally valid stimuli (e.g., violent cartoons) and dependent measures (e.g., aggressing against another person rather than hitting an inanimate doll) (e.g., Josephson, 1987; Potts, Huston, & Wright, 1986).

**The General Aggression Model.** The General Aggression Model (GAM) is an attempt to integrate social learning theory and later-developed theories into a single broad model that would still be specific enough to be falsifiable. GAM does this by describing a cycle consisting of person/situation inputs, an internal state of the individual, and outcomes resulting from the process. The theories integrated in the GAM explicate the theoretically-relevant inputs, states, and outcomes, as well as their relationships.

Causal pathways within the GAM reflect the predictions of many theories. For example, cognitive-neoassociation theory (Berkowitz, 1989) considers learned associations between cues and aggression, suggesting that a conditioned stimulus can later prime associated cognition or affect. Script theory (Huesmann, 1986, 1998) proposes that well-rehearsed sets of concepts are selected and applied for their resemblance to the current context; increased rehearsal of aggressive scripts, then, is expected to increase the likelihood that these scripts are activated and applied. Excitation transfer theory (Zillmann, 1983) argues that that arousal from a previous event can be applied to a later unrelated event, causing inappropriate affective overreactions to interpersonal situations and increased aggressive behavior. Cultivation theory (see Shanahan & Morgan, 1999), which argues that media portrayals influence the receivers’ perception of the real world, suggests that persons exposed to violent media develop a distorted worldview, overestimating the frequency and social normativity of aggressive or violent behavior. Desensitization theory (Wolpe, 1958), which proposes that repeated exposure to an affective stimulus causes decreased affective response over time, indicating that violent media may make aggressive or violent behaviors less affectively aversive and reduce others’ apparent need for help.

GAM broadly describes internal states leading to behavior as belonging to three categories: cognition, affect, and arousal. Violent media is expected to influence all of these in short-term contexts. Given the theories combined by GAM, increased aggressive thought accessibility, hostile feelings, arousal, rehearsal of aggressive behaviors, and expectations of aggressive behavior from others are all believed to increase aggressive behavior. Many experiments have found associations between violent media, violent behavior, and these hypothesized mediating processes.

GAM is also argued to predict *long-term* changes in behavior. Recall that GAM is a cycle. Its outcomes (e.g., aggressive behavior) are thought to shape the individual’s personality and future situations; an aggressive individual is thought to be more likely to find himself in aggressive contexts in the future. In those aggressive contexts, the individual is expected to use previously-exercised aggressive behavior. Repeated exposure to aggressive primes is argued to make the prime *chronically accessible,* causing prolonged priming of aggressive behavior(Anderson & Bushman, 2002).

GAM has recently been further generalized to explain effects of nonviolent media on prosocial behavior in a model called the General Learning Model (GLM; Buckley & Anderson, 2006). This model argues that games can be teaching tools and can teach aggressive or prosocial behaviors. This model is structurally analogous to the GAM, featuring the same series of person/situation inputs, which contribute to a present internal state, leading to outcomes such as appraisals and behaviors. Affect, cognitions, and arousal derived from media are again expected to influence a person’s internal states and choices of actions, allowing calming (Whitaker & Bushman, 2012) or prosocial (Greitemeyer & Osswald, 2010) video games to cause increased prosocial behavior.

**Evidence for violent game effects on aggressive outcomes**

To date, twenty five years of violent video game research indicates a causal effect of violent games on aggressive thoughts, feelings, and behaviors. Researchers have found significant effects of violent game contents on aggressive outcomes whether comparing early arcade games like *Centipede* and *Zaxxon* (Anderson & Ford, 1987) or more modern, realistic video games such as *Grand Theft Auto 4* (e.g., Gabbiadini, Riva, Andrighetto, Volpato, & Bushman, 2013).

In summarizing this literature, meta-analysists have argued that effects are positive and highly statistically significant (Anderson et al., 2010; Greitemeyer & Mügge, 2014), a finding which one researcher saw as “nailing the coffin shut on doubts” (Huesmann, 2010). Effect sizes have been recognized as modest in magnitude (*r* = .21, Anderson et al., 2010; *r* = .19, Greitemeyer & Mügge, 2014), but these effect sizes are argued to be practically meaningful based on their putative implications for public health. Accordingly, professional societies have released public statements on the harmful effects of violent media (American Psychological Association, Task Force on Violent Media, 2005; American Academy of Pediatrics, Council on Communications and Media, 2009). It has been argued that there is now “broad consensus” among media researchers, pediatricians, and parents that media violence increases aggression in children (Bushman, Gollwitzer, & Cruz, in press).

