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Emotional memory in violent video game players and nonplayers

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EMOTIONAL MEMORY IN VIOLENT VIDEO GAME PLAYERS AND NONPLAYERS

by

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Emotional Memory in Violent Video Game Players and Non Players. Holly J. Bowen, MA in Psychology, 2009, Ryerson University.

The present study examined whether chronic exposure to violent media was associated with alterations in emotional long-term memory. Derived from the finding that violent video games reduce physiological arousal to violent stimuli I predicted that violent video game players would show lower recognition accuracy for negative images in general but higher accuracy for violent images in particular, compared to a control group of non-players. Participants completed an old-new recognition task with 300 pictures of scenes ranging in emotion (negative nonviolent, violent, neutral and positive). Violent video game players were matched to non-players on age and gender. Memory accuracy, measured by d', showed no significant effects of group or valence, but there were effects of valence on reaction time. Diffusion modelling analysis revealed that across groups, participants were more liberal in their responses to emotional items and more efficient at detecting novel (unstudied) pictures than at recognizing studied pictures.

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In most industrialized nations, the mass media serve as a primary source of entertainment. American youth spend on average more than 4 hours a day with television, computers, movies, and video games (Woodard & Gridina, 2000), and violent content is omnipresent in these types of media (Haninger & Thompson, 2004; Signorielli, 2003). Anderson and Bushman (2001) conducted a meta-analytic review of studies investigating the effects of violent video games on aggressive behaviour, empathy, proviolence attitudes and aggressive cognitions. The results suggested that violent video games may increase aggressive thoughts, at least in the short term. However, long-term effects of media violence on subsequent cognition and behaviour have rarely been documented to date. In particular, it is not known whether long-term exposure to media violence affects individuals' ability to attend to and remember emotional information. In light of evidence suggesting that violent video games can cause habituation to negative emotional content, particularly violence (Carnagey, Anderson & Bushman, 2007), it is interesting to ask whether desensitization and its cognitive-affective consequences can be long-lasting. The present study focuses on the relationship between exposure to media violence and memory for negative information. It will test the hypothesis that long-term exposure to violent video games, a particularly common form of violent media, is associated with a decline in the emotional response to negative stimuli, and ultimately with a selective reduction in memory performance for these stimuli.

Exposure to violent media and desensitization to violence

Video games became widely available about 30 years ago and have become the fastest-growing, and one of the most profitable, sectors of the entertainment industry, earning almost

$18 billion in the United States in 2007 alone (NDP Group, 2008). Market research data also indicate that 39% of video game players are under 18 years old (Entertainment Software Association, n.d.). The number of allegations in the media about the harmful effects of video games has increased dramatically however there is very little empirical evidence to support these claims. Some research suggests that playing games high in violent content is associated with increases in aggressive affect, aggressive thoughts, and irritability (i.e., a readiness to "explode" with negative affect with the slightest provocation; Anderson & Bushman, 2001). Unlike television, video games are interactive. Players receive rewards for virtual violent acts and can come to identify with the character they control (Carnagey, Anderson, & Bushman, 2007). This identification may explain why, according to recent findings (see Carnagey et al., 2007), individuals who frequently play violent video games may be particularly likely to become desensitized to violence.

Desensitization is defined as a diminished psychological or emotional responsiveness to a stimulus after repeated exposure (Wolpe, 1982) that persists in the long term. Habituation is similar in that there is a diminished response to repeated stimuli; however, habituation effects are short-lived and the response rebounds in the presence of novel stimuli (Bradley, Lang, & Cuthbert, 1993). It is believed that repeated exposure to real-life and entertainment violence may alter cognitive, affective, and behavioural processes (Funk, Bechtoldt Baldacci, Pasold, & Baumgardner, 2004) but most research has focused on emotional components (Funk, Buchman, Jenks, & Bechtoldt, 2003; Funk et al., 2004) and on physiological arousal in response to affective content (e.g., Bradley et al., 1993; Bradley, Cuthbert, & Lang, 1996; Smith, Bradley, & Lang, 2005).

Affective and physiological components of desensitization

Arousal refers to the intensity of affective experience; it can be measured using physiological indices such as skin conductance (SC) or heart rate (HR), or using subjective ratings (i.e., self-report). The findings with respect to arousal and habituation to negative stimuli are somewhat mixed. Bradley and colleagues (1993), for example, investigated the effects of repeated exposure to emotional stimuli on physiological arousal. Participants in their study viewed a set of pleasant, unpleasant and neutral pictures repeatedly before being presented with a set of novel pictures. Both SC and HR were sensitive to valence during the habituation phase, with emotional (pleasant and unpleasant) images eliciting a stronger arousal response than neutral images. There was also some evidence for greater arousal responses to unpleasant pictures, at least early during the habituation phase. Overall, habituation was observed for both SC and HR, and across valence levels, with the exception of the HR response to negative pictures, which persisted across presentations. Additionally, Bradley and colleagues (1996) reported that physiological measures of arousal such as heart rate actually increased after exposure to repeated unpleasant pictures, suggesting sensitization, rather than habituation, to emotional stimuli.

More recent studies that involve video game playing and physiological arousal have evidenced either habituation or sensitization to emotional material, depending on the experimental condition. Carnagey and colleagues (2007) showed that violent video game playing resulted in a reduction in emotion-related physiological reactivity to real violence. Participants were randomly assigned to play either a violent or a non-violent video game after being assessed for baseline HR and SC. After they played the games for 20 minutes, HR and SC were assessed again while participants watched a 10 minute video of "real-life" violent episodes: court-room outbursts, police confrontations, shootings, or prison fights. The researchers found that, compared to participants who had played the non-violent video game, those who had played the violent video game showed a smaller increase in physiological arousal during the real-life violent episodes. Similar effects had previously been reported for exposure to violent television (Hanratty Thomas, Horton, Lippincott, & Drabman, 1977). Carnagey and colleagues proposed several possible explanations for their findings. They suggested that repeated exposure to violence may reduce attention to violent incidents involving others, or individuals may come to interpret violent incidents as less serious. Alternatively, exposure may alter affective mechanisms and change beliefs and attitudes about violence, thereby reducing sympathy for the victim.

Recent findings reported by Staude-Müller, Bliesener and Luthman (2008) paint a slightly different picture. These researchers found that physiological reactions to aggressive stimuli were stronger for participants who had played 20 minutes of a violent video game compared to participants who had played a non-violent version of the game, suggesting sensitization to aggressive images. On the other hand, physiological reactions to non-aggressive aversive stimuli in participants who played the violent video game were significantly weaker than those in individuals who played the non-violent version, consistent with habituation to non-aggressive aversive stimuli. The researchers also found that highly experienced video game players reacted less strongly to aversive stimuli compared to less experienced participants, indicating that there may be a cumulative effect to emotional desensitization or an "emotional hardening" (p. 48) due to repeated exposure to violence in video games.

Repeated exposure and cognitive aspects of desensitization

To my knowledge only two studies (e.g. Kronenberger et al., 2005; Bartholow, Bushman, Sestir, 2006) have examined how repeated exposure to violent video games affects cognitive processes. Kronenberger and colleagues (2005) compared a group of aggressive adolescents to an age-matched control group to investigate the relationship between executive functioning and media violence exposure (television and video games). Self-reports and parental reports were utilized to measure long-term media violence exposure both in the past week and the past year. Executive functioning was measured using a number of questionnaires and tasks such as the Stroop Colour task. The researchers found a moderate negative association between exposure to media violence and executive functioning in both the control group and aggressive adolescents. Given that executive functioning plays a role in memory processes, these findings suggest that individuals with chronic exposure to violence may be at a disadvantage with respect to their long-term encoding and retrieval.

Bartholow and colleagues (2006) measured event-related brain potentials (ERPs) during repeated exposure to violent, negative non-violent and neutral IAPS images. They were specifically interested in the P300 component, a positive-going ERP component that peaks around 300 ms after stimulus onset. The P300 depends on the level of attention and arousal evoked by the stimulus. Its amplitude is positively related to target discriminability, whereas its latency increases when targets are harder to discriminate from non-targets (Linden, 2005). The P300 is thought to be an index of evaluative categorization during processing of emotionally relevant stimuli. To the extent that an individual is desensitized to violence, the P300 amplitude elicited by violent images should be reduced. Compared to non-violent video game players, violent video game players did show reduced P300 amplitude and increased P300 latency to violent images but not to equally negative non-violent images. The latency of the P300 component is generally associated with stimulus evaluation or categorization time. The increased P300 latency among violent video game players thus indicates that it took these individuals longer to categorize violent images compared to non-players. These findings suggest that chronic exposure to violent video games may have lasting effects on cognition and brain function.

Emotional memory

The evidence reviewed thus far suggests that repeated exposure to entertainment violence may alter cognitive, affective, and behavioural processes (see also Funk et al., 2004). However, most research has focused on emotional rather than cognitive aspects, and no studies have examined how repeated exposure to violent media affects long-term memory, specifically memory for emotional content.

Memory for highly emotional positive and negative events such as a wedding day or the death of a loved one is typically far superior to that for less emotional events, such as breakfast yesterday (Reisberg & Heuer, 1992). Enhanced memory for emotional information has been reported many times (for a review, see Hamann, 2001) although it has not been uniformly supported (e.g., Aupée, 2007; Budson et al., 2006; Dougal & Rotello, 2007; Maratos, Allen, & Rugg, 2000; Windmann & Kutas, 2001). Nevertheless, there is widespread consensus that both valence and arousal can affect the memorability of emotional information (Kensinger & Corkin, 2004). Of particular interest in the current context is the "negativity bias" – the finding that humans attend to and remember negative information better than neutral or positive information (e.g. Dewhurst & Perry, 2000; Ochsner, 2000; Kensinger & Schacter, 2006).

