Reduced prefrontal and temporal processing and recall of high "sensation value" ads

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ABSTRACT

Public service announcements (PSAs) are non-commercial broadcast ads that are an important part of televised public health campaigns. "Message sensation value" (MSV), a measure of sensory intensity of audio, visual, and content features of an ad, is an important factor in PSA impact. Some communication theories propose that higher message sensation value brings increased attention and cognitive processing, leading to higher ad impact. Others argue that the attention-intensive format could compete with ad's message for cognitive resources and result in reduced processing of PSA content and reduced overall effectiveness. Brain imaging during PSA viewing provides a quantitative surrogate measure of PSA impact and addresses questions of PSA evaluation and design not accessible with traditional subjective and epidemiological methods. We used Blood Oxygenation Level Dependent (BOLD) functional Magnetic Resonance Imaging (fMRI) and recognition memory measures to compare high and low MSV anti-tobacco PSAs and neutral videos. In a short-delay, forced-choice memory test, frames extracted from PSAs were recognized more accurately than frames extracted from the NV. Frames from the low MSV PSAs were better recognized than frames from the high MSV PSAs. The accuracy of recognition of PSA frames was positively correlated with the prefrontal and temporal, and negatively correlated with the occipital cortex activation. The low MSV PSAs were associated with greater prefrontal and temporal activation, than the high MSV PSAs. The high MSV PSAs produced greater activation primarily in the occipital cortex. These findings support the "dual processing" and "limited capacity" theories of communication that postulate a competition between ad's content and format for the viewers' cognitive resources and suggest that the "attention-grabbing" high MSV format could impede the learning and retention of an ad. These findings demonstrate the potential of using neuroimaging in the design and evaluation of mass media public health communications.

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Introduction

Public service announcements (PSAs) are non-commercial broadcast ads intended to modify public behavior. Televised PSAs are at the core of many public health campaigns. When effective, PSAs carry a great public health benefit (Biener et al., 2000; Emery et al., 2007), however, not all are (Wakefield et al., 2006). The lack of reliable, quantitative and objective means of ad evaluation is one of the impediments to better PSA outcomes. Integrating conceptual contributions from the communication theory with experimental neuroscience methods could provide objective and quantitative measures of PSA evaluation and facilitate targeted ad design.

Prior functional magnetic resonance brain imaging (fMRI) studies of commercial advertising examined the brain response to specific components of ads, such as popular commercial logos. (Erk et al., 2002; McClure et al., 2004). This approach provides information on the public perception of existing consumer brands but not the fundamental issue of the neurophysiologic and behavioral impact of the format in which ad's message is presented.

"Message sensation value" (MSV), is a validated, rater-derived variable of message format that may affect PSA impact and outcomes (Harrington et al., 2003; Palmgreen et al., 1991; Petty and Cacioppo, 1986; Stephenson and Southwell, 2006). MSV reflects the intensity of audio, visual, and content features of PSAs that elicit sensory, affective, and arousal responses (Morgan, 2003; Palmgreen et al., 2002). Higher MSV in anti-smoking PSAs has been associated with increased subjective efficacy in some but not all studies (D'Silva and Palmgreen, 2007; Helme et al., 2007); however, the dose–response relationship and the generalizability of this effect have not been established. Similar approaches are used in commercial advertising, with the sensory salience of ads often outpacing the message.

This empirical strategy assumes that engaging the stimulus-driven, exogenous attention system (i.e. "buying the eyeballs", (Chattopadhyay and Laborie, 2005; Russell and Belch, 2005)), increases cognitive processing of the content. Contrary to this assumption, experimental

brain imaging data on "divided attention" and post-exposure PSA outcome measures suggest that high MSV strategies do not invariably translate to learning or subsequent behavior change (Indovina and Macaluso, 2007; Kang et al., 2006). Moreover, some studies suggest that stimuli engaging the exogenous attention system may be associated with less learning, recall (Hahn et al., 2006; Uncapher and Rugg, 2005), and prefrontal and temporal activity (Foerde et al., 2006) than those engaging the internally regulated endogenous attention system.