**The controversy.** However, not all researchers have been convinced by these research findings. First, critics argue that the evidence has been overstated due to publication bias (Ferguson, 2007), that is, that studies which do not find significant effects are not submitted or not accepted for publication, causing the existing literature to provide a biased overestimate of the effect size. It has also been argued that the construct of “violent games” is lacking in content validity (Hilgard, Engelhardt, & Bartholow, in revision; Ferguson, 2014; Progress and Freedom Foundation & Electronic Frontier Foundation, 2009). For example, many violent game scholars have defined mostly-innocuous games like *Pac-Man* as being “violent” (Thompson & Haninger, 2001; Rushton, 2013) and meta-analyzed research findings accordingly (e.g. “best-practices” criteria from Anderson et al., 2010). Finally, the internal and external validity of aggression measures is sometimes called into question. It has been argued that the CRTT does not have a single standardized form of quantification, and so researchers may flexibly analyze several quantifications and selectively report the one that rejects the null or indicates the largest effect size (Elson et al., 2014). Flexible analysis would, like publication bias, overestimate the size of the true effect.

**Testing specific effects of violent game contents**

Researchers have attempted to test the specific effects of violent game content, not other potential confounding game features. However, violent and nonviolent games are often very different, usually belonging to very different genres with very different rules of play. For example, violent games are often shooter games, fighting games, or action games, while nonviolent games are often racing games, puzzle games, or sports games. Therefore, while tested games do differ in their *violent content,* they are also different in their controls, strategies, and other gameplay features we call *game mechanics* (Hilgard, Engelhardt, & Bartholow, in revision)*.* It would be possible that these confounding differences in game mechanics, rather than the actual violent content, are responsible for the observed changes in aggressive outcomes.

Researchers have attempted several ways to account for these potential differences. First, one might conduct a pilot test, collecting ratings of some potential confounds, hoping not to observe a significant difference between the games on any confound. This approach is flawed in that retention of the null hypothesis does not provide evidence for the null hypothesis, especially when sample sizes are small, as they often are in pilot tests (Hilgard, Engelhardt, Bartholow, & Rouder, submitted). Another approach is to apply the potential confounds as covariates. This approach, however, is less than ideal. On the one hand, if the confound does cause aggression, in the case that the confound is measured with error (as is likely, given that these confounds are often measured with single-item covariates), residual variance will remain in the model. Analysis of covariance might mitigate, but not eliminate, influence of the confound, leading to an overestimated effect size. On the other hand, certain apparent confounds might be meaningful outcomes of violent content, mediating the relationship between violent content and aggressive outcomes. Applying these mediators as covariates would eliminate much of the relationship between violent content and aggressive outcome, underestimating the effect size.

Game modification paradigms provide greater experimental control and eliminate the need for post-hoc statistical adjustments of questionable value. Rather than comparing two separate games, or different activities within a single game, modification allows the researcher to exercise control over the game contents. For example, a game can be modified so that the same level is played either with violent or nonviolent contents, but all other game parameters are kept the same (as demonstrated in Carnagey & Anderson, 2005; Elson, Breuer, Van Looy, Kneer, & Quandt, in press; Engelhardt, Hilgard, & Bartholow, in press; Przybylski, Deci, Rigby, & Ryan, 2013). This approach allows for accurate tests of the effects of very specific game features.

**2D:4D Ratio**

Media is not the only anticipated cause of aggression. Because males are generally more aggressive (see Campbell, 2006), it has been suggested that aggression, being a sexually-influenced trait, is affected by the sex hormone testosterone. Some support for this idea has been found in lizards (Moore & Marler, 1987) and in birds (Wingfield, Ball, Dufty, Hegner, & Ramenofsky, 1987), but effects among humans are less apparent, perhaps because of the role of culture in establishing sexually-dimorphic behavior (see Archer, 2009).