In one of the early studies of emotional memory, Ochsner (2000) compared memory for negative, neutral, and positive images. Recognition memory was tested using a remember/know

task (Tulving, 1985), yielding separate measures of recollection and familiarity. "Remember" experiences are characterized by specific memories of feelings, thoughts or sensory details, whereas "know" experiences are characterized by a sense of familiarity in the absence of specific contextual recollection. Negative items were recognized more accurately and recollected more often than positive or neutral items, whereas memory for the positive pictures was comparable to memory for neutral pictures. Ochsner (2000) proposed several explanations for this negativity bias. First, there may be an attentional bias for negative stimuli which is not found for positive stimuli. Second, individuals may rehearse or elaborate negative information more than positive information. Third, negative stimuli may be encoded as survival-relevant information (e.g., threat-related stimuli; Öhman, 1988).

Dewhurst and Parry (2000) reported similar results in a study of the effects of emotion on recollective experience. In Experiment 1, negative and neutral words were presented in random intermixed order (i.e., mixed list presentation) and memory for the words was tested using a remember/know task. Participants made more correct "remember" and "know" responses to negative words than to neutral words, suggesting that negative words were both better recollected and more familiar than neutral words. In a second experiment, negative and neutral words were presented in separate lists (i.e., purely negative or purely neutral). The effects of emotional valence observed in Experiment 1 were eliminated when emotional and neutral items were presented in separate pure lists rather than intermixed. The distinctiveness-fluency framework (Rajaram, 1996) states that recollection-dependent "remember" responses are boosted by variables that enhance the distinctiveness of the to-be remembered items—they stand out relative to the neutral word background. These results thus suggest that the negativity bias observed for mixed lists may be due to the distinctiveness of negative items. When these items are presented in pure lists, the distinctiveness is reduced, thereby eliminating the negativity bias.

Building on the distinctiveness findings, Talmi, Luk, McGarry, and Moscovitch (2007) investigated the roles of semantic relatedness and distinctiveness in the negativity effect. Negative images, semantically-unrelated neutral images and semantically-related neutral images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997) were utilized as stimuli. Memory for emotional items was better than memory for neutral items when these items were presented in mixed lists. However, when pure lists were presented and both relatedness and distinctiveness were controlled, emotional items were no longer significantly better remembered than neutral items. When only distinctiveness was controlled for, the negativity effect reappeared, suggesting that higher distinctiveness and relatedness of emotional items in combination may be responsible for the effect of emotion on memory. Alternatively, Talmi et al. (2007) suggest that pure-list presentation could have desensitized participants so that they were no longer aroused by negative pictures presented in late serial positions. In other words, the memory differences found between the mixed-list and pure-list conditions may have resulted not from differences in distinctiveness, but from desensitization in the pure-list condition. This view implies that emotional arousal is the factor that drives immediate memory enhancement. As described earlier, however, the evidence for habituation of arousal responses during repeatedly presented emotional material is mixed.

In sum, very little research on desensitization to violence has focused on the possible effects on cognitive processes. To my knowledge, no research has examined how repeated exposure to violent media affects memory, and specifically memory for emotional content. It is generally accepted that memory for emotional information is better than neutral information and

that younger adults exhibit a "negativity bias" in memory for emotional information. This negativity effect is demonstrated by better accuracy and shorter reaction times for negatively valenced material. One way to analyse memory accuracy is using signal detection theory which is detailed in the next section.

Signal Detection Theory

Experiments with binary decision tasks often analyse data using signal detection theory (Green & Swets, 1966) which provides separate measures of sensitivity and response bias. Sensitivity refers to the ability to discriminate between stimulus classes (e.g., old and new stimuli in an old-new recognition task; Macmillan & Creelman, 2005). Response bias refers to a preference for one response over the other (e.g., a tendency to respond "old" in an old-new recognition task; Macmillan & Creelman, 2005). Separating sensitivity and response bias is of interest because it clarifies the mechanisms underlying the effects of emotion on memory. However, a rigorous application of signal detection theory requires analysis of receiver-operating-characteristic (ROC) curves, which are obtained by plotting hit and false alarm rates across multiple levels of recognition confidence. Studies using this approach have suggested that enhanced memory for positive and negative stimuli may be due to a more liberal response bias (i.e., a tendency to respond "old") for emotional items compared with neutral items (Dougal & Rotello, 2007; Kapucu, Rotello, Ready, & Seidl, 2008; see also Budson et al., 2006; Windmann & Kutas, 2001).

One problem with signal-detection analysis is that it only takes into account memory accuracy and not reaction time (RT) data. The simultaneous analyses of both accuracy and RT may be more telling of the entire decision making process. Reaction time could be especially interesting to examine in the VG player population because these individuals may show faster responding due to their sharp motor skills (see Messaris & Humphreys, 2004, for a review).

The temporal aspect of memory retrieval can be captured with sequential-sampling models, such as Ratcliff's (1978) diffusion model. This class of models is well suited to binary decision making. The main assumption is that information is accumulated over time toward one of two decision criteria, and that this evidence accumulation-process is noisy. The model takes into account all aspects of the experiment data, including both correct and error RTs, full distributions of RTs, and the probabilities of correct versus error responses (Ratcliff, 1985; Ratcliff & Tuerlinckx, 2002).

The Diffusion Model

The diffusion model assumes that RTs in two-choice decisions can be broken down into two components: nondecisional processes involved in stimulus perception and motor response (model parameter t_0), and decisional processes. Figure 1 illustrates the process underlying the decisional RT component. In the example, the decision involves discrimination between two stimulus categories, A (upper boundary) and B (lower boundary).

The decision process moves from a starting point (parameter z) toward either of two response boundaries. The position of the starting point z between the boundaries can introduce response bias. If, for example, z is closer to the upper boundary the individual favours "A" responses whereas if z is closer to the lower boundary, a bias for "B" responses results. Variability in position of the starting point (s_z) reflects the inability to hold the starting point of the accumulation of information constant across trials. Large values of s_z are associated with fast error responses. The starting point, conceptually similar to the response bias parameter in signal-

detection theory (Green & Swets, 1966), can be manipulated experimentally, for example, via response-specific payoffs (Voss, Rothermund, & Voss, 2004).

Boundary separation (parameter a) is the distance between the lower and upper boundaries and indicates how much information is required on average before a decision is made. Experimental manipulations such as speed-accuracy instructions can affect boundary separation. When accuracy is emphasized, the boundaries are set far apart, so that accuracy is high but reaction times are long. When speed is emphasized, boundaries are moved closer together resulting in shorter response times, but the accumulation process is now more likely to hit the wrong boundary by accident, which lowers accuracy.

The drift rate (parameter v) is the rate at which information accumulates towards either the upper or the lower boundary. Once a boundary is reached, the decision process ends and a response is given (i.e., button press). A positive drift rate drives the decision process toward the upper boundary, as illustrated in the example by the single arrow pointing up, whereas a negative drift rate drives the decision process toward the lower boundary. Drift rate captures the strength or quality of the retrieved information, and is similar to signal detection parameter d'. Unlike d', however, drift depends on both accuracy and speed. Steeper (i.e., larger) drift rates are associated with higher accuracy and shorter reaction times.

Within-trial variability in drift, illustrated by the jagged lines, contributes to the probability of error responses (Ratcliff & Tuerlinckx, 2002). This variability in drift rate leads to distributions of finishing times (i.e., RT distributions). One distribution for correct RTs (to Category A items) is shown on the top of Figure 1, and one distribution for error RTs (to Category A items) is illustrated on the bottom of the figure. During accumulation of information, drift varies across trials with a standard deviation of s_v.

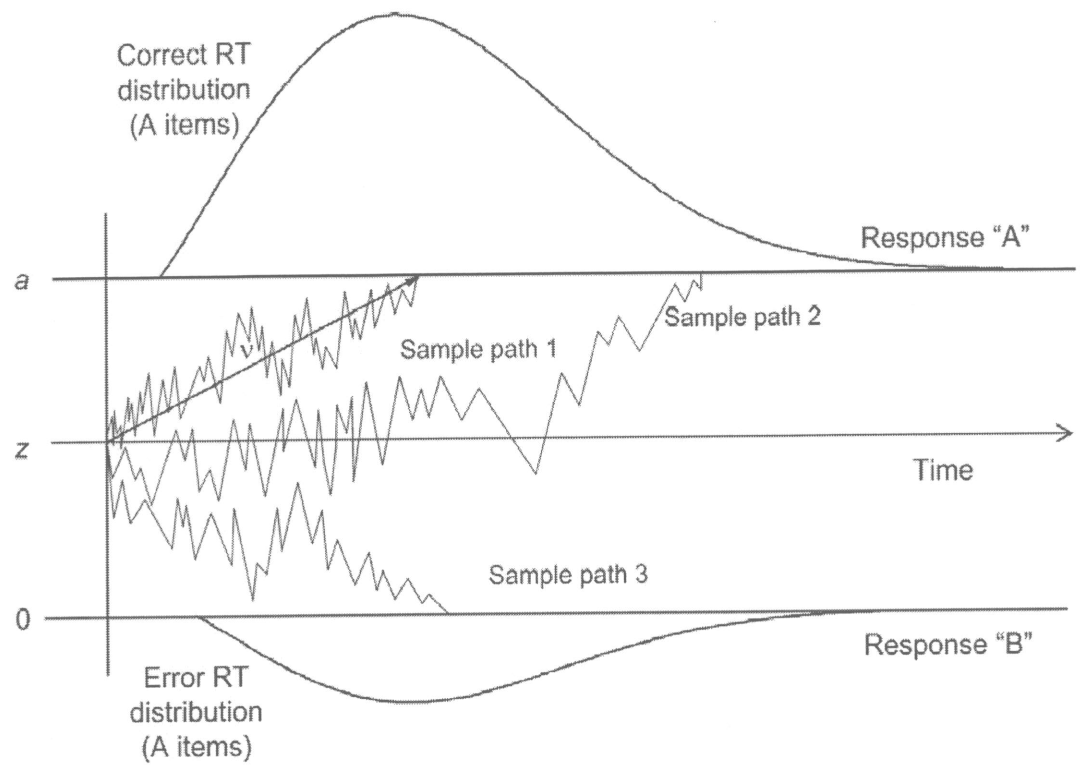

Figure 1. The Diffusion Model (Ratcliff, 1978; diagram from Spaniol, Madden, & Voss, 2006). Illustration of the diffusion process for the classification of a Category-A item into Category A or Category B. The decision process starts at point *z* and moves toward the upper boundary or lower boundary by a drift rate v. In this example, "A" response corresponds to the upper (and correct) boundary *a*, and is driven by a positive drift rate. Three sample paths are illustrated with responses 1 and 2 ending in a correct response at the upper boundary ("A") but path 3 drifts toward the lower boundary 0, ending in an incorrect response "B". RT= reaction time.

