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

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Though 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, 8 children viewed televised violent and nonviolent video sequences while brain activity was measured with functional magnetic resonance imaging. Both violent and nonviolent viewing activated regions involved in visual motion, visual object and scenes, and auditory listening. However, viewing TV violence selectively recruited a network of right hemisphere regions including precuneus, posterior cingulate, amygdala, inferior parietal, and 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 and 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.

Concerns about the impact of TV violence on children have been addressed in social and behavioral science research for almost 50 years (Murray, 1973, 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, Abercrombie, Nitschke, & Putnam, 1999; Davidson et al., 1990; Davidson, Putnam, & Larson, 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; Liotti et al., 2000; Mayberg et al., 1999). Prefrontal cortex has been associated with aggressive behavior by the finding that (a) patients with aggressive impulsive personality disorder have an absent response in PFC and anterior cingulate cortex (ACC) serotonin challange 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); and (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, Buchsbaum, & LaCasse, 1997; Raine et al., 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., 1996; Morris, Friston, & Dolan, 1997; Morris, Ohman, & Dolan, 1999; Whalen et al., 1998). 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 this 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 nonviolent 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. Participants 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 versus deceleration. In this functional magnetic resonance imaging (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 heart rate (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 3 min video sequences of violent (two boxing scenes from *Rocky IV*, a PG-rated movie broadcast on commercial TV), and 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 participants's eyes through a LCD projector (Sharp XV-H30U, Osaka, Japan), 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 participants' reactions to the violent video clips 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 min of viewing. There were two cycles of the three tasks. Order of presentation was randomized across participants, 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 participant). Structural MRI images (T1-weighted, anatomical MRI) were acquired after the completion of the viewing period.

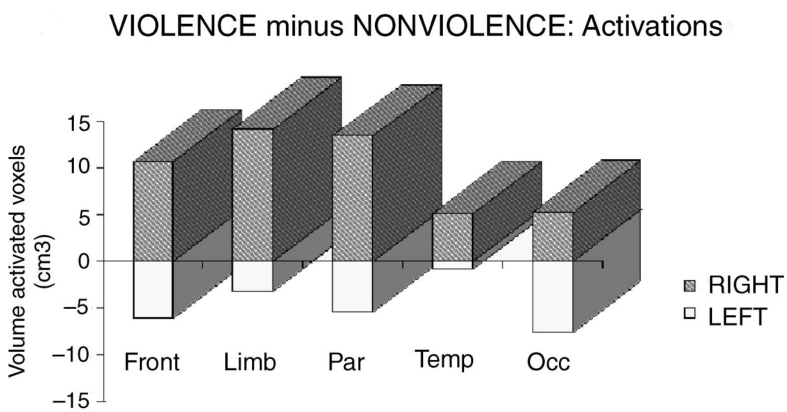

FIGURE 1 Total volume of activated voxels (in cm^3) for Violence versus Nonviolence, for each cerebral lobe and hemisphere. Blood oxygenation-level dependent increases only. Cut-off t 7 = ±3.5, p < .01, uncorrected. See the overall prevalence of right-hemispheric activation. *Note.* L= left hemisphere; R = right hemisphere; Front = frontal lobe; Limb = limbic; Par = parietal; Temp = temporal; Occ = Occipital.