Nevertheless, it has been suggested that prenatal testosterone exposure could influence a variety of physiological and psychological constructs through organizational effects on the developing brain. While ethical reasons forbid the investigation of the effects of prenatal testosterone on psychological development, the measurement of 2D:4D digit ratio has been suggested as an alternative approach to measurement of prenatal testosterone. 2D:4D ratio, the ratio of the lengths of the index and ring finger, is thought to be sexually dimorphic. On average, men have shorter index fingers relative to their ring fingers (2D:4D: ~ 0.95) as compared to women (2D:4D: ~ 1.0; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Phelps, 1952).

**Inconsistent effects of 2D:4D ratio on aggressive behavior.** The testosterone-aggression hypothesis would predict that 2D:4D ratios indicative of greater developmental androgen exposure would be associated with greater aggression. However, evidence does not seem to support this relationship. Meta-analysis indicates that there is no relationship between 2D:4D and aggression in females, and that the relationship between 2D:4D and aggression in males is quite small (*r* = -.06) (Hönekopp & Watson, 2011). Effect sizes for several studies were not reported other than as “not significant” and imputed as *r* = .00 (n = 284 out of the total sample N = 1895), so this may provide an overly conservative test.

In an attempt to resolve this inconsistency, it has been proposed that 2D:4D ratio only predicts aggressive behavior in an aggressive context (Millet, 2011). For example, 2D:4D ratio is argued to interact with the effect of an aggressive music video on aggressive intent, with more masculine ratios leading to greater aggressive intent when the music video was aggressive (*r* = -.46), but not when the music video was not aggressive (*r* = -.03) (Millet & Dewitte, 2007). Similarly, it is argued that the relationship between 2D:4D ratio and an behavior in an economic dictator game reverses depending on whether participants are in a neutral or aggressive context, e.g., having been previously primed with aggressive words or an aggressive music video (Millet & Dewitte, 2009). It is possible, however, that these moderation models are overfitting the data, especially if they are attempted post-hoc when the main effects do not present.

**Null results from gene expression data.** Recent meta-analytic efforts call into question the validity of 2D:4D ratio as a measurement of prenatal testosterone action. Voracek (submitted) investigated the estimated effect of the gene Xq11.2-12, expected to influence androgen responsivity. Longer variants of this gene are less active, and thus would be expected to lead to reduced response to testosterone, and thus, less masculine 2D:4D ratio. An initial small-sample study did indeed find such a relationship (Manning, Bundred, Newton, & Flanagan, 2003). However, several subsequent studies have found no significant relationship, and Voracek estimates the effect size as *r* = .02, [-.02, .06]. Thus, it is possible that 2D4D is not a valid measurement of prenatal testosterone activity in typical populations.

**Purpose**

The proposed study examines the effects of game violence, game difficulty, and 2D:4D ratio on aggressive behavior among college-aged males. The study will thereby test the hypotheses generated by previous research and theory. First, I aim to test the effect of violent game content on aggressive behavior, deriving the first hypothesis:

H1: Violent game content will increase aggressive behavior as measured by duration of coldpressor assignment, even when games are identical in all ways save violent content.

It has also been argued that observed changes in aggressive behavior are not due to the violent content of tested games, but rather, confounded elements of difficult or competitive game content (Adachi & Willoughby, 2011a, 2011b; Przybylski et al., 2013). My previous research suggests that challenging games may also deplete cognitive resources typically employed in the control of behavior (Engelhardt, Hilgard, and Bartholow, in press). Since cognitive control is theorized to be an important element in inhibiting aggressive behavior (Anderson & Bushman, 2002), depletion of cognitive control resources would be expected to increase aggressive behavior. I thereby derive my second hypothesis:

H2: Difficult games will increase aggressive behavior relative to easy games, whether through increased competitive content or the depletion of cognitive resources.

As summarized before, it has been suggested that lower, more masculine 2D:4D ratio predicts increased aggression. Although this effect may be context-dependent, the current context should allow the effect to emerge, as participants are provoked by their partners. From this suggestion, I derive my third hypothesis:

H3: Lower 2D:4D ratio will predict greater aggression.