The Present Study

To date no research has studied the effects of long-term exposure to violent media on long-term memory. The goal of the present study was to determine whether long-term exposure to violent media is associated with reduced memory for negative stimuli. An incidental encoding task (brightness judgments) was used during the study phase, and an old-new recognition task was used during the test phase. Ochsner (2000) found that explicit encoding of affect is not

necessary for emotional enhancement of memory. I chose brightness judgments as an incidental encoding task to ensure that participants stayed engaged while viewing the images without explicitly focusing on a later memory test, or on the valence and arousal dimensions. Like other researchers (for a review see Anderson & Bushman, 2001) I chose video games players as a population in which to study the effects of long-term exposure to media violence. Violent video games are extremely popular among the undergraduate student population, and are played over long periods of time, often with high frequency (i.e., daily). Undergraduate students are an accessible group with varying degrees of exposure to violent video games, making comparisons between groups possible.

VG players were age and gender matched to a non-playing control group. All participants completed questionnaires assessing personality and mood. Although much research has assessed links between aggression and video game playing, as noted above, to my knowledge no studies have looked at other personality characteristics that could be associated with video game playing. Personality characteristics and mood were measured for both general research interest and to explore their role in potential group differences on the dependent measures listed below.

Measures and hypotheses

Accuracy and reaction time. The sensitivity index *d'* (Green & Swets, 1966) served as an estimate of memory accuracy. *d'* was calculated from each participant's hit and false alarm rates on the recognition test. A 2 (VG player vs. non-player) x 4 (negative vs. violent vs. positive vs. neutral) repeated measures analysis of variance (ANOVA) was utilized to determine whether group differences in memory accuracy were present, and whether these differed as a function of valence. Correct reaction times were submitted to a similar analysis.

Based on the desensitization research reviewed above, I predicted that violent video game players would show a reduced negativity effect, that is, lower accuracy and longer reaction times for recognition of negative images, compared to a control group of non-players. This prediction was derived from the finding that violent video game playing reduces physiological arousal during the encoding of negative stimuli (Carnagey et al., 2007; Staude-Müller et al., 2008). To the extent that the negativity bias in long-term memory is caused by arousal during encoding, reduced arousal should lead to a reduction in subsequent memory for negative information. The findings by Staude-Müller and colleagues additionally suggest that exposure to violent media may cause selective sensitization to violent stimuli. I therefore also examined the possibility of selectively enhanced memory accuracy for violent stimuli in VG players.

The diffusion model. Diffusion modelling was used to assess accuracy and RT simultaneously rather than separately as described above. The diffusion parameters also allow for an examination of a possible response bias for emotional stimuli. There were too few observations in the violent category (28 images) to reliably estimate separate diffusion models for this category, thus the violent and negative non-violent stimuli were collapsed into a single "negative" category for the purpose of these analyses.

Response bias. To calculate response bias, the starting point parameter (z) is divided by the response boundary separation (a). A value of z/a greater than .5 indicates a bias toward the upper boundary and a value of z/a lower than .5 indicates a bias toward the lower boundary. Based on some previous literature (Kapucu et al., 2008; Spaniol, Voss, & Grady, 2008) I predicted that emotional stimuli, and negative stimuli in particular, would elicit a more liberal response bias, such that participants overall would be more likely to say "old" to these items.

Whether VG players would show a different response bias for negative images compared to non-players was an open question.

Drift rate. As noted above, drift refers to the rate of approach to a particular boundary, with steeper (i.e., larger) drift rates indicating more efficient categorization of stimuli. "Old" responses are driven toward the upper boundary, which is assigned a positive value, and "new" responses are driven toward the lower boundary, which is assigned a negative value. As a result of this arbitrary assignment, target stimuli are expected to elicit positive drift rates and distractors are expected to elicit negative drift rates. To allow a meaningful comparison of target and distractor drift rates, as well as group and valence effects on drift, the distractor drift rates were sign-reversed before being entered into the analyses. Based on the desensitization hypothesis, I predicted that VG players, compared to non-players, would have smaller drift rates for negatively valenced items.

Method

Participants

A total of 134 undergraduate students, recruited from the Ryerson psychology participant pool, participated in return for partial course credit. All procedures were approved by the Ryerson Ethics Board. Participants provided written consent and completed a health questionnaire assessing a history of brain or head injuries, psychiatric illnesses, use of medication, and current depression. Eight participants were excluded from analysis because of responses on the health assessment. Four other participants were excluded because they chose to discontinue the study before completion, resulting in a total of 122 eligible participants (20 male and 97 female). The median age of the sample was 19.0 years, with a range from 17 to 38 years.

Of the 122 participants, 45 had a least some video game playing experience and 77 did not have any video game playing experience within the last six months.

The 122 eligible participants were separated into two matched groups based on age and gender (if possible): 45 video game players (VG players) and 45 non-players. Matching was done to create two groups of equal size, thus 32 non-players were excluded from the following analyses. Characteristics of the matched groups are presented in Table 1. Note that the mean violence exposure score (VES) for non-players is 0 and the average for VG players is 19.5 (with a range from 2 to 79), a statistically significant difference, $t(88) = 9.66$, $p < .001$. Non-players scored significantly lower than VG players on both positive affect and the neuroticism subscale of the NEO, $t(88) = 2.10$, $p = .039$, and $t(88) = 2.55$, $p = .013$ respectively; however the two groups did not significantly differ on any other personality characteristics. [1]

Questionnaires

Violent video game exposure was assessed with a video game inventory with a test-retest reliability (α) of .86 (Anderson & Dill, 2000). Participants are asked to name up to 5 of their favourite video games, and to rate on a Likert scale of 1-7 the frequency with which they play each game, as well as the violence of content and graphics. A violence exposure score (VES) was computed for each participant by summing the content and graphics ratings, multiplying the result by the frequency rating, and averaging over the number of listed games (see Appendix A). Higher scores indicate a higher degree of exposure to violence.

1. As mentioned in the introduction, personality and mood assessments were included to explore whether VG players would differ from non-players on these variables. They were also included to test whether personality and mood could account for potential group differences on the dependent measures. Since there were no effects of group on any of the measures of interest, the personality and mood variables were not used as covariates.

Table 1.

Means of all questionnaire data for VG-Players and Non-Players

Characteristic	VG Player (N=45)	Non-Player (N=45)
Age (years)	20.5 (3.5)	20.7 (4.2)
Age range	17-31	17-37
Sex (male)	11	15
Sex (female)	34	30
Negative mood	13.3 (4.5)	13.5 (4.1)
Positive mood	30.5* (6.3)	27.9 (5.6)
AQ	69.9 (18.3)	75.4 (14.2)
IS	76.8 (17.0)	76.8 (21.9)
TAS-20	46.7 (11.6)	45.9 (11.0)
VES	19.5* (13.5)	0
Neuroticism	21.9* (12.4)	15.4 (11.6)
Extraversion	25.9 (8.7)	28.6 (8.2)
Openness	29.5 (8.2)	28.3 (5.8)
Agreeableness	30.2 (7.6)	30.4 (5.7)
Conscientiousness	32.6 (6.0)	32.6 (6.7)

Note: Negative mood and positive mood are Positive and Negative Affect Schedule scores. AQ = Aggression Questionnaire. IS = Irritability Questionnaire. TAS-20 = 20 item Toronto Alexithymia Scale. VES = Violence Exposure Score from the video game questionnaire. Neuroticism, extraversion, openness, agreeableness, and conscientiousness are from the revised NEO Five-Factor Inventory.

* Significant group differences $p<.05$. Standard Deviations are in parentheses.

To assess individual differences on irritability and aggression, the Irritability Scale (IS; Caprara et al., 1985) and Buss and Perry's (1992) Aggression Questionnaire (AQ) were administered. The IS contains items such as "Sometimes when I am angry I lose control over my actions". Responses are made on scales anchored at 1 (*This doesn't characterize me at all*) and 5 (*This characterizes me very well*). The AQ contains 4 subscales, labelled Physical Aggression (9 items; α = .78; e.g., "I have threatened people I know"), Verbal Aggression (5 items; α = .85; e.g., "I often find myself disagreeing with people"), Anger (7 items; α = .84; e.g., "I have trouble controlling my temper"), and Hostility (8 items; α = .77; e.g., "Other people always seem to get the breaks"). Responses are made on scales anchored at 1 (*Extremely uncharacteristic of me*) and 6 (*Extremely characteristic of me*).

To explore the possibility that video game playing is associated with personality characteristics that may affect emotional memory, participants completed several personality measures, including the 60-item NEO Five-Factor Inventory (Costa & McCrae, 1989). The measure has five subscales measuring different personality characteristics: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. The 20-item Toronto Alexithymia Scale (TAS-20; Taylor, Bagby, Ryan, & Parker, 1990) was also administered. Lower scores on this scale indicate less possibility or a smaller degree of alexithymia, defined as the inability to identify one's own emotions or the emotions of others.

Current mood was assessed using the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) to investigate the possibility that pre-existing negative or positive mood states affected participants' responses on the memory test. High scores on these scales indicate strong current positive and negative affect, respectively.

Stimuli and Apparatus

The stimuli included 100 positive, 100 negative and 80 neutral images from the IAPS (Lang et al, 1997). Twenty additional neutral images were added from another source (Spaniol et al., 2008), to ensure similar levels of semantic relatedness within each valence category. The 20 additional images contained people or faces in order to match emotional images on this semantic category. The mean valence of IAPS norms at each level of valence were significantly different from each other, $F(2,299) = 1294.61$, $p < .001$, MSE = 487.54, $\eta^2 = .90$, with negative, neutral and positive images receiving average ratings of 2.69, 5.07, and 7.10, respectively. Arousal ratings for the positive (M = 5.58) and negative (M = 5.73) images did not differ significantly, but were both significantly higher than arousal ratings for neutral images (M = 3.55), $F(2, 299) = 9.50$, $p < .001$, MSE = 148.28, $\eta^2 = .060$.

