

Children's Brain Activations While Viewing Televised Violence Revealed by fMRI

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Running Head: TV violence and fMRI

Date Submitted: September 23, 2004. Revised: April 27, 2005.

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## Abstract

While social and behavioral effects of TV-violence have been studied extensively, the brain systems involved in TV violence viewing in children are, at present, not known. In this study, eight children viewed televised violent and nonviolent video-sequences while brain activity was measured with fMRI. Both violent and nonviolent viewing activated regions involved in visual motion, visual object/scenes, and auditory listening. However, viewing TV violence selectively recruited a network of right-hemisphere regions including precuneus, posterior cingulate, amygdala, inferior parietal, prefrontal and premotor cortex. Bilateral activations were apparent in hippocampus, parahippocampus and pulvinar. TV violence viewing transiently recruits a network of brain regions involved in the regulation of emotion, arousal/attention, episodic memory encoding and retrieval, and motor programming. This pattern of brain activations may explain the behavioral effects observed in many studies, especially the finding that children who are frequent viewers of TV violence are more likely to behave aggressively. Such extensive viewing may result in a large number of aggressive scripts stored in long-term memory in the posterior cingulate, which facilitates rapid recall of aggressive scenes that serve as a guide for overt social behavior.

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### Introduction

Concerns about the impact of TV violence on children have been addressed in social and behavioral science research for almost 50 years (Murray, 1973; Murray, 1980; Pecora, Murray, & Wartella, 2006). Three main classes of behavioral effects that have been demonstrated over this half-century of research are increased aggression, desensitization and fear (Murray, 1998; 2000). Behavioral studies have demonstrated that TV violence, in combination with the associated fast action and excitement, holds attention to the screen and is emotionally arousing for children and adults (Bandura, 1994; Berkowitz, 1984; Huston, et al., 1992). Studies with children (Ekman, et al., 1972) have shown that children's expression of emotional arousal or interest while viewing video violence was related to higher levels of aggression in subsequent play interactions.

Recently interest in the neurobiological causes of violence and aggressive behavior has expanded (Blumstein, 2000; Davidson, et al., 1990; 1999; 2000; Panksepp, 1998). A key circuit proposed to be associated to increased propensity for impulsive aggression and violence includes bilateral projections between orbital and dorsolateral prefrontal cortex (PFC), amygdala, and anterior cingulate cortex (Davidson, et al., 2000). Abnormalities in this limbic-cortical network are associated with failures of emotion regulation (Davidson, et al., 2000; Mayberg, et al., 1999; Liotti, et al., 2000). Prefrontal cortex has been associated to aggressive behavior by the finding that: a) patients with aggressive impulsive personality disorder have an absent response in PFC and ACC to serotonin challenge with fenfluramine (Siever, et al., 1999; Volkow, et al., 2000); b)

lesions in ventral prefrontal cortex result in released control of impulsive and aggressive behavior (Davidson, et al., 2000); c) neuroimaging evidence of hypoactivation of lateral and medial PFC, and hyperactivation of right hemisphere subcortical structures including amygdala, hippocampus, thalamus and midbrain in individuals with impulsive aggressive behavior compared to age- and sex-matched controls (Raine, et al., 1997; 1998). The amygdala is a phylogenetically old structure critically involved in learning the association between stimuli and primary punishers and rewards (Rolls, 1999). In human neuroimaging studies, the amygdala is associated with stimuli communicating threat, such as fearful faces (Breiter, et al., 1997; Whalen, et al., 1997; Morris, et al., 1997; 1999). There is convergent evidence that PFC and amygdala mutually inhibit each other, with PFC lesions resulting in release of amygdalar function (review in Davidson, 2000). In addition, there is a large body of evidence involving a distributed cortico-subcortical right hemispheric network in various aspects of emotional processing, including perception, expression and subjective states (see reviews in Liotti & Tucker, 1995).

The brain systems activated by TV violence viewing in children are, at present, not known. In the current study, we hypothesized that the same circuits involved in the regulation of emotion and the control of aggression may also be transiently active in children simply *viewing* TV violence relative to viewing non-violent televised scenes.

## Methods

*Screening session.* Forty 8-to-12-year-old children from a local school (20 boys, 20 girls), without known behavioral disturbances, participated in a screening session, with parental permission and informed consent. Subjects were shown the televised violent videotape segments while various physiological measures were recorded. Based on heart rate, we identified two patterns of physiological response to TV violence: acceleration vs. deceleration. In the present

fMRI study, we focused on accelerators, because it was the prevailing response; it likely identified children more responsive to TV violence; and it allowed for greater homogeneity in the group. Fifteen HR accelerators were selected and invited to participate to the experimental session.