Finally, theories of aggressive behavior predict that multiple effects should have super-additive effects. For example, violent games may prime and facilitate aggressive thoughts and behaviors, but these effects should be especially potent when cognitive resources are depleted (Anderson & Bushman, 2002). These predictions are mirrored by I3 Theory (Finkel, 2013), which describes sources of aggression as being instigating, impelling, or (dis)inhibiting. Not only are all participants provoked (instigation), but others are hypothetically driven by prenatal testosterone and violent game content (impelled) and/or cognitively depleted by challenging gameplay (disinhibited). Thus, I derive my fourth and last hypothesis:

H4: Combinations of aggression-inducing factors tested in H1, H2, and H3 should lead to superadditive increases in aggression, as predicted by I3 theory and the General Aggression Model.

**Sample size**

Previous attempts to test better-controlled violent game manipulations have often suffered from insufficient sample size. When sample size is too small, and the hypothesis test underpowered, a nonsignificant test result does not necessarily present positive evidence for the truth of the null hypothesis. In our Bayesian re-analysis of these studies, we find that evidence for the null is mixed, and that some studies reporting nonsignificant results nonetheless find some evidence for the alternative hypothesis of an effect (Hilgard, Rouder, Engelhardt, & Bartholow, submitted).

In an attempt to avoid these mistakes, I preregisted the plan to collect a large sample (n = 450, expecting to lose about 50 of these to failures of deception and other experimental problems). A sample of this size should provide a precise estimate of the effect size.

Because 2D:4D ratio effects are expected to hold only among men, only male subjects were recruited. This also had the positive side-effects of reducing variance in the data due to gender (males are often more aggressive than females) and concerns about aggressing against the other sex (e.g., males may be more willing to aggress against a male confederate than a female confederate).

**Scientific integrity**

Hypotheses and sample size were preregistered at https://osf.io/cwenz/. Data and analytic code are also available at that website.

**Participants**

Participants were ***450*** male undergraduate students at a state university. Participation was restricted to males because 2d4d ratio effects are thought to apply only to males (citation needed). [Race and other demographic information]

**Measures**

*2D:4D ratio*

Participants placed their hands on a flatbed scanner, fingers held together and fully extended. The scanner imaged their hands. Hand scans were double-coded by research assistants. The distance from tip to basal crease of each index and ring finger was measured using the caliper tool in the GNU Image Manipulation Program ([www.gimp.org](http://www.gimp.org)), a freeware Photoshop-like tool. 2D:4D ratios were created for each hand by taking the ratio of lengths of the index and ring fingers. Inter-rater reliability was ALPHA%.

*Coldpressor task*

Participants had an opportunity to aggress against their partner in the experiment by assigning the partner to immerse his fist in a bucket of painfully-cold water for an amount of time. Before making the assignment, the participant first sampled the cold water himself for five seconds to learn that cold-water immersion is unpleasant. The participant then assigned the partner to a duration of cold-water immersion on a 9 point scale, ranging from 0 to 80 seconds in 10-second intervals. This measure can be quantified only in one way (e.g. 1-9 rating), eliminating the concerns about which is the “correct” quantification strategy often associated with the competitive reaction time measure of aggression (see Elson et al., 2014). This measure is attached as Appendix A.

*Manipulation checks*

Participants completed a questionnaire assessing the efficacy of the various parts of the experimental manipulation. First, participants rated their exchange with their partner for how helpful, pleasant, irritating, etc. their partner’s feedback was. Then, participants rated the video game they played, indicating how violent, enjoyable, exciting, and challenging it was. Participants then rated their degree of experience with video games, first-person shooter video games, and playing video games with a keyboard and mouse. Finally, participants provided demographic information about themselves. This measure is attached as Appendix B.

*Probe for Suspicion*

Participants completed a questionnaire intended to imitate a funneled debriefing. It begins with broad questions about the study and its purpose, and whether anything seemed strange about the study, and then grows increasingly specific, asking the participant about the aggression measure and other participant in the study. This measure is attached as Appendix C.

**Methods**

Participants arrived at the lab in pairs and were immediately escorted to separate adjacent rooms. Following consent, participants’ hands were photographed with a flatbed scanner for measurement of 2D4D ratio. Because there was only one scanner, participants were able to see each other as scans were taken, demonstrating the presence of another participant in the study. After scanning, participants returned to their desks.