The negative images were categorized as either *violent* (N = 28) or *non-violent* (N = 72). Images were considered violent if they portrayed aggressive behaviour, signs of physical abuse, attacks and intimidation or intentional acts causing harm to another living being. There was no significant difference in IAPS valence norms between violent (M = 2.55) and negative non-violent (M = 2.75) images, $t(98) = 1.395$, p = .166. IAPS arousal norms, however, were significantly higher for violent images (M = 6.09) than for non-violent images (M = 5.60).

The assignment of specific stimuli to target or distractor status was counterbalanced across participants. To this end, two lists were created. For half of the participants, List 1 images served as targets and List 2 images served as distractors; the other half of the participants received the reverse assignment. The lists were equated for average IAPS valence norms, as well as for semantic content. Matching for semantic content was accomplished by categorizing the images by semantic category (e.g., animals, faces, inanimate objects). The average valence scores of the two lists ($M_1 = 4.99$ and $M_2 = 4.91$) were not significantly different, $t(298) = .401$, $p = .689$, nor were the average arousal scores ($M_1 = 5.11$ and $M_2 = 4.79$), $t(298) = .701$, $p = .484$. Additionally, the negative images and positive images were not significantly different from each other on arousal levels, $t(198) = .228$, $p = .820$, across the two lists and within each list.

The experimental task was created in E-Prime (Psychology Software Tools, Inc.). Stimulus presentation was controlled by a Toshiba laptop with a viewing distance of approximately 50 cm. All study and test stimuli appeared in the centre of the screen against a black background.

Procedure

The experimental session included a study phase, a filled retention interval, and a recognition test. Participants were told that they were completing a study investigating the effect of emotion on brightness perception and were unaware that their memory for the images would be tested later. Prior to the study phase, the health questionnaire and the PANAS were completed. During the study phase, participants viewed a series of 156 images. The order of the images was randomized with the exception of the first 6 stimuli, which were identical for all participants and served as practice items that were excluded from the analyses. Each trial started with a fixation cross lasting 750 ms, followed by a 500-ms pause, and a 2-s picture stimulus. After the image was presented, participants were asked to rate its brightness on a 7-point scale. Participants were instructed that on this scale, a 1 (not at all bright) corresponds to the amount of light given off by a small night light in a very large room at night, a 7 (very bright) corresponds to the amount of light present on a sunny, cloudless day (Ochsner, 2000). Immediately following the response, the next trial started.

During the 1-hour retention interval, participants completed the personality assessments, including the NEO and TAS, IS and AQ, on the computer. During the subsequent recognition test, participants viewed the 150 target images and 150 distractor images, presented in a random intermixed order. Participants used the "X" and "," keys to indicate old-new. The assignment of response keys to the two responses was counterbalanced across participants. Each stimulus remained onscreen for up to 5s or until a response was made. Following the recognition test, participants were shown all 300 images again and provided arousal ratings using the Self-Assessment Manikin (Bradley, Greenwald, & Hamm, 1993) on a 5-point scale. Following the arousal ratings participants completed the VES if they indicated that they had played video games in the last 6 months.

Results

The following analyses include only the 90 matched participants, 45 VG players and 45 non-players. Analyses of brightness judgments, accuracy, and reaction time are presented first using analysis of variance (ANOVA) to detect significant main effects or interactions of group and valence on the behavioural measures. Analyses of the diffusion parameters are presented next. The subsequent section, Supplementary Analyses, includes only 44 participants: 22 VG players with the highest VES scores and their 22 matched controls. Analyses on the 32 excluded participants are presented in Appendix B. Incidental findings from the analysis of the diffusion model parameters involving the entire sample are reported in Appendix C.

Brightness judgments

The brightness judgments were submitted to a 2 x 4 mixed analysis of variance (ANOVA) with group (VG player vs. non-player) as the between-subjects variable and valence (violent vs. negative vs. positive vs. neutral) as the within-subjects variable. Mauchly's test indicated that the assumption of sphericity was violated for valence, $X^2(5) = 170.43$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .47$. The only significant effect was a main effect of valence, $F(1.41, 124.41) = 102.83$, $p < .001$, MSE = 67.91, $\eta^2 = .539$. Pairwise comparisons revealed that participants rated negative images and violent images as less bright than neutral and positive images and neutral as less bright than positive. Refer to Figure 2 for the means of these brightness judgments.

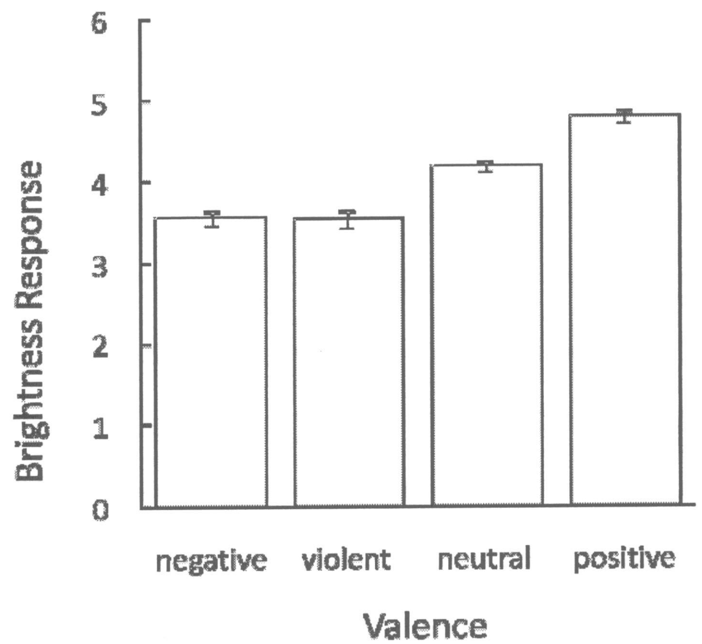

Figure 2. Means of brightness judgment responses across groups. Error bars represent the standard errors.

Brightness judgment RTs were submitted to a 2 x 4 mixed ANOVA. Mauchly's test indicated that sphericity was violated for valence, $X^2(5) = 60.64$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .71$. Again, only the effect of valence on RT was significant, $F(2.115, 186.13) = 12.12$, $p < .001$, MSE = 153546.58, $\eta^2 = .121$. Pairwise comparisons revealed that the brightness judgment RTs for

negative and violent images were significantly longer than those for positive and neutral images. RTs were also significantly longer for positive images than for neutral images (see Figure 3).

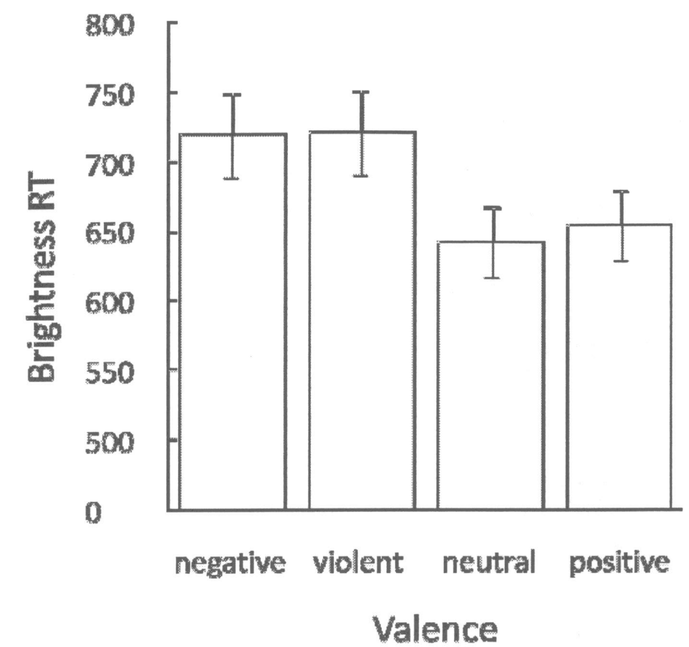

Figure 3. Median of the brightness judgment reaction times across groups. Error bars represent the standard errors.

Accuracy

To examine memory sensitivity in the old-new recognition task, the signal-detection index *d'* (Green & Swets, 1966) was calculated. Hit rates, false alarm rates and *d'* for VG players and non-players are presented in Table 2. A 2 x 4 mixed ANOVA was performed on *d'* with group (VG player vs. non-player) as a between-subjects variable and valence (negative vs. violent vs. neutral vs. positive) as a within-subjects variable. Group and valence did not interact significantly, $F(3, 264) = .696$, $p = .555$, MSE = .155, $\eta^2 = .008$. Contrary to the hypothesis, VG players did not show reduced sensitivity for negative non-violent images, nor did they show increased sensitivity for violent images. In addition, there was no main effect of valence, *F*(3,

264) = 1.455, p = .227, MSE = .323, η^2 = .016, nor a main effect of group F(1, 88) = 1.514, p = .222, MSE = .1.598, η^2 = .017.

Table 2

Hit Rates, False Alarm Rates and d' in VG Players and Non-players for all levels of Valence

	M		SD	
	VG Player	Non-player	VG Player	Non-player
		Negative		
HR	.74	.77	.12	.13
FAR	.12	.10	.08	.07
d'	2.03	2.32	.51	.65
		Violent		
HR	.76	.74	.20	.18
FAR	.12	.09	.13	.08
d'	2.10	2.11	.69	.70
		Neutral		
HR	.69	.72	.17	.13
FAR	.08	.06	.06	.05
d'	2.15	2.33	.68	.62
		Positive		
HR	.74	.74	.14	.14
FAR	.11	.09	.09	.08
d'	2.07	2.20	.58	.78

Note: HR = hit rate; FAR = false alarm rate.