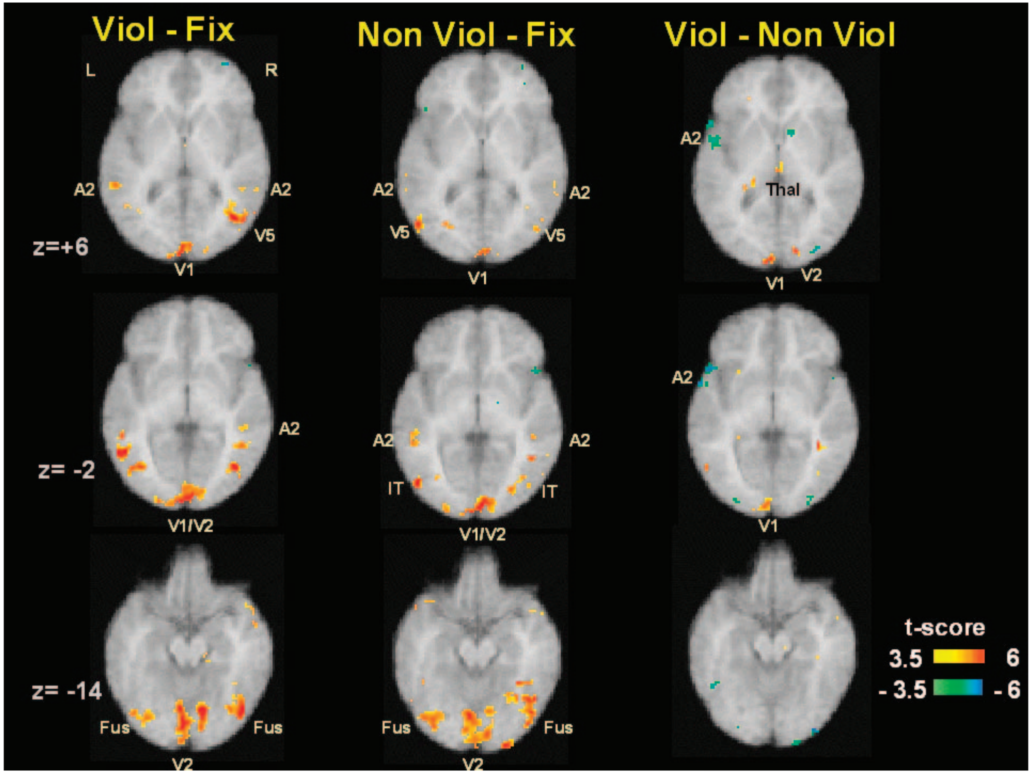

FIGURE 2 Significant group average changes in blood oxygenation-level dependent signal in the Violence versus Fixation left, Nonviolence versus Fixation center, and Violence versus Nonviolence right. *Note.* Cut-off t 7 = ±3.5, $p < .01$. Horizontal views overlaid on group average T1 images. See the near cancellation of visual and auditory activations in the Violence minus Nonviolence contrast. L = left hemisphere; R = right hemisphere; V1 = primary visual area; V2 = secondary visual area; V5 = motion area; Fus = fusiform gyrus (object area); A2 = secondary auditory area; Thal = thalamus.