Participants were then given an envelope, a sheet of loose-leaf paper, and a printed essay prompt. They were informed that the first task is to write a five-minute persuasive essay of their personal views on abortion, which will later be judged by the other participant. (To justify this practice, participants will be told that participants rate essays just as well as trained research assistants.) At the end of these five minutes, the essays will be collected, purportedly so that they can be exchanged with the other participant.

Instead of exchanging the essays, each participant will receive a fake, premade essay designed to oppose their beliefs. That is, participants writing a pro-life essay will receive a pro-choice essay, while participants writing a pro-choice essay will receive a pro-life essay. With this essay, participants will receive a form for rating the essay. This form asks participants to rate the organization, originality, writing style, clarity of expression, persuasiveness of arguments, and overall quality of the essay. Participants also may leave comments. Once finished, the participant will return the essay and the evaluation form to the partner’s envelope, which is then taken from the room, ostensibly for for data entry.

*Video game*. Participants then will play their assigned version of the video game. Each will receive a cover story which explains the story and controls of the game (see attached; in Appendix D). In the nonviolent condition, the story explains that the booger aliens are lost and confused, and that when the player has “zorched” them all, he sees a scene of the aliens playing together on their homeworld. By comparison, in the violent condition, the story explains that the aliens must all be slain, and that when the player has killed them all, he sees a scene of the player character posing with his shotgun. The game is further modified to have a difficult condition and an easy condition. In the difficult condition, the monsters attack the player according to their default programming, and the player must find ammunition for his weapons or zorchers. In the easy condition, the monsters do not attack the player, instead slowly walking towards the player and waiting passively to be shot or zorched. The player also has unlimited ammunition, and so does not need to search the environment for ammunition.

Participants are then given 15 minutes to play the game. They are monitored for a few minutes to make sure that they successfully complete the first level of the game and move on to the second level, after which the research assistant leaves the room.

While the participant plays the video game, materials are prepared for subsequent provocation and measurement of aggression. An insulting essay evaluation form is placed in the participant’s envelope; on it, the partner has rated all dimensions as between -8 and -10 in quality, and commented “This is the stupidest thing I’ve ever read.” A dozen ice cubes are added to the coldpressor pitcher 5 minutes before the end of the game session.

When the game session ends, the research assistant brings the coldpressor pitcher and a towel into the room. A key is pressed on the keyboard to print the game variables, which the assistant then logs. The game is quit by pressing Alt+F4. The RA then navigates to a folder containing an e-prime task in preparation for the purported second portion of the experiment.

At this point, the participant is told that the next portion of the experiment involves performing a computer task while distracted by cold-water exposure. The participant is asked to sample the coldpressor by placing his fist in it for five seconds. At the end of five seconds, the participant is allowed to withdraw his hand and towel off. The participant is then asked if he will be okay with the coldpressor.

The research assistant then brings the participant’s original envelope into the room and asks him to read the partner’s rating of his essay. The research assistant again leaves the room to fetch a distraction assignment form and give it to the participant, explaining that “to avoid experimenter bias,” participants are being asked to randomly assign each other to the various levels of distraction. The participant is asked to circle a number on the sheet, thereby assigning the partner to an amount of coldpressor exposure ranging from 0 seconds to 80 seconds in 10 second intervals.

Once this sheet is retrieved, participants are told that the experiment is running out of time and that the distraction task will be skipped. Participants complete post-questionnaires asking them to rate the games, their partner’s feedback, and what they suspected was the purpose of the study. Participants were then fully debriefed and dismissed.

**Results**

**Manipulation check.** Participant ratings on the post-questionnaires will be subjected to 2 (Violence) x 2 (Difficulty) ANOVA. A successful manipulation would indicate a main effect of violent content on perceived violent content and a main effect of difficulty on perceived difficulty. The mean of participants’ ratings of their reaction to the confederate’s insult will also be analyzed and are expected to indicate provocation.

The collection of in-game variables also allows for more thorough checking of participant data. Because the monsters cannot attack in the easy versions of the game, participants whose gameplay log indicates any received wounds or deaths have had their condition misrecorded due to an error and should be discarded. Similarly, players who manage to kill or zorch very few aliens are likely to have ignored instructions or failed to play the game effectively and can also be discarded.