The number of violent images (N = 28) may have been too low to provide a reliable measure of memory sensitivity for this class of items. I therefore conducted an additional analysis, collapsing violent and negative non-violent scores into a single "negative" valence category. Again there was no significant interaction of group and valence on *d'*, F(2, 176) = .082, p = .921, MSE = .014, η^2 = .001, nor a main effect of valence, F(2, 176) = 2.372, p = .096, MSE = .405, η^2 = .026.

Reaction Time

RT data for correct responses (both hits and correct rejections) are presented in Table 3. Mauchly's tests indicated that the assumption of sphericity was violated for both hits and correct rejections, $X^2(5)$ = 86.550, p < .001, and $X^2(5)$ = 61.32, p < .001, respectively. Degrees of freedom were therefore corrected using Greenhouse-Geisser estimates of sphericity, ε = .60 and ε = .70.

The Hit results show, contrary to hypotheses, that neither the main effect of group, F(1, 88) = 1.295, p = .258, MSE = 156562.66 η^2 = .015, nor the interaction of group and valence were significant, F(1.806, 158.963) = 1.129, p = .338, MSE = 17605.426, η^2= .013. VG players were not slower than the non-players in their recognition of violent images or any other types of images. However, there was a significant main effect of valence, F(1.806, 158.963) = 12.02, p < .001, MSE = 187525.319, η^2 = .120. Pairwise comparisons revealed that the RT for violent images was significantly longer than for all other types of images. In addition, RTs for negative and positive images were significantly longer than those for neutral images. Figure 4 shows the median RTs for hits at each level of valence.

Table 3

Median Reaction Times for Hits and Correct Rejections (in ms) for VG players and Non-players at all levels of Valence

	M		SD	
	VG Players	Non-players	VG Players	Non-players
		Negative		
Hit	1,030	1,011	167	171
CR	1,110	1,049	244	210
		Violent		
Hit	1,106	1,059	298	204
CR	1,172	1,114	272	247
		Neutral		
Hit	1,004	981	154	159
CR	974	933	176	175
		Positive		
Hit	1,026	1,013	184	201
CR	1,053	1,001	188	190

Note: Hit= correctly identifying target as "old"; CR= correct reject of distractor item as "old"

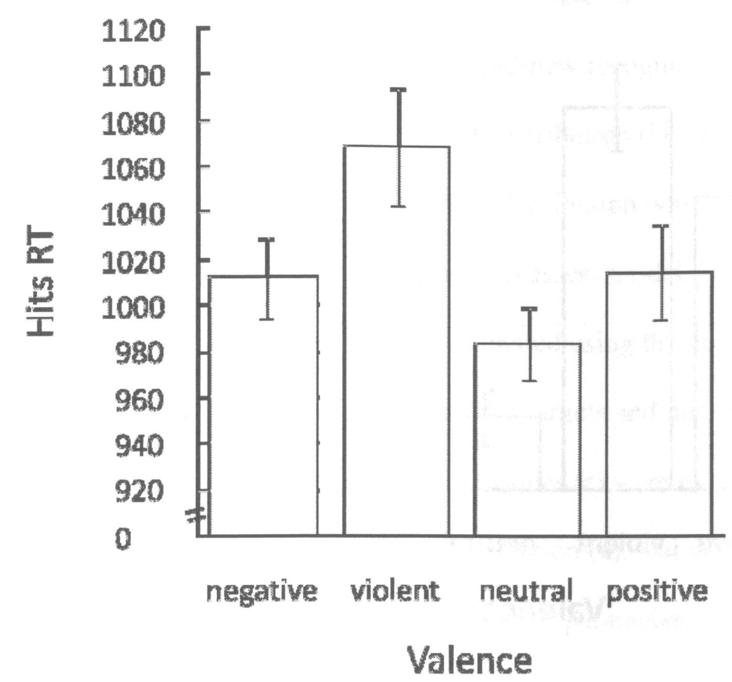

Figure 4. Median reaction time for correctly identified target items at each level of valence across groups. Error bars represent the standard errors.

Correct rejection RTs showed no significant interaction of valence and group, $F(2.110, 185.668) = .138$, $p = .882$, MSE = 1757.584, $\eta^2 = .002$, nor a main effect of group, $F(1, 88) = 2.598$, $p = .111$, MSE = 359987.38, $\eta^2 = .029$. The main effect of valence was again significant, $F(2.110, 185.668) = 67.548$, $p < .001$, MSE = 862354.225, $\eta^2 = .434$. Pairwise comparisons revealed that RTs at each level of valence were significantly different from all others. Correct rejection RTs were longest for violent images, followed by negative, positive, and neutral images (see Fig. 5).

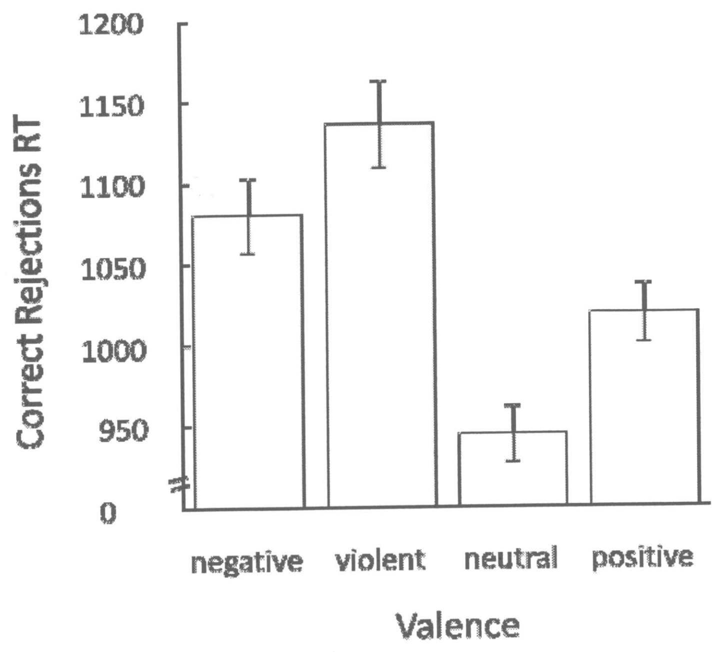

Figure 5. Median reaction time for correct rejection of distractor items at each level of valence across groups. Error bars represent the standard errors.

Diffusion Models

To estimate the parameters of the diffusion model, the Kolmogorov-Smirnov (KS) test statistic *T* was used to optimize the fit between the predicted and the empirical RT distributions (see Voss et al., 2004). *T* indicates the maximal vertical distance between the empirical cumulative RT distribution and the RT distribution predicted by the model. A small *T* statistic indicates good fit since the difference between the empirical and predicted distributions is small, whereas a large *T* statistic (i.e., $p < .05$) signals a large discrepancy between the two distributions that likely did not come about by chance.

To estimate the diffusion parameters using the KS test as optimization criterion, two theoretical cumulative RT distributions need to be simultaneously fitted to two empirical cumulative RT distributions. One distribution is associated with the lower response boundary

(i.e., the *new* boundary in the old-new recognition task), and the other is associated with the upper boundary (i.e., the *old* boundary in the old-new recognition task). A negative sign is arbitrarily assigned to the lower boundary RT distribution (i.e., *new* responses) and the two distributions are concatenated to form a single distribution with negative and positive RT ranges (see Fig. 1). A single KS test can then be used to assess model fit.

Parameters of the model were estimated using the *fast-dm* program (Voss & Voss, 2007). Separate drift rates (v) were estimated for targets and distractors at each level of valence (neutral, negative, positive). Separate starting values (z) were estimated at each level of valence, as well as non-decision time (t_o), boundary separation (a), and variance in non-decision time (s_t), starting point (s_z) and drift rate (s_v), for a total of 14 parameters per participant. As noted earlier, there were too few violent stimuli for reliable diffusion model analysis, so three levels of valence were created by collapsing across the negative non-violent and violent categories.

Model Fit

Of the 90 participants included in this analysis, 25 participants had poor model fit (i.e., $p < .05$). One possible cause of model misfit is a low error rate. Indeed, there was a significant correlation ($r = .29$, p = .01) between the false alarm rate for negative items and the model fit index (significance value p), indicating that participants with fewer false alarms to negative items tended to have worse model fit. All analyses were calculated both with and without the 25 participants with poor model fit and the trend in results remained consistent. All 90 participants were therefore included in the analyses reported next.

Model Parameters

Group and overall means of the diffusion parameters are presented in Table 4. The groups did not differ on nondecision time, $t(88) = -1.176$, $p = .243$ or boundary separation, $t(88)$

= -1.078, p = .284. The variability of nondecision time (s_t) did differ between groups $t(88)$ = -2.049, p = .043, as did starting point variability (s_z) $t(88)$ = 2.884, p = .005. The variability in drift rate (s_v) did not show any significant group differences, $t(88)$ = -1.032, p = .305.

Response bias. The placement of the starting point relative to the response boundaries, *z/a*, served as a measure of response bias. *z/a* values greater than .5 indicate a bias toward the response associated with the upper boundary (i.e., "old"), whereas values of *z/a* lower than .5 indicate a bias toward the response associated with the lower boundary (i.e., "new"). Mauchly's test showed the assumption of sphericity to be violated for valence, $X^2(5) = 15.975$, $p < .001$, so degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, ε = .86. There was no significant Group x Valence interaction, $F(1.713, 150.717)$ = 1.773, p = .178, MSE = .018, $\eta^2 = .020$, but as predicted, a significant effect of valence on response bias was present across groups, $F(1.713, 150.717) = 9.221$, p = .001, MSE = .093, $\eta^2 = .095$. Participants were more liberal in their responses (i.e., more likely to respond "old") to negative items and positive items compared to neutral items. Figure 6 shows response bias means at each level of valence. One-sample t-tests indicated that response bias for negative and positive stimuli was significantly greater than .5, $t(89) = 9.664$, $p < .001$, $t(89) = 6.455$, $p < .001$, whereas response bias was not significantly different from .5 for neutral stimuli, $t(89) = 1.530$, p = .130.