Tobacco use is one of the gravest preventable public health problems worldwide (IOM, 2007) and a target of a large number of PSAs, making the anti-tobacco PSAs representative of the public health PSAs genre (Ibrahim and Glantz, 2007; Wakefield et al., 2005). Our primary objective was to characterize the brain systems sensitive to MSV, the key theoretical concept of public health communications thus making the first step toward the integration of the communications theory and experimental neuroscience. We hypothesized that compared to the high MSV (hiMSV) PSA, the low MSV (loMSV) PSA will produce greater BOLD fMRI signal in the brain regions mediating attention and memory, while the hiMSV PSA will produce greater activation in the brain regions mediating visual processing than the loMSV PSA. Our secondary objective was to demonstrate the brain systems activated during the viewing of a 30-second long PSA. We hypothesized that PSA will produce greater BOLD fMRI signal in the brain regions mediating attention and memory, than non-PSA neutral video segments (NV).

Methods

Study protocol was approved by the University of Pennsylvania Institutional Review Board. The participants were 18 regular smokers ($M = 13$ cigarettes per day, $SD = 5.14$), 18 to 48 years old ($M = 23$, $SD = 7$; 15M; 3F), recruited through advertising. Mean nicotine dependence level (Fagerstrom Test for Nicotine Dependence (Pomerleau et al., 1994) was 2.17, $SD = 1.89$ (on a scale of 1 to 10).

Ninety-nine 30-second long PSAs targeting adult smokers (Centers for Disease Control and Prevention, USA) produced prior to 2002, were rated for MSV following a previously reported and validated rating procedure (Morgan, 2003; Strasser et al., 2009). Briefly, the MSV variables are visual (cuts, edits, special effects, motion change, vivid coloring), audio (sound saturation, sound level, music and voices) and content (i.e. surprise ending, narrative) PSA format elements. The mean MSV was 7.0 (range 1–19, $SD = 4.0$). Four high MSV (hiMSV) and 4 low MSV (loMSV) PSAs were selected from the upper and lower extremes of the distribution of PSA MSV scores. The mean MSV of the low category was 3.5 ($SD = 1.3$) and the mean MSV of the high category was 11.5 ($SD = 4.4$). The MSV of the hiMSV PSAs was significantly greater than the loMSV PSAs ($t(6) = 3.46$, $p = 0.01$). To ensure balance in these two conditions for message content, PSAs were also assessed for the strength of their arguments (Argument Strength, AS) using a previously reported procedure (Fishbein et al., 2002; Strasser et al., 2009). The AS scores for the hiMSV ($M = 27.75$, $SD = 2.2$) and loMSV PSAs ($M = 29.75$, $SD = 1.5$) did not differ, $t(6) = -1.00$, $p < 0.2$, 2-tailed t-test. The MSV/AS scores of the eight PSAs were: 2/28; 3/31; 4/29; 5/25; 8/30; 10/25; 10/30; 18/27. Eight 30-second neutral video clips (NV) were segments from a documentary film narrating arctic wildlife. This type of "neutral" stimuli allowed us to characterize

the brain fMRI response to ads, by using an active baseline with complex audiovisual content that was neither a commercial ad nor a PSA.

PSA video task

Participants were shown eight PSAs and eight NVs in a pseudorandom order separated by 6-second inter-stimulus intervals (ISIs, homogenous black background with grey (+) fixation point). Three 20-second baseline periods with fixation point were presented at the beginning, middle, and end of the task. Stimuli were not repeated and total task duration was 10 min and 42 s. Before the imaging session, participants were asked to watch all the PSA video task video clips carefully, told that their memory of portions of the videos would be tested after a brief delay and that their performance on this test is an integral part of the experiment in which they agreed to participate (Fig. 1).