**Primary Outcome.** Participant cold-pressor assignments will be analyzed by a 2 (Violence) x 2 (Difficulty) x 2D:4D (continuous) GLM. Hypotheses 1, 2, and 3 will be tested by the presence or absence of main effects of violence, difficulty, and 2D:4D ratio, respectively. Hypothesis 4 will be tested by exploration of higher-order interactions of predictors. Effect sizes and confidence intervals will be derived for all tests. With the intended sample sizes, margins of error will be small, and an argument could be made for the null hypothesis in the case of a confidence interval sufficiently close to zero.

**Ancillary analyses.** Other relationships could be interesting to explore. For example, one might explore the amount of variance predicted by participants’ reactions to the provocation. While provocation in experiments is expected to universally influence participants and increase the average aggression, it is possible that it introduces another source of error variance, as some participants are more provoked than others. Modeling the heterogeneity in participant provocation might influence the estimated effect of game violence on aggressive behavior and provide greater model fit.

Other models might explore alternative hypotheses of game effects on aggression. For example, Pryzyblski et al. (2013) argue that thwarted needs for competence cause increases in aggressive outcomes. Players who die (or are slimed) many times in the game, then, might be expected to experience thwarted competency and be more aggressive. Alternatively, if violent content does predict aggressive behavior, players who engage in relatively more violent content should be expected to be still more aggressive. Thus, players in the violent game conditions who kill more enemies and fire their weapons more might be expected to be more aggressive in the coldpressor task.

**Discussion**

The proposed experiment has substantial potential for advancing understanding of violent media’s effects on aggressive behavior. Compared with previous research efforts, it has improved experimental control and statistical power, and may be less influenced by research bias.

**Improved experimental control.** Many previous experiments have achieved only partial experimental control, either by roughly attempting to match experimental stimuli on potential confounding dimensions or by applying these confounds as covariates. By comparison, the proposed experiment has control over all stimulus attributes, ensuring that the two game stimuli are equivalent except in violent content. This approach, which attains experimental control rather than approximates it by statistical analysis, is to be preferred. It also helps to identify the specific game feature responsible for increases in aggressive behavior, which may aid in attempts to translate and apply the insights gained from this research.

**High statistical precision.** Much of previous research has suffered from moderate to poor statistical power. Lack of statistical power has potentially inflamed the controversy in this research area. It risks overestimating the effect size in the published literature, as significant studies are more likely to be published, and when studies are underpowered, studies must overestimate the effect to attain statistical significance. On the other hand, underpowered studies also increase the likelihood that a critic will conduct a study and retain the null hypothesis. Such underpowered studies have previously been improperly interpreted as disproving the effect (e.g. Adachi & Willoughby, 2011b; Ferguson et al., 2009).

By comparison, the proposed study will have appropriate statistical power that the effect size can be estimated within a precise margin of error. Results should thereby be informative whether the null or the alternative seems more likely to be true. Hypotheses and sample size are preregistered so that the results will be less likely to be influenced by significance-chasing, and I intend to publish regardless of the direction of the results.

**Replication across laboratories.** Research in this area has been somewhat divided, with certain researchers tending to find effects (e.g. Anderson and Bushman) and other researchers tending to not find effects (e.g. Ferguson). One recent meta-analysis has suggested heterogeneity in effect size according to research team (Greitemeyer & Mügge, 2014). Independent research by new research teams may help to reduce the dichotomization of research findings and bring a greater degree of consensus to research findings.

**Predictive validity of 2D:4D ratio.** It is presently unclear whether 2D4D is an effective indicator of prenatal T exposure and predictor of aggressive behavior. It has been suggested that 2D:4D predicts aggressive behavior, but only in aggression-related contexts (Millet, 2011). In the proposed experiment, all participants are provoked, and many play a violent video game filled with aggressive monsters. The proposed experiment therefore provides a test of the effects of 2D:4D ratio in a highly theory-relevant paradigm. Again, the large study sample will allow a more precise estimate of the relationship between 2D:4D ratio and aggressive behavior.

**Future directions.** If the observed effect size is smaller than that found in meta-analysis, it would be interesting to determine which game features account for the missing portions of effect size. For example, if violent content only accounts for *r* = .10 alone, does difficulty account for the other *r* = .10? A systematic and programmatic research effort might tease apart the specific effects of specific game contents on aggressive behavior. However, such effects may be too small to feasibly research, or the expected *r* = .21 may already represent an overestimate of the true effect of violent games on aggressive behavior in experiments.