*fMRI session.* Seven children were not included in the final analysis because of failure to complete the MRI session or excessive head motion. Eight children (5 boys, 3 girls, 9-13 years old) composed the final sample. Stimuli consisted of two, three-minute video-sequences of violent (two boxing scenes from *Rocky IV*, a PG-rated movie broadcast on commercial TV), two nonviolent (*Ghostwriter*, a PBS children's program, and a National Geographic animal program for children) video sequences, and two visual fixation condition (a static X on a blue screen) video sequences, presented in succession while the children were supine in the MRI scanner. The stimuli were projected into the bore of the scanner and onto a back projection screen placed 5 inches above the subject's eyes through a LCD projector (Sharp XV-H30U), a focus lens, and a reflection mirror. In addition, children listened to the audio track via headphones closely fitted to their ears. Heart Rate was recorded throughout the MRI scanning session using a pulse-oximeter. Subjective ratings of subjects' reactions to the violent videoclips were taken at the end of the session.

The study was performed on an Elscint Gyrex 2-T whole-body MRI scanner operating at 1.5 T. We conducted whole-brain (18-22 slices) echoplanar fMRI (time of echo [TE] =45 msec, time of repetition [TR] =9 sec, flip angle=90 deg, slice thickness=6mm) throughout the 18 minutes of viewing. There were two cycles of the three tasks. Order of presentation was randomized across subjects, with the exception that the two Violent trials were always adjacent to each other to avoid spillover effects. There was a total of 20 images per task per cycle (120

images per subject). Structural MRI images (T1-weighted, aMRI) were acquired after the completion of the viewing period.

Both the fMRI and aMRI images were normalized to Talairach space (Talairach and Tournoux, 1988). Statistical analyses were conducted with task-induced BOLD (blood oxygenation-level dependent) changes detected using a conventional voxel-wise statistical parametric mapping method. Each voxel in each averaged set of TV Violence, TV Nonviolence, and Fixation image pairs for each subject was subjected to a Student's paired t-test, across the group of eight subjects ( $p < .01$ , two-tailed,  $t\text{-value} = \pm 3.5$  with  $df = 7$ , uncorrected).

## Results

*Physiological Measures.* Heart Rate mean values were statistically different between Violent vs. NonViolent videos (75.2 bpm vs. 71.8 bpm),  $p < .01$ .

*fMRI results.* Results of the contrasts of Violence viewing minus Fixation, and Nonviolence viewing minus Fixation, revealed patterns of activation expected on the basis of previous hemodynamic studies involving similar types of visual and auditory stimulation. Both types of TV viewing produced robust activations of extrastriate visual cortex, including cuneus medially (BA18), MT/V5 laterally (visual motion), and fusiform gyrus inferiorly (visual object/scenes), as well as the auditory association cortex (auditory discrimination). Of relevance here is the fact that such activations were largely canceled out in the Violence minus Nonviolence contrast that was designed to isolate the effects of Violence viewing (see, Figure 1, right side).

----- (Insert Figure 1 and 2 here) -----

Of greater interest here are the results of the Violence minus Nonviolence contrast -- which identify TV violence viewing effects. Significant violence-related activations were

present in all cerebral lobes, with a striking right hemisphere predominance (see Table 1 and Figure 3). The major right hemisphere activations included the limbic system, parietal lobe, temporal lobe, and to a lesser extent, the frontal lobe.

----- (Insert Table 1 here) -----

As can be seen in Figure 2, the strongest effects associated with TV violence were in right precuneus (BA7) and posterior Cingulate cortex (BA31/23), bilateral posterior thalamus (Pulvinar nucleus), bilateral hippocampal formation (right greater than left), bilateral parahippocampal gyri (BA30/35/36), right amygdala, right superior premotor cortex, both medial and lateral (BA6/8), right precentral gyrus (motor BA4), right dorsolateral prefrontal (BA9) and right inferior parietal cortex (BA40).

----- (Insert Figure 3 here) -----

## Discussion

The pattern of activations observed strongly implicates known brain networks in viewing televised violence, with a considerable overlap with regions involved in emotional processing of threatening and arousing stimuli. First, the total volume of significant activations in limbic, paralimbic and association neocortex was considerably larger in the right hemisphere, confirming the prediction that TV violence viewing recruits paralimbic and neocortical association regions involved in emotional processing (Etcoff, 1989; Borod, et al., 1988; Ross, 1981; Mesulam, 1999; Bear, et al., 1983; Adolphs, et al., 2000; Raine, et al., 1997). The strongest activations were found in the right precuneus (BA7) and in the right posterior

Cingulate (BA31). The precuneus has been implicated in several studies of episodic memory retrieval for both words and pictures (Shallice, et al., 1994; Fletcher, et al., 1995; Buchner, et al., 1996; McDermott, et al., 1999). This was first explained by the role of visual imagery as mnemonic strategy. However, recently, precuneus involvement in episodic memory retrieval has been demonstrated independent of imagery content or stimulus modality (Krause, et al., 1999).