Frame Recognition Test

After a 5-min delay, participants performed the Frame Recognition Test, adapted from an electroencephalography study of the retention of TV ads (Rossiter and Silberstein, 2001). This forced choice recognition task consisted of 128 randomly presented still frames. Four frames were extracted from each of the 16 (8 PSA and 8 NV) videos that were included in the PSA task. The remaining 64 frames were extracted from the additional eight PSAs and eight NV drawn from the same source, but not used in the PSA task. Stimuli were presented for 3 s each, in an optimized pseudo-random order (Dale, 1999) that included a variable ISI (0.25 to 16.25 s) during which a fixation point was present (see above). For each trial, participants were instructed to respond "Yes" or "No" to the question "Have you seen this ad", using a two-button keypad (FORP™, Current Design Inc., Philadelphia, PA). The question intentionally implied the PSA as a whole though only a single frame was displayed. Stimuli were not repeated and the total task run time was 10 min and 39 s. After the completion of both tasks, participants were de-briefed about having seen any of the clips included in the PSA video task in the past.

Stimulus delivery

All visual tasks were programmed in the Presentation (Neurobehavioral Systems Inc., Albany, CA) stimulus presentation package and rear projected to the center of the visual field using a PowerLite 7300 Video projector system (Epson America, Inc., Long Beach, CA) that was viewed through a mirror mounted on the scanner head coil. The video soundtrack was delivered through Silent Scan2100 MRI-compatible headphones (Avotec Inc., Stuart, FL).

Image acquisition

Siemens Trio 3T (Erlangen, Germany) system was used for MRI imaging. BOLD fMRI (Bandettini et al., 1992; Kwong et al., 1992) was performed, using a whole-brain, single-shot gradient-echo (GE) echoplanar (EPI) sequence with the following parameters: TR/TE = 3000/30 ms, FOV = 220 mm, matrix = 64 × 64, slice thickness/gap = 3/0 mm, 40 slices. After BOLD fMRI, 5-min magnetization-prepared, rapid acquisition gradient echo T1-weighted image (MPRAGE, TR 1620 ms, TE 3.87 ms, FOV 250 mm, Matrix 192 × 256, effective voxel resolution of $1 \times 1 \times 1$ mm) was acquired for anatomic
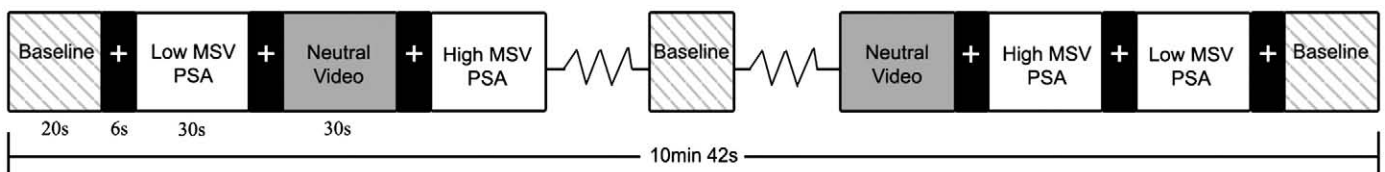

Fig. 1. Design of the PSA video task.

Table 1
Frame Recognition Test: mean recognition accuracy and response time for the frames from the PSA and Neutral videos (NV)

Class	Accuracy		Response time	
	%-correct	*SD*	*M (ms)*	*SD*
PSA	82.57	10.78	1309	121
NV	70.78	11.22	1331	91
PSA hiMSV	78.36	15.28	1363	158
PSA loMSV	87.76	9.56	1263	133

overlays of functional data and spatial normalization (Talairach and Tournoux, 1988).