**Limitations.** It is possible that a mere 15 minutes of gameplay in the laboratory is not enough to elicit and test the effects of violent video games. This is not a unique weakness of this research, as most experimental studies involve approximately 15-30 minutes of gameplay. However, this would make it possible for the proposed study to yield null findings when the true effect in the real world after many hours is nonzero. Future longitudinal research may be needed to inspect the influence of game violence as an effect unique from game content or game genre. Other research might intend to inspect the influence of several hours of violent game play over several weeks.

The proposed study is also limited in that the research assistants are not blind to the participants’ conditions. When bringing participants their cover stories and when recording their gameplay variables, the research assistants may be able to detect whether participants are assigned to the violent or nonviolent game. However, previous research has not been blinded, either. While it is an enticing possibility that the divergent results between research labs is due to the beliefs of research assistants, this idea would have to be explored in a later research project with greater resources.

It is also possible that the violent game used in this study differs meaningfully from that used in other studies. For example, perhaps Doom is too fantastic of a setting, and a more realistic and grounded game such as Grand Theft Auto would instead show larger effects. However, effects have been observed for fantasy games (Anderson & Ford, 1987; Konijn, Nije Bivank, & Bushman, 2007), as well as realistic ones, so this might not be a problem.

Finally, it is possible that the nonviolent Chex Quest game involves substantial amounts of violence. Current definitions and practices indicate that even E-rated games can contain substantial violence (Anderson et al., 2010; Thompson & Haninger, 2001), and that the effect of cartoon E-rated violence is as strong as that of explicit M-rated violence (Anderson, Gentile, & Buckley, 2007). These definitions and practices would seem to contradict the current theories of violent media that they are said to support; for example, exposure more extreme violent content should be more desensitizing than mild violent content. In any case, it is possible that an effect might not be found in the present study because even a relatively mild game such as Chex Quest may have effects on aggression equal to those of Brutal Doom. Future research may seek to compare the Brutal Doom game against a control game which involves no harm or conflict whatsoever, although this may risk confounding the effects of in-game conflict with those of violent content.

**Summary**. The proposed study provides a more precise test whether violent content, specifically, causes changes in aggressive behavior. While previous research studies have generally studied the effects of violent content with confounded differences in competition, difficulty, or genre, the present research paradigm controls all these factors for a precise test.

The proposed study also manipulates whether the monsters fight back. This has been proposed repeatedly as a potential confound in violent game research, whether as differences in competition priming more aggressive behavior (Adachi & Willoughby, 2011) or as differences in difficulty which cause frustration and subsequent aggression (Przybylski et al., 2013). The proposed study manipulates these factors orthogonally, allowing for tests of independent main effects and interactions.

The proposed study also investigates the purported effect of 2D:4D ratio on aggressive behavior. Previous research has been inconclusive, with meta-analysis indicating only a minimal effect, and theorists proposing that perhaps the effect only holds when aggressive behavior is primed, provoked, or context-appropriate. In the proposed study, all participants are provoked, so a main effect of 2D:4D ratio can be tested under the conditions suggested by Millet (2011). Alternatively, perhaps there is an interaction of violent content and 2D:4D ratio, indicating a highly context-specific effect of 2D:4D ratio.

This study will be highly informative with a large sample size, pre-registered measures and hypotheses, and open data and analytic code. This ensures a fair and adequately-powered test of the hypotheses, as well as an opportunity for other researchers to inspect the validity of the research conclusions and their sensitivity to subjective decisions such as outlier exclusion. The research findings should help to bring greater theoretical resolution and more powerful evidence to this contentious field.

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Appendix A. The coldpressor assignment measure of aggressive behavior.

Duration of other participant’s distraction

**Directions**: Using the scale below, indicate how long (in seconds) the other participant should be distracted as he/she performs the next task by circling the desired number:

1 2 3 4 5 6 7 8 9

(0 sec) (10 sec) (20 sec) (30 sec) (40 sec) (50 sec) (60 sec) (70 sec) (80 sec)

No slight moderate strong very strong distraction distraction distraction distraction distraction

at all

Appendix B. Post-questionnaire measure. Measure checks the strength of manipulations of provocation and game content, while also collecting demographics and previous video game exposure.

Please provide us with feedback on your experience in the essay exchange by circling the number which best represents how you felt.