Activation of right posterior cingulate cortex is consistent with recent evidence of its role in episodic memory retrieval and in the processing of aversive emotional stimuli, including watching emotion-generating videoclips or emotional pictures (Lane, et al., 1999) or listening to threat-related words (Maddock, 1999). The posterior cingulate cortex is reciprocally connected to parahippocampal gyrus and entorhinal cortex on one side, and both dorsolateral and orbital frontal cortex and precuneus on the other, leading to a proposed role in emotional episodic memory (Maddock, 1999).

The participation of the pulvinar nuclei in TV violence viewing is explained by the role of this region in the detection of external visual salience, including emotional salience, as indicated by activations of the pulvinar to fearful faces (Morris, et al., 1997), and its significant covariance with the right amygdala during the presentation of fearful faces (Morris, et al., 1999). The finding of a significant activation of the striate and extrastriate visual cortex may be related to some residual activation caused by a minor mismatch of stimulus rate, or it may be explained by attentional enhancement of visuo-spatial processing in the visual cortex during TV violence viewing. In support of the latter interpretation, similar activations in extrastriate visual cortex have been reported in PET (Positron Emission Tomography) studies comparing viewing emotional to neutral pictures (Lane, et al., 1999; Lang, et al., 1998).

The activation of the right amygdala in TV violence is consistent with its recognized function of signaling threat in the external environment, as revealed by animal and human



studies of fear conditioning and perception of fearful faces, and its specific role in emotional memory (Ledoux, 1996; Adolphs, et al., 1994; Morris, et al., 1996; Breiter, et al., 1996; Hamann, et al., 1999). It is worth noting that metabolism was found significantly elevated in the right amygdalar region in impulsive aggressive individuals (Raine, et al., 1997).

The activation of the hippocampi and parahippocampal gyri is consistent with the role of these structures in episodic memory encoding, with the right side particularly involved in the encoding of new perceptual information about the appearance and layout of scenes (Aguirre, et al., 1996; Epstein, et al., 1999). These findings suggest greater memory encoding during TV violence, although recall or recognition for the details of the videoclips were not performed in this study. Activations in the right dorsolateral prefrontal cortex (BA9) and inferior parietal cortex (BA40) are consistent with the role of these regions in the control of externally-directed attention and vigilance/alertness (Mesulam, et al., 1991; 1999; Pardo, et al., 1990; Corbetta, et al., 1993).

A final result that deserves comment is the finding of premotor and motor activations in TV violence viewing -- more pronounced on the right, including the dorsomedial premotor (SMA), dorsolateral, and inferior lateral premotor cortex, and precentral gyrus (BA4). The best interpretation of these findings comes from recent evidence that action or tool observation in monkeys and humans produces activation of premotor cortex and even primary motor cortex, suggesting that action recognition may take place in premotor cortex (Rizzolatti & Arbib, 1998).

Because emotional arousal has such a central role in social and behavioral studies and theories of the effects TV violence (Murray, 1994; 1998; 2003; Zillmann, 1971; 1982; Zillmann & Bryant, 1994), the violent and non-violent videoclips were deliberately chosen to reflect differences in arousal level (high arousal in TV-violence, low-arousal in non-violence).

Accordingly, heart rate significantly increased while viewing the violent relative to nonviolent videos, confirming that TV violence viewing was accompanied by more emotional arousal.

Dimensional accounts of emotion emphasize the importance of arousal in perceived emotion (Lang, 1994). Recent lesion-correlation findings and neuroimaging in healthy volunteers confirm that some brain regions appear to respond to negative arousal rather to the type of emotion (Adolphs, et al., 1996; Lane, et al., 1999). A recent PET study in young adults directly compared the level of perceived arousal (calm vs. excited) in emotional picture sets. Regional changes included extrastriate cortex, anterior temporal cortex, amygdala, thalamus and right prefrontal cortex BA9 (Lane, et al., 1999). The partial overlap of results with our findings confirms that TV violence viewing taps into a network of brain regions involved in emotional arousal. Emotional arousal has been found to heighten sensitivity to environmental cues related to the motivational state induced by the provoking stimulus, particularly for stimuli with inherent significance for survival (Lane, et al., 1999).

It could be argued that the effects of TV-violence in our study were *entirely* due to differences in levels of emotional arousal between Violent and Non-Violent videoclips. However, the strongest effects of TV violence (precuneus, posterior cingulate cortex, hippocampi and parahippocampi) were not present in the Lane, et al. (1999) study. More importantly, the latter findings are experimentally associated in the literature with brain regions subserving episodic memory encoding and retrieval, suggesting that TV violence viewing in children is associated to *specific* changes in known substrates of long-term memory.