Data analysis

Behavioral

Subject responses (%-correct) and mean response time (in milliseconds) on the Frame Recognition Test were evaluated. In order to satisfy the normality assumptions of the *t*-test, an arcsine transformation (Cohen, 1988) was applied to accuracy proportions. Differences in the %-correct and response time between PSA and NV and between hiMSV and loMSV conditions were evaluated with paired *t*-tests.

Imaging

fMRI data were preprocessed and analyzed using FEAT (fMRI Expert Analysis Tool) Version 5.1, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Images were slice time-corrected, motion corrected to the median image using tri-linear interpolation with six degrees of freedom (Jenkinson et al., 2002), high pass filtered (80 s), spatially smoothed (6 mm FWHM, isotropic) and scaled using mean-based intensity normalization. Datasets with motion or signal to noise ratio exceeding 2 standard deviations from the group average were excluded. Datasets of 15 (12M; 3F) participants survived the fMRI data quality control procedures and were included in the final analysis. The median functional and anatomical volumes were co-registered, and then transformed into standard space (T1 MNI template) using tri-linear interpolation (Jenkinson et al., 2002; Jenkinson and Smith, 2001). BET (Smith, 2002) was used to remove non-brain areas. Subject-level time-series statistical analysis was carried out using FILM (FMRIB's Improved Linear Model) with local autocorrelation correction (Woolrich et al., 2001). The three condition
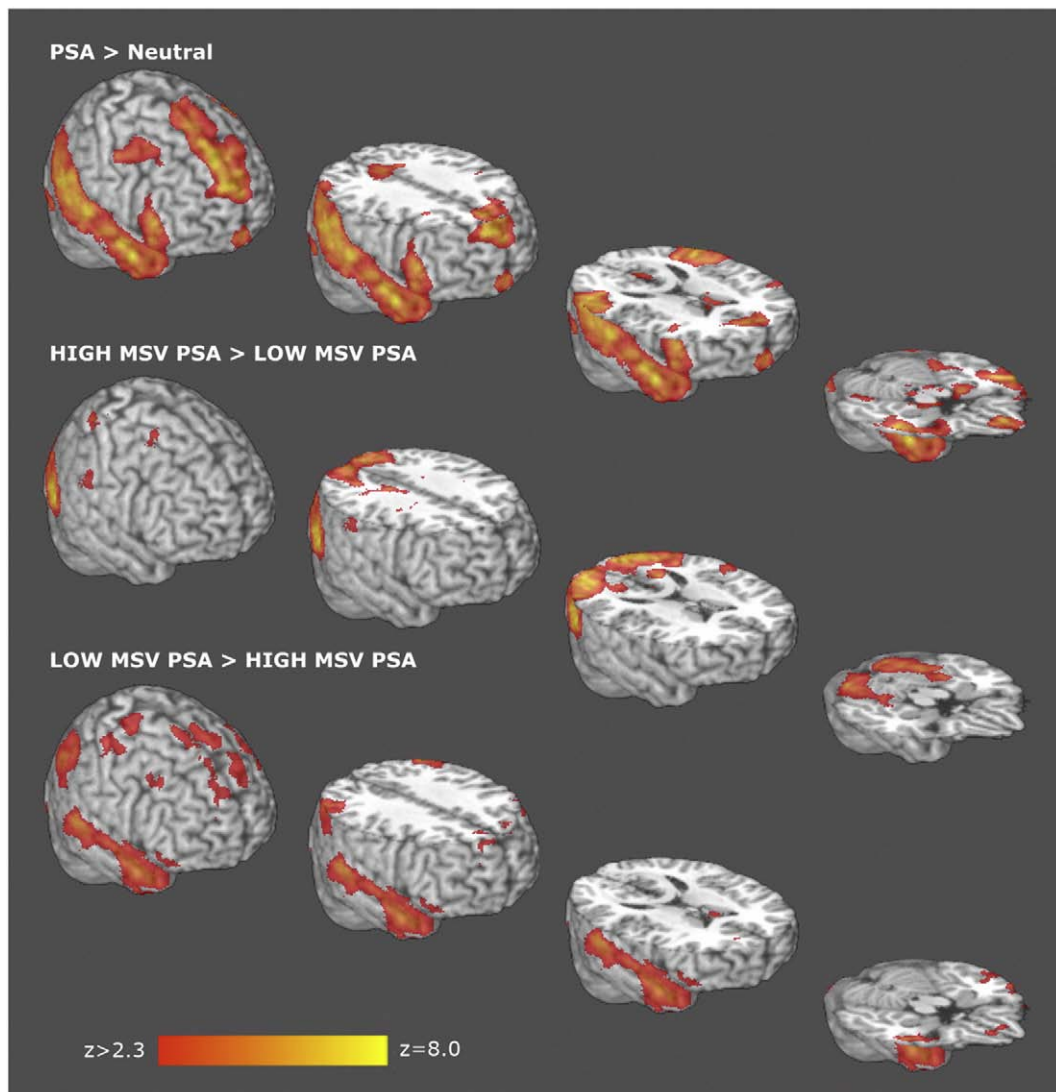