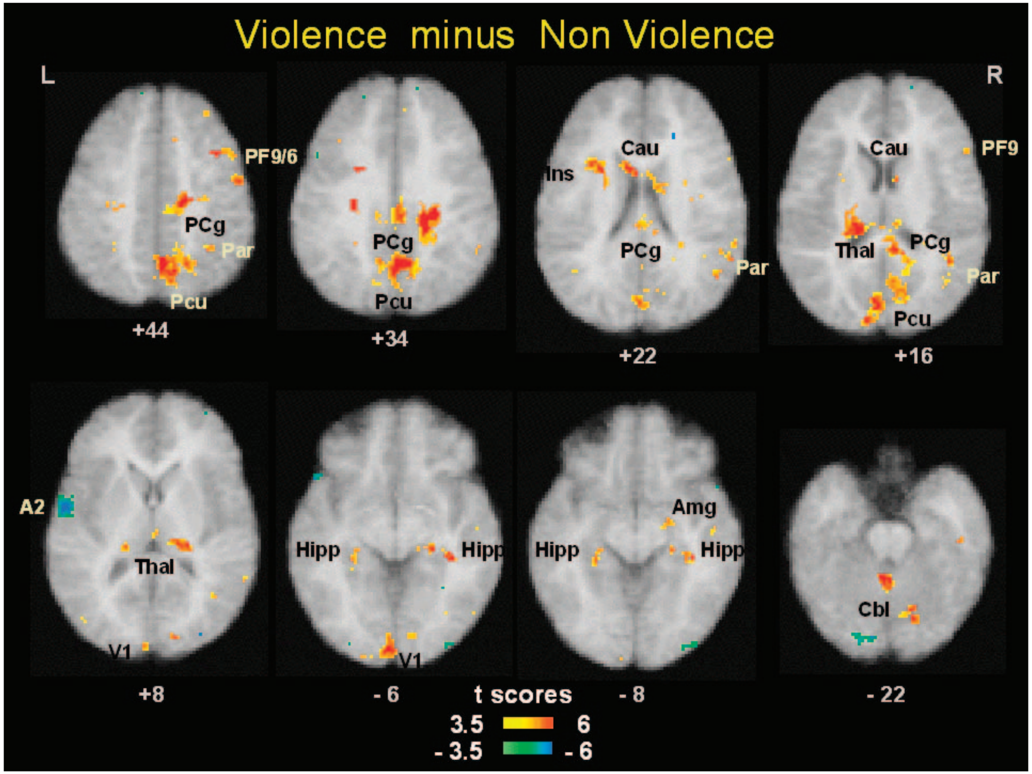

FIGURE 3 Main significant group average changes in blood oxygenation-level dependent signal in the Violence minus Nonviolence t score image. Cut-off t 7 = ±3.5, $p < .01$, uncorrected. Horizontal axial views are overlaid on group average T1 images. *Note.* L= left hemisphere; R = right hemisphere; A2 = secondary auditory area cortex; V1 = primary visual area; Thal = thalamus; PcU = precuneus; PCg = posterior cingulate; PF9/6 = prefrontal cortex 9/6; Ins = insula; Cau = caudate nucleus; Par = parietal lobe; Hipp = hippocampal region; Amg = amygdala; Cb1 = cerebellum.

Both the functional MRI (fMRI) and the anatomical MRI (aMRI) images were normalized to Talairach space (Talairach & Tournoux, 1988). Statistical analyses were conducted with task-induced 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 participant was subjected to a student's paired *t* test across the group of eight participants ($p < .01$, two-tailed, t value = ±3.5, $df = 7$, uncorrected).

RESULTS

Physiological Measures

Heart rate mean values were statistically different between Violent versus Nonviolent videos (75.2 beats per min vs. 71.8 beats per min), $p < .01$.

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 activation of extrastriate visual cortex, including cuneus medially (BA 18), MT/V5 laterally (visual motion), and fusiform gyrus inferiorly (visual object or scenes), as well as the auditory association cortex (auditory discrimination). Of relevance here is the fact that such activation was largely canceled out in the Violence minus Nonviolence contrast that was designed to isolate the effects of Violence viewing (see Figure 1, right side).

Of greater interest are the results of the Violence minus Nonviolence contrast, which identify TV violence viewing effects. Significant violence-related activation was present in all cerebral lobes, with a striking right hemisphere predominance (see Table 1 and Figure 3). The major right hemisphere activation included the limbic system, parietal lobe, temporal lobe, and to a lesser extent, the frontal lobe.

As can be seen in Figure 2, the strongest effects associated with TV violence were in right precuneus (BA 7) and posterior Cingulate cortex (BA 31,23), bilateral posterior thalamus (Pulvinar nucleus), bilateral hippocampal formation (right greater than left), bilateral parahippocampal gyri (BA 30, 35, 36), right amygdala, right superior premotor cortex, both medial and lateral (BA 6, 8), right precentral gyrus (motor BA 4), right dorsolateral prefrontal (BA 9), and right inferior parietal cortex (BA 40).

TABLE 1
Significant Changes in Blood Oxygenation-Level Dependent Signal in the Violence Versus Nonviolence (Activations Only)

Hem	*Gyr*	*BA*	*x*	*y*	*z*	*ext-mm3*	*t Score*	*p*
Main effects*								
Limbic lobe								
R	PCing	BA 31	20	–29	35	2208	14.14	0
R	PCing	BA 31	18	–19	43	1784	11.31	0
R	PCing	BA 30	4	–37	17	1008	8.48	.0006
R	Hipp		37	–33	–6	608	8.48	.0006
R	Hipp		25	–28	–5	432	7.07	.0016
Frontal lobe								
L	MFG	BA 8, 9	–38	12	41	480	8.48	.0006
L	SFG	BA 8	–27	34	51	696	7.07	.0016
R	SFG	BA 6	31	19	55	1360	8.48	.0006
R	SFG	BA 8	40	18	48	512	8.48	.0006
Parietal lobe								
R	Pcu	BA 7	5	–58	37	3392	22.62	0
R	Pcu	BA 7	11	–66	41	1680	8.48	.0006
R	Pcu	BA 7	20	–59	44	1408	7.07	.0016
L	GPoc	BA 2	–55	–20	27	416	8.48	.0006
R	LPi	BA 40	27	–27	34	1032	8.48	.0006
R	LPi	BA 40	27	–41	30	1608	8.48	.0006
Temporal lobe								
R	MTG	BA 39	38	–48	–2	600	8.48	.0006
Occipital lobe								
R	Cu	BA 17	15	–88	6	736	8.48	.0006
L	Ling	BA 17	–2	–92	–4	1560	8.48	.0006
L	Cu	BA 17	–1	–79	16	2056	8.48	.0006
Thalamus								
L	Pulv		–14	–31	15	1400	9.89	.0001
R	Pulv		23	–30	8	888	7.07	.0016
Basal ganglia								
R	Caud		9	1	18	680	11.31	0
L	Caud		–20	–1	23	824	8.48	.0006
L	Caud		–21	–33	14	416	7.07	.0016
Cerebellum								
L	Cbll		–1	–48	–22	520	11.31	0
R	Cbll		48	–58	–31	752	12.72	0
R	Cbll		45	–63	–37	688	8.48	.0006
R	Cbll		16	–73	–23	1280	11.31	0
R	Cbll		20	–66	–27	472	7.07	.0016