## Conclusions

The present pattern of results may suggest five conclusions -- TV violence viewing in children: 1) is emotionally arousing; 2) leads to activation of a network of regions involved in attention/arousal/salience; 3) recruits a phylogenetically-old brain system involved in the

detection of fear/threat in the environment; 4) is accompanied by activation of limbic and neocortical systems likely to be involved in the episodic encoding and retrieval of the environmental context associated with such threat; and 5) is accompanied by activation of premotor regions possibly involved in the programming of motor plans (fight or flight).

The relevance of these findings resides in the demonstration that while the child may not be aware of the threat posed by TV violence at a conscious level, and may even perceive it as interesting and arousing, a more primitive system within his/her brain (amygdala, pulvinar) may not discriminate between real violence and entertainment fictional violence, suggesting that TV violence may act at a preconscious level. Proof that this may be the case is provided by a recent study showing that masked (not consciously seen) fearful faces activate the same right-amygdala-pulvinar circuit present in our study (Morris, et al., 1999). Second, the simple act of *viewing* TV violence appears to transiently activate a network of right-lateralized regions which are hyperactive in the resting state of individuals with impulsive aggressive behavior (Raine et al, 1997). Moreover, the strong activation of long-term memory systems during TV violence viewing (precuneus, posterior cingulate, hippocampus and parahippocampus, amygdala) may suggest that the impact of TV violence viewing on brain function may extend in time *beyond* the simple act of viewing TV violence.

Thus, one general conclusion from this study is the suggestion that the human brain does not distinguish between real life violence and the so-called “fantasy” or “entertainment” violence. Although the children in this study were aware that they were watching “entertainment” violence in the form of Sylvester Stallone as “Rocky” the famous movie character, their brains responded to the violence as real and perceived the threat. In the past, some have argued that there are many different forms of violence, even suggesting the concept of “positive violence” where the aggressor is fighting for a ‘just cause’ or to avenge a wrong. Our results suggest that there is

only one type of violence and it is universally perceived by the human brain as a threat to the survival of the organism.

This study was conducted in a small sample of healthy children, using only one type of violence (male-to-male physical violence), and did not include a higher-order non-violent comparison task matched for arousal level (such as viewing a car race or a basketball game). Future investigations will have to address other factors likely affecting the brain response to TV violence, including gender, age of the viewer, type of violence portrayed, and vulnerability of the viewer (e.g., victims or perpetrators of violence), and will include measures of later memory recall or recognition to directly address behavioral effects of TV violence exposure. Indeed, we are developing such studies at Harvard Medical School's Center on Media and Child Health at Children's Hospital Boston. However, the results of the present study provide the first, preliminary, neuroimaging evidence of the effects of viewing TV violence in children that also explain the extensive findings from prior research on social behavior.

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### Acknowledgements

Thanks to John Wright, Ellen Wartella, and Aletha Huston of the University of Texas at Austin and Catherine Cook, Elizabeth Costello and Joseph Dial of the Mind Science Foundation at San Antonio for their assistance in developing this research program. Betty Heyl, Diana Martinez-Fonts and Emily Juen provided outstanding assistance on this project. Finally, thanks to the children, parents and teachers at the San Antonio schools, Saint Mary's Hall and Saint Anthony's Academy, who participated in or supported this study. This research was funded by a grant from the Mind Science Foundation of San Antonio.

### Legend Figures

Figure 1 -- Significant group average changes in BOLD signal in the Violence vs. Fixation (left), Nonviolence vs. Fixation (center), and Violence vs. Nonviolence (right). Cut-off  $t(7)=\pm 3.5$ ,  $p<0.01$ . Horizontal views overlaid on group average T1 images.

L and R= Left and Right Hemisphere. Note the near cancellation of visual and auditory activations in the Violence minus Nonviolence contrast.

Figure 2 -- Main significant group average changes in BOLD signal in the Violence minus Nonviolence t-score image. Cut-off  $t(7)=\pm 3.5$ ,  $p<0.01$ , uncorrected. Horizontal axial views are overlaid on group average T1 images.

Figure 3 -- Total volume of activated voxels (in  $\text{cm}^3$ ) for Violence vs. Nonviolence, for each cerebral lobe and hemisphere. BOLD increases only. Cut-off  $t(7)=\pm 3.5$ ,  $p<0.01$ , uncorrected. Note the overall prevalence of right-hemispheric activations.

### Legend Table

Table 1 -- Significant changes in BOLD signal in the Violence vs. Nonviolence. Activations only. Main effects:  $t(7)=7.0$ ,  $p<0.001$ , uncorrected. Other effects:  $t(7)=4.5$ ,  $p<0.01$ , uncorrected. X,Y,Z are coordinates in mm from the anterior commissure (Tallarach and Tournoux, 1988). BA=Brodmann Area.