Fig. 2. Brain response to anti-tobacco public service announcements (PSA). Top row: Greater response to PSA videos (PSA) compared to Neutral Videos (NV) in the orbitofrontal, occipital and temporal cortex. Middle row: Regions of increased response to the high MSV PSAs compared to the low MSV PSAs, predominantly in the occipital cortex. Bottom row: Regions of increased response to the low MSV PSAs compared to the high MSV PSAs, predominantly in the prefrontal and temporal cortex. Statistical maps (yellow–red scale) are displayed over the Montreal Neurological Institute (MNI) brain template and thresholded at $Z = 2.3$, $p < 0.01$, corrected for multiple comparisons and spatial extent.

events (hiMSV, loMSV and NV) were modeled using a canonical hemodynamic response function. Six rigid body movement parameters from the motion correction were modeled as nuisance covariates. Second level analysis: Subject level contrast maps were entered into single group t-tests to identify brain activation for conditions and contrasts of interest. Group Z (Gaussianised T) statistic images were generated for the following pairs: 1) PSA>NV; 2) NV>PSA; 3) hiMSV>loMSV, 4) loMSV>hiMSV. To control type 2 error, group maps were cluster corrected using a minimum Z threshold of 2.3 and probability of spatial extent $p < 0.001$ (AFNI AlphaSim, R. W. Cox, National Institutes of Health). Each cluster was assigned an anatomical label based on location of the peak voxel using the Talairach Daemon database (Lancaster et al., 2000).

Correlation analysis

In addition to the contrasts described above, an analysis was conducted to correlate PSA-based brain activation with recognition performance. In this second level analysis, the total percent correct (TC) score for each subject's Frame Recognition Test was entered as a covariate of interest for the PSA>Baseline contrast. We restricted the analysis to voxels significantly activated in the PSA>Baseline contrast and the neutral videos were treated as a covariate of no interest. The resulting positive and negative correlation maps were examined at an uncorrected Z threshold of 1.64. To further visualize the nature of the relationship between BOLD fMRI signal and recognition performance, mean percent signal was extracted from the clusters showing the peak positive and negative correlations and plotted against accuracy using SAS (Gary, Indiana). Percent signal change and recognition accuracy were also plotted for the prefrontal cluster with a peak in the medial frontal gyrus, a representative area of interest.