(continued)

TABLE 1 *(Continued)*

Hem	*Gyr*	*BA*	*x*	*y*	*z*	*ext-mm3*	*t score*	*p*
Other Effects**								
Limbic								
R	Amygd		22	–10	–8	304	4.52	.0091
L	Hipp		–25	–37	2	328	5.65	.0048
L	GH	BA 35	–24	–35	–7	472	5.65	.0048
R	GH	BA 27	16	–28	–5	256	4.24	.005
R	ACing	BA 24	11	4	37	160	5.65	.0048
R	ACing	BA 32	1	4	38	624	5.65	.0048
R	AIns		33	–5	21	928	4.24	.005
Nonlimbic								
R	STG	BA 39	49	–59	20	1344	5.65	.0048
R	STG	BA 22	43	–51	16	840	5.65	.0048
R	Front	BA 9	7	41	27	336	5.65	.0048
L	Prem	BA 6	–31	5	60	1680	5.09	.005
R	GPrC	BA 6	10	–18	49	928	4.71	.008

Note. Main effects: $t(7) = 7.0, p < .001$, uncorrected. Other effects: $t(7) = 4.5, p < .01$, uncorrected. x,y,z are coordinates in mm from the anterior commissure (Tailarach & Tournoux, 1988). Hem = Hemisphere. Gyr = Gyrus. BA = Broadmann Area. R = right. L = left.

*$p < .001$. **$p < .01$.

DISCUSSION

The pattern of activation 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 activation 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 (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Bear, 1983; Borod et al., 1988; Etcoff, 1989; Mesulam, 1999; Raine et al., 1997; Ross, 1981). The strongest activations were found in the right precuneus (BA 7) and in the right posterior cingulate (BA 31). The precuneus has been implicated in several studies of episodic memory retrieval for both words and pictures (Buckner et al., 1996; Fletcher et al., 1995; McDermott et al., 1999; Shallice et al., 1994). 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 video clips or emotional pictures

(Lane, Chua, & Dolan, 1999), or listening to threat-related words (Maddock, 1999). The posterior cingulate cortex is reciprocally connected to parahippocampal gyrus and enthorinal 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 activation 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 positron emission tomography (PET) 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 (Adolphs, Tranel, Damasio, & Damasio, 1994; Breiter et al., 1996; Hamann, Ely, Grafton, & Kilts, 1999; LeDoux, 1996; Morris et al., 1996). 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, Detre, Alsop, & D'Esposito, 1996; Epstein, Harris, Stanley, & Kanwisher, 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. Activation in the right dorsolateral prefrontal cortex (BA 9) and inferior parietal cortex (BA 40) are consistent with the role of these regions in the control of externally-directed attention and vigilance/alertness (Corbetta, Miezin, Shulman, & Petersen, 1993; Mesulam, 1999; Pardo et al., 1991).

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, dorsolateral, and inferior lateral premotor cortex, and precentral gyrus (BA 4). 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 of TV violence (Murray, 1994, 1998, 2003; Zillmann, 1971, 1982; Zillmann & Bryant, 1994), the violent and nonviolent video clips were deliberately chosen to reflect differences in arousal level (high arousal in TV violence, low arousal in nonviolence). 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, Damasio, Tranel, & Samasio, 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 BA 9 (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 Nonviolent video clips. 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 important, 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

This pattern of results may suggest five conclusions: TV violence viewing in children (a) is emotionally arousing; (b) leads to activation of a network of regions involved in attention, arousal, and salience; (c) recruits a phylogenetically-old brain system involved in the detection of fear or threat in the environment; (d) 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 (e) 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 though 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 or 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 (Morris et al., 1999) showing that masked (not consciously seen) fearful faces activate the same right amygdala–pulvinar circuit present in our study. Second, the simple act of viewing TV violence appears to transiently activate a network of right lateralized regions that 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, and 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 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 (man-to-man physical violence), and did not include a higher order nonviolent 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 this 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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