Table 4

Means of the Diffusion Parameter Values

	VG player	Non-player	Overall
t_o	0.69 (0.46)	0.61 (0.10)	0.65 (0.35)
a	1.84 (0.36)	1.76 (0.35)	1.80 (0.35)
z			
Neg	1.07 (0.28)	1.02 (0.25)	1.05 (0.26)
Neu	1.02 (0.39)	0.88 (0.31)	0.95 (0.36)
Pos	1.04 (0.28)	0.99 (0.24)	1.01 (0.26)
v_{old}			
Neg	0.82 (0.64)	0.94 (0.68)	0.88 (0.66)
Neu	0.73 (0.96)	1.11 (0.91)	0.92 (1.02)
Pos	0.92 (0.80)	0.99 (0.92)	0.96 (0.84)
v_{new}			
Neg	-1.57 (0.60)	-1.68 (0.62)	-1.63 (0.61)
Neu	-2.10 (1.12)	-2.10 (1.06)	-2.10 (1.08)
Pos	-1.62 (0.90)	-1.89 (0.84)	-1.76 (0.88)
s_t	0.27 (0.14)	0.22 (0.10)	0.24 (0.13)
s_z	0.45 (0.28)	0.61 (0.22)	0.53 (0.26)
s_v	0.54 (0.30)	0.48 (0.28)	0.54 (0.29)

Note. Standard Deviations are in parentheses. Neg = negative; Neu = neutral; Pos = positive. Overall refers to the means across groups.

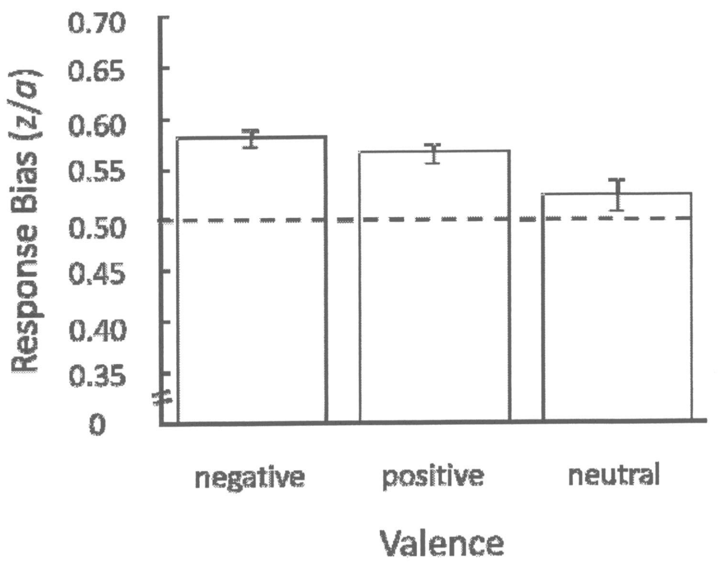

Figure 6. Mean values of response bias (z/a) for negative, positive, and neutral images across groups. Error bars represent the standard errors. Values above .5 (see dotted line) indicate a bias to classify items as "old", whereas values below .5 indicate a bias to classify items as "new".

Drift rates: Effects of group, status and valence. The assignment of "old" responses to the upper boundary and "new" responses to the lower boundary is arbitrary, resulting in positive average target drift and negative average distractor drift estimates. The following analyses therefore used sign-reversed drift rate estimates. These drift rates were submitted to a 2 x 2 x 3 ANOVA with group (VG player vs. non-player) as the between subjects variable and status (distractor vs. target) and valence (neutral vs. negative vs. positive) as the within subjects variables. There were no significant effects of group or Group x Valence on drift rates, contrary to the hypothesis. Mauchly's test indicated that the assumption of sphericity was violated for valence, $X^2(2) = 11.88$, $p = .003$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .88$). Across groups, a main effect of valence was found, with drift rates significantly lower for negative (M = 1.25) and positive items (M =

1.36) compared with neutral items (M = 1.51), $F(1.774, 156.079) = 13.029$, $p < .001$, MSE = 3.076, $\eta^2 = .129$. A main effect of status was also present, with drift rates significantly lower for target items (M = 0.92) than for distractor items (M = 1.83), $F(1, 88) = 100.85$, $p < .001$, MSE = 111.314, $\eta^2 = .534$. Finally, the Status x Valence interaction was significant, $F(1.88, 165.55) = 7.70$, MSE = 3.61, $p = .001$, $\eta^2 = .080$. Pairwise comparisons revealed that neutral distractors elicited significantly higher drift rates than negative or positive distractors (see Figure 7).

Figure 7. Mean drift rates for negative, positive, and neutral items separately for targets and distractors across groups. Error bars represent the standard errors.

Arousal Ratings

Mean arousal ratings for each group are presented in Table 5. Two participants' arousal ratings were not recorded because of equipment failure. A 2 x 4 ANOVA was conducted on the arousal ratings with group (VG player vs. non-player) as the between subjects variable and valence (violent vs. negative vs. positive vs. neutral) as the within subjects variable. Mauchly's test indicated that the assumption of sphericity was violated for valence, $X^2(5) = 79.095$, $p = .001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .67$). There was a main effect of valence on arousal, $F(2.011, 172.958) = 303.973$, $p < .001$, MSE = 90.11, $\eta^2 = 0.779$, such that violent images were rated as the most arousing (M = 3.47), followed by negative images (M = 3.21) which in turn were rated as more arousing that positive (M = 2.47) and neutral images (M = 1.63). VG players did not differ from non-players in their arousal ratings, $F(1, 86) = 1.097$, $p = .298$, $\eta^2 = 0.013$.

Table 5

Mean Arousal Ratings for VG players and Non players

Type of Image	VG Players	Non players
Violent	3.31 (0.74)	3.12 (0.71)
Negative	3.59 (0.95)	3.35 (0.83)
Positive	2.51 (0.75)	2.44 (0.78)
Neutral	1.65 (0.47)	1.60 (0.39)

Note. Standard deviations are in parentheses.

Supplementary Analyses

In the analyses reported so far, the group variable (VG player vs. non-player) was not associated with any significant effects. To rule out the possibility that group differences had been "washed out" by the inclusion of VG players with low VES scores, a median split (Md = 19.0) was performed on the VES scores among VG players. I then conducted additional analyses

that included only the VG players (N = 22) with VES scores above the median and an equal number of matched non-players. No significant effects of group emerged on any of the dependent measures. The main effect of valence on *d'* remained non-significant, indicating memory for emotional items was not better than neutral across groups. Collapsing across violent and negative non-violent to create a single category of "negative" also did not elicit an effect of valence on *d'*.

Because of the nature of the VES, it is possible for people who play non-violent video games frequently to end up with a high score. A sample of 18 VG players with high exposure to violent video games in particular and their matched controls were submitted to this same 2 x 4 ANOVA on *d'* and the results remained non-significant. The main effect of valence on reaction time remained consistent with the trend observed in the matched group data for hits and correct rejections: Violent stimuli were categorized slowest and neutral stimuli fastest.

Of the 44 extreme group participants, 16 had poor model fit ($p < .05$) and 28 had good model fit. The groups did not differ on any diffusion model parameters. The main effect of valence on response bias did not remain significant when restricting the sample to extreme groups. The Status x Valence interaction on drift rate remained significant, again revealing that neutral distractors evoked significantly higher drift rates than emotional distractors.

Discussion

VG players were age and gender matched to a group of non-player controls but no significant group differences emerged on any of the dependent measures. Furthermore, the data did not support the prediction of a negativity bias in memory, in either group. Valence did not affect memory sensitivity, and the RTs for hits and correct rejections were significantly longer (not shorter) for negative stimuli. As has been recently shown in the literature, emotional material did elicit a more liberal response bias compared to neutral material. A somewhat perplexing interaction on drift rate indicated that neutral distractors were processed more efficiently than emotional distractors, although this was not true of target items. Finally, participants were better at identifying evidence in favour of a "new" response than they were at identifying evidence in favour of an "old" response.

Accuracy and RT analyses

Accuracy. It has previously been shown that violent video game playing reduces physiological arousal during the encoding of non-violent negative stimuli (Carnagey et al., 2007; Staude-Müller et al., 2008), whereas it may increase physiological arousal during the encoding of violent stimuli (Staude-Müller et al., 2008). I therefore hypothesized that VG players would show reduced arousal and reduced recognition accuracy for negative non-violent stimuli. Additionally, I predicted the reverse finding (increased arousal and recognition accuracy) for violent images in particular. Neither of these hypotheses was supported; there were no significant effects of group, valence, or their interaction, on *d'*. The same result was obtained when only VG players with high scores on the VES scale were included.

The hypothesis of a Group x Valence effect on memory sensitivity was contingent on differences in arousal between VG players and non-players. Analysis of the self-reported arousal ratings, however, showed no significant differences between the groups. Positive and negative images were equated on average arousal according to the IAPS norms, but participants in this study gave significantly higher arousal ratings to negative items than to positive items. One possible reason for this discrepancy is that the researcher was always in the room while participants were making their arousal ratings. Many of the positive high-arousing images were

pornographic in nature and participants may have been reluctant or embarrassed to assign high ratings to these images. This potentially lower arousal experience of positive images did not ultimately seem to affect the accuracy for positive images since there was no significant difference in accuracy between positive and negative images.

In addition to no group differences, there was also no main effect of valence on memory accuracy. Contrary to the hypothesis, memory for negative stimuli was not significantly better than memory for positive or neutral stimuli. Although some previous research has found an effect of valence on memory, and a negativity effect in particular (Kensinger & Corkin, 2003; Mather, Shafir, & Johnson, 2000; Ochsner, 2000), null effects have also been reported (e.g., Dougal & Rotello, 2007; Maratos et al., 2000; Kensinger & Corkin, 2003, Experiment 5; Windmann & Kutas, 2001).