Results

Behavioral

Participants denied having seen any of the PSA prior to the study. PSA frames were more accurately recognized than NV frames, $t(17) = 3.96$, $p < 0.001$. There was no difference in response time between PSA

Table 2
Location and magnitude of the differences in the brain response to PSA and Neutral (NV) videos

Region (Brodmann area)[a]	Size	HEM[b]	Z-MAX[c]	X	Y	Z
PSA>NV						
Superior temporal gyrus (BA 22)	11096	L	5.82	−52	−58	16
Superior temporal gyrus (BA 22)	11737	R	6.79	56	−36	8
Medial frontal gyrus (BA 8)	5263	L	5.59	−8	44	40
Parahippocampal gyrus (BA 30)	2076	R	4.53	10	−30	−10
Precuneus (BA 31)	1636	L	4.78	−6	−52	32
Medial frontal gyrus (BA 11)	882	R	5.61	4	46	−18
Middle frontal gyrus (BA 6)	555	R	4.78	46	2	42
Lingual gyrus (BA 18)	582	R	4.11	24	−96	−6
Caudate	234	R	3.45	10	0	10
Cerebellum	2164	L	4.68	−18	−78	−34
Cerebellum	1759	R	5.04	26	−80	−30
Neutral video>PSA video						
Superior parietal lobule (BA 7)	35521	R	5.34	18	−64	54
Insula	630	L	4.22	−30	12	8
Insula (BA 13)	160	R	3.99	40	−2	−2
Middle frontal gyrus (BA 11)	510	L	4.6	−30	38	−14
Middle frontal gyrus (BA 9)	256	R	3	40	28	34
Middle occipital gyrus (BA 19)	199	R	4.02	54	−60	−6

Location of the clusters and the local maxima of BOLD fMRI signal change.
[a] Regions exceeding $Z \geq 2.3$ and a (corrected) cluster significance $p \leq 0.001$ with estimated Brodmann's areas and coordinates from Talairach and Tournoux (1988).
[b] HEM = cerebral hemisphere.
[c] Z-MAX values represent peak activation for cluster.

Table 3
Location and magnitude of the differences in brain response to the high MSV PSA (hiMSV) and low MSV PSA (loMSV)

Region (Brodmann area)[a]	Size	HEM[b]	Z-MAX[c]	X	Y	Z
High MSV PSA>low MSV PSA						
Middle occipital gyrus (BA 19)	29013	L	5.91	−44	−72	10
Superior temporal gyrus (BA 42)	196	R	3.97	60	−24	12
Precentral gyrus (BA 6)	541	L	3.92	−30	−4	46
Cerebellum	450	L	3.48	14	−46	−43
Low MSV PSA>high MSV PSA						
Middle temporal gyrus (BA 21)	3084	L	4.64	−64	−40	2
Middle temporal gyrus (BA 21)	2984	R	4.87	48	−36	2
Inferior parietal lobule (BA 39)	1221	L	4.11	−50	−62	40
Inferior parietal lobule (BA 39)	1081	R	4.25	50	−62	40
Superior frontal gyrus (BA 6)	589	R	3.53	8	24	58
Middle frontal gyrus (BA 6)	262	R	3.6	44	12	46
Superior frontal gyrus (BA 8)	228	L	2.88	−6	38	46
Superior frontal gyrus (BA 8)	250	R	3.25	16	44	42
Orbital frontal gyrus (BA 11)	173	R	3.17	6	42	−20
Precentral gyrus (BA 6)	198	L	3.26	−28	−14	66
Postcentral gyrus (BA 3)	158	L	3.42	−46	−24	58
Inferior occipital gyrus (BA 17)	192	L	4.25	−24	−98	−8
Cerebellum	467	L	3.62	−18	−82	−36
Cerebellum	836	R	4.11	32	−80	−28

Location of the clusters and the local maxima of the BOLD fMRI signal change.
[a] Regions exceeding $Z \geq 2.3$ and a (corrected) cluster significance $p \leq 0.001$ with estimated Brodmann's areas and coordinates from Talairach and Tournoux (1988).
[b] HEM = cerebral hemisphere.
[c] Z-MAX values represent peak activation for cluster. For clarity, clusters with less than 150 voxels are not reported in this table.

and NV frames, $t(17) = 0.72$, $p = 0.48$. LoMSV PSA frames were more accurately recognized than hiMSV PSA frames $t(17) = 2.59$, $p = 0.019$, and response time was shorter for loMSV frames than hiMSV frames $t(17) = -2.74$, $p = 0.014$. A summary of the accuracy and response time statistics is reported in Table 1.