**1. I felt *irritated* by my partner’s essay evaluation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**2. I felt *happy* about my partner’s essay evaluation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**3. I felt *angered* by my partner’s essay evaluation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**4. I felt my partner’s essay evaluation was *helpful*.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agre |

**5. I felt *pleased* by my partner’s essay evaluation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**6. I felt *annoyed* by my partner’s essay evaluation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

Did you know any of the other participants in the study? (Circle one) Yes / No

Did you suspect you were partnered with someone you knew? Yes / No

The following statements relate to the video game you played. Please respond to each item by circling the number that best represents how you feel. There are no right or wrong answers.

**1. The game level was easy to navigate.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**2. I felt *excited* while playing the video game.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**3. I felt *engaged* while playing the video game.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**4. I found the video game I played to be *challenging*.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**5. I found the video game I played to be *stressful.***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**6. I felt the video game featured a great amount of violence**.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**7. I felt it was difficult to find my way through the video game level.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**8. I felt I needed quick reflexes to play the video game effectively.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**9. I felt that my equipment was *satisfying to use*.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**10. I felt that my equipment was *effective* at eliminating monsters.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**11. I felt the monsters in the video game were *difficult* to get rid of.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**12. I felt the monsters in the video game put up a good fight.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**13. I felt the video game controls (e.g., movement, aiming) were hard to get used to.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**14. I felt the video game I played required *mental effort* (i.e. brain power) to play it well.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**15. I felt that I was comfortable with the controls by the end of the video game session.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**16. I felt the video game I played was *mentally exhausting*.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**17. I felt like I behaved aggressively during the video game.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

**18. I enjoyed the video game I played today.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

Please circle the number to indicate how well each statement describes you.

1. I’ve often played games like the one I played today.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

2. I have experience playing first-person shooter games.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

3. I am good at first-person shooter games.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

4. I am comfortable with using a mouse and keyboard to play video games.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

5. I play video games frequently.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

6. Over the course of my life, I’ve played a lot of video games.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Strongly Disagree |  |  | Neither Agree nor Disagree |  |  | Strongly  Agree |

DEMOGRAPHIC INFORMATION:

GENDER: FEMALE \_\_\_\_\_\_\_ MALE \_\_\_\_\_\_

AGE: \_\_\_\_\_\_\_\_\_

What race would best describe you?

1. Asian American 2. African American

3. Latino/Hispanic 4. West Indian

5. White/non-Hispanic 6. Other (specify):\_\_\_\_\_\_\_\_\_\_\_\_\_

What year of college are you in?

1. Freshman 2. Sophomore

3. Junior 4. Senior 5. Other (specify): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What is your (approx.) GPA in college (or high school if you are a freshman) (0 – 4)?\_\_\_

Appendix C. Debriefing questionnaire. This questionnaire attempts to assess the degree of participants’ suspicion about the manipulation and awareness of the study hypothesis.

To ensure that we are fulfilling our responsibility to educate students about psychological research, please answer these questions. **Your responses do not affect your credits – these are just to ensure that we are briefing and debriefing you properly.**

**1.** What do you think we were trying to study in this experiment?

**You may circle more than one answer.**

a) Effects of video games on aggression

b) Relationships between game skill and persuasive skill

c) Whether video games affect your ability to focus attention

d) Whether experienced gamers are more or less polite than non-gamers

e) Relationship between hormones and game skill

**2.** Was there any part of the experiment that seemed suspicious or strange?

**You may circle more than one answer.**

a) The hand scan

b) The essay topic

c) My partner’s essay

d) The game I played

e) The way my game progress was logged

f) Judging each others’ essays

g) Assigning each other’s distraction period

h) The distraction computer task

Why do you think we asked you to assign each others’ amount of distraction?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Do you expect that the game you played affected the amount of distraction time you set?

Yes / No / Maybe

Would it surprise you to know that you never actually traded essays with another participant?

Yes / No / Maybe

In this study, we were interested in seeing whether finger length, game violence, and game difficulty affect or do not affect aggression. Our measure of aggression is the amount of distraction people assign to somebody who insulted them.

Please indicate how much you suspected the distraction assignment was actually a measure of aggression:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 |
| I had no idea | I was a little suspicious | I was very suspicious | I was almost certain | I knew it right away |