There are several possible reasons for the absence of a valence effect on accuracy. Overall memory performance was high, and the retention period between study and test was short (i.e., one hour). Kensinger and Corkin (2003) found that the negative images were better recalled than neutral images only after a 1-2 day delay between study and test. In the same study, emotional content had no effect on the accuracy of working memory performance during an n-back task, although there was an effect of emotion on speed of processing, with slower responses to fearful faces than to neutral faces. Part of the enhancement of emotional information in long-term memory could result from a modulation of consolidation processes. Emotional content, and more specifically, emotionally arousing information, may be more frequently consolidated than neutral information so that emotional memory enhancement increases over time (Cahill, et al., 1996; Cahill & McGaugh, 1998). Arousal is thought to activate the amygdala which in turn modulates memory consolidation because of its projections into many other brain areas associated with memory, such as the hippocampus (McGaugh, 2006). By this logic, after a longer delay period not only should valence effects emerge, but group differences may also be revealed.

Another factor that may have contributed to the null findings was the selection of the stimulus materials. Great care was taken to equate the average semantic relatedness of the stimuli within each valence category. As noted in the introduction, some researchers have found that valence effects on memory accuracy may become smaller or disappear when the emotional and neutral items are equated on semantic relatedness (Dougal & Rotello, 2007; Talmi & Moscovitch, 2004).

Reaction time. Based on the finding by Bartholow and colleagues (2006), that VG players took longer to categorize negative images than non-players, I predicted that VG players would show longer reaction times for recognition of negative stimuli compared to the non-players. Consistent with the results for arousal ratings and recognition accuracy, however, there were no significant differences between groups on reaction times for categorization of target or distractor items. Participants in the study by Bartholow and colleagues (2006) regularly played violent video games at home, similar to the participants in the current study. It is worth noting, however, that although Bartholow and colleagues (2006) found a significant difference in reaction time for categorization during ERPs, participants were not actually making decision judgments. It is possible that cognitively VG players are slower at categorizing violent images, however this does not affect their actual reaction time when making decisions and pressing a button.

Although no group differences arose, there was a significant main effect of valence on reaction time for correct responses (hits and correct rejections), although not in the predicted direction. Specifically, reaction times for violent images were longer than reaction times for non-

violent negative images, which in turn exceeded reaction times for positive images. Neutral images elicited the fastest responses.

There are several possible explanations for why violent and negative images produced longer reaction times compared to positive and neutral images. Ochsner (2000) suggested that negative stimuli may demand attention to the extent that they are ‘survival-relevant’ and threatening. Consistent with this view, participants took longer to make brightness judgements when the stimuli were violent or negative rather than positive or neutral.

It is also possible that the images in the different valence categories varied along dimensions that affect decision making reaction times but are not emotion-specific. Such dimensions may include visual complexity, novelty, or salience. Although great care was taken to equate the semantic relatedness of the stimuli within each valence category, visual complexity was not considered. Comblain, D’Argembeau, Van der Linden, and Aldenhoff (2004) had participants rate 140 IAPS images on visual complexity and found that positive, negative and neutral images, as well as low, medium and high arousal images differed in their visual complexity. Given these findings, it is difficult to disentangle whether the longer reaction times for emotional compared to neutral stimuli in the current study were due to valence or to visual complexity. Having a separate group of participants rate the stimuli on visual complexity would have allowed for the lists to be equated not only on arousal and semantic relatedness but also on visual complexity.

In addition to visual complexity, novelty may have been another dimension on which the stimulus categories differed. For example, most people do not encounter war scenes, starving children, or erotic couples on a regular basis. In contrast, neutral faces and scenes are more typical of what is encountered in everyday life. In an examination of the effects of novelty in news photographs on attention and memory, Mendelson (2001) found that novel images were deemed more interesting, were chosen by participants for further viewing more often than typical content photos, and were subsequently remembered better.

Although the novelty of emotional stimuli may capture attention, it is possible that neutral stimuli were actually more distinctive in the context of this experiment. For example, Strack and Bless (1994) found that salience (i.e., distinctiveness) of objects significantly affected recognition responses, such that if objects did not belong to the majority category, old-new discrimination was enhanced relative to non-salient objects. The stimulus set in the current study included 100 low-arousal neutral items and 200 high-arousal emotional items. Neutral items therefore may have been more salient and may have "popped out," thereby becoming easier to identify as old or new. Schacter, Israel and Racine (1999) have termed this phenomenon the "distinctiveness heuristic". Increasing the number of neutral stimuli relative to the number of emotional stimuli would allow testing the possibility that a distinctiveness heuristic was operating in the current study.

In sum, contrary to hypotheses, VG players did not differ from non-players on accuracy or reaction time, possibly because the materials elicited similar levels of arousal in both groups. Across groups, the data did not provide evidence for a negativity effect, or indeed any valence effect, on memory accuracy. At the same time, reaction times for negative stimuli were longer, rather than shorter, than reaction times for positive and neutral stimuli. Factors that may explain this valence-specific slowing include survival relatedness, visual complexity, novelty, and salience/distinctiveness. It is not clear, however, why the same factors did not affect recognition accuracy. The diffusion model analyses, discussed next, provided insight into this question by shedding light on the cognitive processes underlying behavioural performance.

Diffusion model findings

Twenty-five participants (28% of the matched sample) had poor model fit ($p < .05$), but because removing these participants did not change the results, I retained all matched participants in the final analyses.

Response bias. Based on previous findings (Dougal & Rotello, 2007; Kapucu et al., 2008; Spaniol et al., 2008; Windmann & Krüger, 1998; Windmann & Kutas, 2001), it was predicted that emotional stimuli would evoke a more liberal response bias, compared to neutral images. The prediction was borne out by the model results: A significant 'old' bias was present for negative and positive stimuli, but neutral stimuli evoked no bias. It is not clear why these patterns occurred, however I suspect that participants (unconsciously) view emotional information, both negative and positive, as important. They therefore may be reluctant to "miss" an emotional item by identifying it as new, because this item may be instructive or "missing" it could result in negative consequences.

Drift Rate. In the diffusion model, the drift rate indicates the quality of the information driving the decision process (Ratcliff, 1978). The desensitization hypothesis led to the prediction that, relative to non-players, VG players would show reduced drift for negative stimuli. Contrary to this hypothesis, drift rate analyses yielded no interaction of group and valence, which was consistent with the memory accuracy and reaction time results.

A significant Status x Valence interaction on drift rate did emerge, due to the fact that neutral distractors were detected more efficiently than emotional distractors, whereas no valence effect was present for targets. This is an important finding because it indicates that valence did affect the rate of information accumulation, and not merely the response bias settings. It also highlights the utility of the modeling approach, because the separate analyses of accuracy and

RT yielded ambiguous results (shorter RTs but equal accuracy for neutral stimuli, compared with emotional stimuli). Moreover, the RT results suggested that the decision process was faster for neutral stimuli, however the drift analysis probed this effect revealing that neutral distractors in particular are processed more efficiently.

Why were distractors detected more efficiently than targets, at each level of valence? This finding is slightly counterintuitive, though not unique (Ratcliff, Thapar, & McKoon, 2004; Spaniol et al., 2008). The large discrepancy between target and distractor drift rates could be explained by *diagnostic monitoring* (e.g., “I would remember that picture if I had seen it... I don’t remember it... so it must be new”). When target items are made so memorable that participants feel confident that they would remember them vividly, the absence of recollection provides diagnostic evidence that the item is new (Gallo, 2004; Schacter, Israel & Racine, 1999; Strack & Bless, 1994). Overall memory performance in the current experiment was indeed quite high, and participants were likely making “old” judgments on the basis of recollection. The total absence of recollection may have provided immediate diagnostic evidence that a stimulus was new. One problem for the diagnostic monitoring account is that it is not clear why targets would not benefit from this type of monitoring to the same extent as distractors. Further discussion of this issue is beyond the scope of this thesis, as are incidental findings (see Appendix C) which show a correlation between distractor drift rate and response bias that is nonexistent for target drift rate and response bias.

Overall, results from the diffusion model consistently showed that there were no significant differences between VG players and non-players. As hypothesized, emotional items produced a liberal response bias that neutral items did not. Interestingly, drift rate analysis revealed that neutral distractors were processed more efficiently than emotional distractors, and

that distractors were processed more efficiently than targets in general. The reason why distractors were processed more efficiently than targets remains unclear and requires further exploration.

Lack of Group Differences: Evidence Against Desensitization?

Contrary to the hypotheses there were no significant differences between VG players and non-players on any of the dependent measures. VG players did not show a compromised negativity bias with lower accuracy and longer reaction times for negative images, nor did they show increased accuracy for violent images as speculated. Given that the sample of VG players came from a university population it is possible they were not representative of VG players in general or may not reflect true “chronic” violent VG players. However, the relatively large sample size (N = 44 per group) afforded reasonable statistical power ($1-\beta = .971$; Erdfelder & Buchner, 1996) to detect a medium effect. Furthermore, the pattern was identical even in an extreme sample of 18 VG players with high exposure to violent video games. It seems reasonable to conclude from these results that there may be no lasting effects of violent video games on arousal levels and subsequent memory for negative information. However, this conclusion can only be regarded as preliminary since the study is quasi-experimental (participants were not randomly assigned to VG player or non-player status), and thus allows no strong inferences about the presence or absence of causal links.

Other researchers have found that playing even 20 minutes of violent video game play can affect physiological arousal and categorization of negative stimuli. The results of the present study suggest that previous research may have found evidence for habituation, rather than desensitization. These experimental studies did not follow up with the participants so it is unknown how long the video game effects lasted and whether participants returned to baseline levels. The present study suggests that VG players, who play for their own enjoyment rather than being assigned to a condition of playing in the lab, do not perform any differently from non-players with respect to categorization (brightness ratings), rated arousal, or memory for negative and neutral images. It may be that VG players rebound quickly from any effects of violence exposure.

Limitations and future directions

One limitation of the study was the short interval between study and test. If the retention interval was increased to 24 hours, perhaps the valence and arousal effects sometimes shown for memory sensitivity would emerge, thus also allowing the possibility of group effects to manifest. In the future, a better approach may be to test half of the studied items the same day and half the next day to determine if the retention interval is indeed a factor.