Imaging

Compared to the NVs, PSAs were associated with higher activity in the inferior and medial prefrontal cortex, the occipital cortex including the fusiform and lingual gyri and the temporal cortex, including the hippocampus and parahippocampus, (Fig. 2, top row and Table 2). The NVs (Table 2) were associated with higher occipito-parietal, middle frontal and insular activity than the PSAs.

Table 4
Location and magnitude of correlation between the Frame Recognition Test TC score and the PSA BOLD fMRI signal

Region (Brodmann area)[a]	Size	HEM[b]	Z-MAX[c]	X	Y	Z
Positive correlation						
Temporal pole (BA 38)	582	L	4.11	−40	20	−28
Middle temporal gyrus (BA 21)	1093	L	3.54	−60	−46	10
Middle temporal gyrus (BA 21)	356	R	3.44	50	−34	0
Medial frontal gyrus (BA 11)	252	R	3.31	6	52	−12
Middle temporal gyrus (BA 21)	311	L	3.03	−54	−16	−6
Medial frontal gyrus (BA 8)	396	R	2.96	2	48	38
Middle temporal gyrus (BA 21)	231	R	2.87	56	−18	−10
Negative correlation						
Fusiform gyrus (BA 20)	84	R	3.00	42	−38	−18
Middle occipital gyrus (BA 19)	81	L	2.70	−26	−84	8
Cerebellum	314	R	2.63	38	−56	2
Lingual gyrus (BA 18)	56	L	2.61	0	−88	−4
Middle occipital gyrus (BA 18)	63	L	2.45	−32	−86	0
Fusiform gyrus (BA 19)	52	L	2.36	−32	−64	−12