The composition of the participant sample may also have been an issue. As mentioned previously, the VG players in this sample may not be representative of VG players in the general population. The participants were university students which may limit the amount of time and money one has to spend on video games. Perhaps recruiting VG players through a video game store or online gaming site would result in a more representative sample.

Finally, it is interesting to ask why neutral distractors were processed more efficiently than emotional distractors, and why distractor processing was more efficient than target processing. One would expect target processing to be equally efficient as distractor processing, since both involve evaluation of the same mnemonic evidence. The answer to why the absence of recollection is more compelling evidence than the presence of recollection is not apparent from the current study and deserves further investigation.

Conclusions

To my knowledge, this study was the first to investigate possible differences in memory and the negativity effect in VG players and non-players. Given that violent video games are gaining popularity and that short-term effects on physiological arousal and cognition have already been demonstrated, understanding the long-term effects of these media is vital. No evidence for a relationship between video game exposure and memory emerged in the current study. However, the study was quasi-experimental, with all of the limitations inherent in this method. Follow-up studies, perhaps incorporating the approaches suggested above, are needed to establish more firmly whether or not violent video games have long-term effects on how we think and remember.

Appendix A

Video Game Questionnaire

Please list up to five (5) of your favourite video games. After naming each game, indicate using the scale below of 1 to 7, how *violent the content and graphics are*. Also, please indicate how often you play this game currently and which of the following six categories best describes each of the games.

1= rarely, little or no violent content / little or no violent graphics
7= often, extremely violent content / extremely violent graphics

1. ____

Violent Content: _____

Violent Graphics: _____

Game Theme: Educational; Skill; Fantasy; Sports; Fighting with Hands; Fighting with Weapons.

How often: Rarely Occasionally Often

2. ____

Violence Content: _____

Violent Graphics: _____

Game Theme: Educational; Skill; Fantasy; Sports; Fighting with Hands; Fighting with Weapons

How often: Rarely Occasionally Often

3. ____

Violence Content: _____

Violent Graphics: _____

Game Theme: Educational; Skill; Fantasy; Sports; Fighting with Hands; Fighting with Weapons

How often: Rarely Occasionally Often

4. ____

Violence Content: _____

Violent Graphics: _____

Game Theme: Educational; Skill; Fantasy; Sports; Fighting with Hands; Fighting with Weapons

How often: Rarely Occasionally Often

5. ____

Violence Content: _____

Violent Graphics: _____

Game Theme: Educational; Skill; Fantasy; Sports; Fighting with Hands; Fighting with Weapons

How often: Rarely Occasionally Often

At what age did you begin to play video games? __________

Please estimate the **number of hours per week** you have played video games in the following:
The last 3 months: _________
The 3 months prior to that: _________

Appendix B

Questionnaire data for excluded participants (N=32)

Characteristic	Mean	SD
Age (years)	21.1	5.68
Age range	18-38	
Negative mood	12.5	2.34
Positive mood	27.8	6.11
AQ	71.1	15.7
IS	80.9	12.5
TAS-20	46.3	10.6
VES	0	0
Neuroticism	17.3	14.9
Extraversion	25.9	7.23
Openness	27.9	7.08
Agreeableness	31.4	4.74
Conscientiousness	32.1	6.58

Note: Negative mood and positive mood are Positive and Negative Affect Schedule scores. AQ = Aggression Questionnaire. IS = Irritability Questionnaire. TAS-20 = 20-item Toronto Alexithymia Scale. VES = Violence Exposure Score from the video game questionnaire. Neuroticism, extraversion, openness, agreeableness, and conscientiousness are scores based on responses from the revised NEO Five-Factor Inventory. SD=standard deviation.

Brightness Judgments

Brightness judgments among the 32 excluded participants were similar to those for the included participants. The brightness judgments were submitted to a repeated measures ANOVA

valence (violent vs. negative vs. positive vs. neutral) as the within-subjects variable. Mauchly's test indicated that the assumption of sphericity was violated for valence on response and RT, $X^2(5) = 220.38$, $p < .001$, $X^2(5) = 68.82$, $p < .001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, ε = .49 and ε = .15, respectively. There was a main effect of valence on brightness judgments, $F(1.480, 95.321) = 146.76$, $p < .001$, MSE = 88.03, $\eta^2 = .526$. The pairwise comparisons revealed that negative (M = 3.64) and violent (M = 3.58) stimuli were judged as significantly less bright as positive (M = 4.22) and violent was less bright than neutral (M = 4.80). Positive images were judged as significantly brighter than neutral. A main effect of valence was also found on brightness RT, $F(2.260, 298.321) = 22.46$, $p < .001$, MSE = 263868.50, $\eta^2 = .145$. Pairwise comparisons revealed that RTs for negative stimuli (M = 721ms) and violent stimuli (M = 720ms) were significantly smaller than neutral (M = 650) and positive (M = 638ms).

Accuracy

As found with the matched sample, there was no effect of valence on memory sensitivity (*d'*) for the excluded participants, $F(3, 93) = 2.452$, $p = .068$, MSE = .416, $\eta^2 = .073$. Accuracy for negative (M = 1.97), violent (M = 1.83), positive (M = 2.06) and neutral images (M = 2.07) did not differ significantly. When violent and non-violent negative categories were collapsed, the main effect of valence on *d'* ($M_{neg} = 2.065$, $M_{pos} = 2.116$, $M_{neu} = 2.190$) approached significance, $F(2, 242) = 3.011$, $p = .051$, MSE = .483, $\eta^2 = .024$.

RT

The RTs for hits and correct rejections of the excluded participants maintained a pattern consistent with the matched participants. Mauchly's test indicated that the assumption of sphericity was violated for the main effect of valence on hits and correct rejections, $X^2(5) =$

118.68, $p < .001$, $X^2(5) = 86.19$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .59$ and $\varepsilon = .71$, respectively.

There was a main effect of valence on RT for Hits $F(1.778, 215.130) = 21.028$, $p < .001$, MSE = 202080.455, $\eta^2 = .148$. Participants took longer to categorize violent images (M = 1083ms) compared to negative (M = 1006ms), positive (M= 1012ms) and neutral (M = 992ms) images. RTs for neutral images were significantly shorter than RTs for negative and positive images.

There was also a main effect of valence on RT for correct rejections $F(2.115, 255.926) = 78.847$, $p < .001$, MSE = 1113711.194, $\eta^2 = .395$. Pairwise comparisons revealed that all RT means were significantly different from each other. Neutral images (M = 950ms) were categorized faster than negative (M = 1078ms), positive (M = 1021ms) and violent images (M = 1138ms).

Diffusion Models

Diffusion model parameters were calculated for the excluded participants to examine model fit, response bias, and drift rates. Separate drift rates (v) were estimated for targets and distractors at each level of valence (neutral, negative, positive). Separate starting values (z) were estimated at each level of valence, as well as non-decision time (t_o), boundary separation (a), and variance in nondecision time (s_t), starting point (s_z) and drift rate (s_v) for a total of 14 parameters per participant.

Model fit. Of the 32 participants, 4 had poor model fit (i.e., $p < .05$), most likely due to the relatively low number of false alarms made by these participants. Negative (r = .519), violent (r = .371), neutral (r = .433) and positive (r = .531) false alarm rates significantly correlated with

the p value of the diffusion model ($p < .05$), confirming that high false alarm rates were associated with higher p values.

Response bias. As a measure of response bias, z/a was calculated for each level of valence. A main effect of valence was found on response bias, $F(2, 62) = 5.789$, $p < .005$, MSE = .044, $\eta^2 = .157$. Participants were again more likely to respond "old" to both negative (M = .59) and positive (M = .58) items, compared to neutral items (M = .52). One-sample t-tests revealed that mean response bias values for negative and positive items were significantly above 'no-bias' value of .5, $t(31) = 5.760$, $p < .001$, and $t(31) = 4.237$, $p < .001$. In contrast, there was no significant response bias for neutral images, $t(31) = .71$, $p = .481$.

Drift rates. Analysis of the absolute drift rates revealed a significant main effect of status on drift, $F(1, 31) = 37.224$, $p < .001$, MSE = 63.152, $\eta^2 = .546$, such that targets (M = .685) had lower drift rates than distractors (M = 1.832). There was also a main effect of valence on drift, $F(2, 62) = 5.608$, $p = .006$, MSE = .795, $\eta^2 = .153$, such that negative items (M = 1.132) had significantly smaller drift that neutral (M = 1.341) and positive (M = 1.304) items. The status x valence interaction also observed in the matched group analysis was again significant, $F(2, 62) = 6.203$, $p = .004$, MSE = .004, $\eta^2 = .167$, indicating a valence effect on distractor drift but not target drift. Drift rates for neutral distractors (M = 2.103) were significantly larger than drift rates for positive distractors (M = 1.816) and negative distractors (M = 1.578).

Conclusions

The patterns observed in the analyses of the matched groups were largely replicated in the analysis of the excluded participants. There were no effects of valence on memory sensitivity (d'), but there were valence effects on reaction time. Valence also affected response bias, and drift rate similar to what was seen in the analyses with the matched groups. Overall, these findings confirm that the included and excluded non-players showed identical patterns, alleviating concerns about selection bias.

Appendix C

Bivariate correlations were calculated for the entire sample (N =122) to look at relationships between the personality assessments and the diffusion modelling parameters. Although the personality scores did not correlate significantly with any of the diffusion parameters, some interesting correlations between diffusion parameters emerged.

The positive correlations between response bias and distractor drift (but not target drift) suggest that participants with high distractor drift (i.e., those who were good at identifying new items) also tended to display a response bias favouring "old" responses.

Correlations between diffusion parameters drift and response bias.

	v_{new}_neg	v_{new}_neu	v_{new} _pos	v_{old}_neg	v_{old}_neu	v_{old}_pos
*z/a*_neg	.494**	.330**	.398**	-.085	-.010	.089
*z/a*_neu	.138	.641**	.231**	.115	-.157	.045
*z/a*_pos	.207**	.361**	.592**	.216**	.099	-.095

Note. ***p* < .01. The v_{new} values are sign reversed (i.e. absolute values). *z/a* is the response bias calculation.

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