[a] Regions exceeding $Z \geq 1.64$ (uncorrected) with estimated Brodmann's areas and coordinates from Talairach and Tournoux (1988).
[b] HEM = cerebral hemisphere.
[c] Z-MAX values represent peak Z score for cluster. For clarity, positive correlations with less than 200 voxels and negative correlation with less that 50 voxels are not reported in this table.
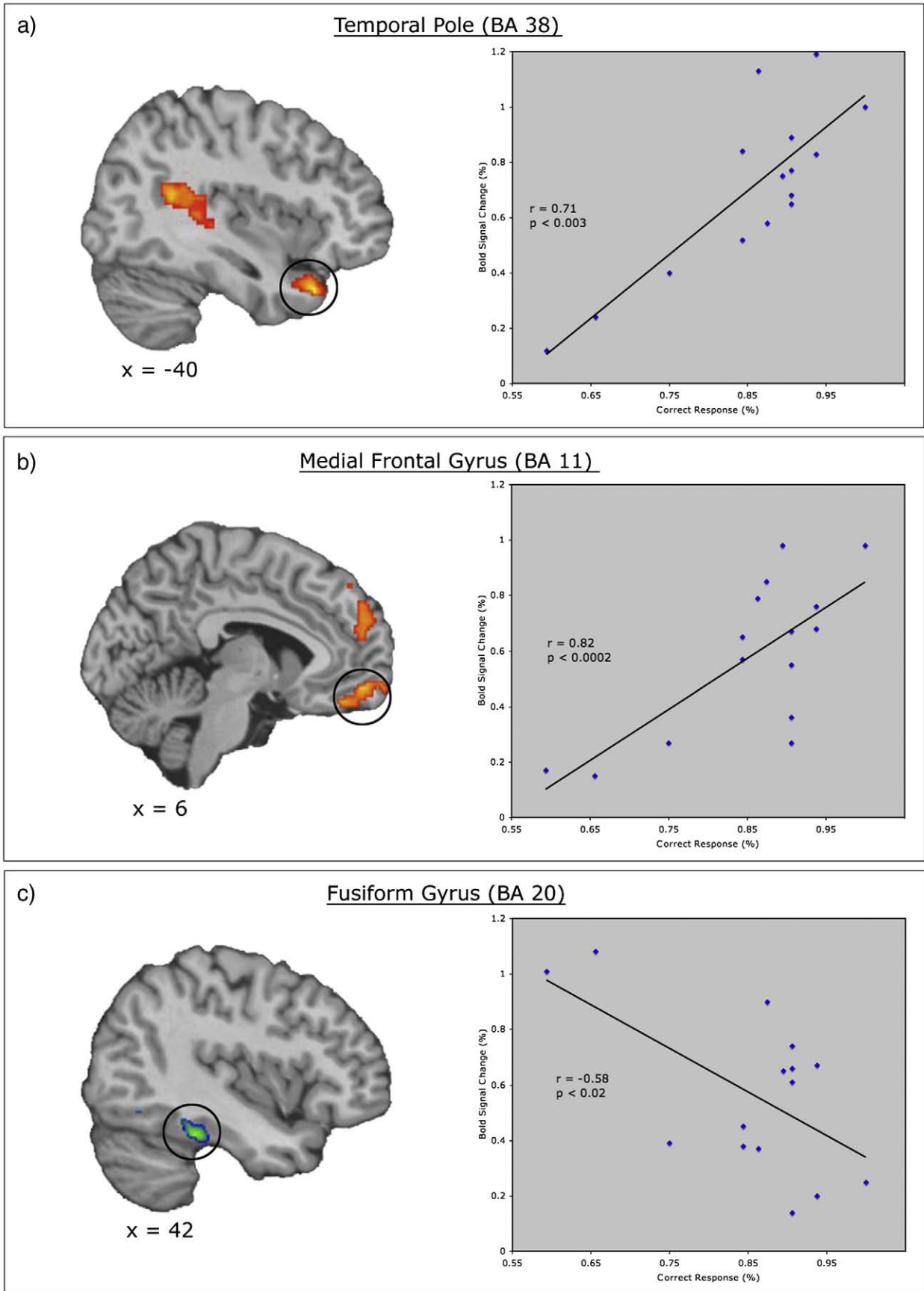
Fig. 3. Correlation between the Frame Recognition Test TC score and PSA BOLD fMRI signal. Colored regions represent significant positive (red scale) and negative (blue scale) correlation between mean percent signal change and TC score. Corresponding scatter plots display the mean percent signal change for the PSA vs. Baseline contrast plotted against the Frame Recognition Task TC score.

Compared to the hiMSV PSAs, the loMSV PSAs were associated with greater response in the prefrontal cortex, including the orbitofrontal and superior frontal and precentral gyri, the temporal cortex including the middle and inferior temporal gyri and the temporal poles and the inferior parietal cortex (Fig. 2, bottom row and Table 3). The hiMSV PSAs were associated with higher activity in the fusiform and lingual gyri of the occipital cortex, when contrasted with loMSV PSAs (Fig. 2, middle row and Table 3).

Correlation analysis

The Frame Recognition Test TC scores were positively correlated with the PSA BOLD fMRI signal in the bilateral temporal and medial cortex and negatively correlated with signal in the occipital cortex and the cerebellum at a threshold of $p<0.05$, uncorrected (Table 4). The mean percent signal change for clusters that contained the peak positive (Temporal Pole, BA 38) and negative (Fusiform Gyrus, BA 20) correlations as well as a prefrontal region of interest (Medial Frontal Gyrus), were plotted against TC score (Fig. 3). Additionally, the mean signal and TC scores were fit to a simple linear model resulting in the following correlations: $r=0.71$, $p<0.003$ (Temporal Pole, BA 38), $r=0.58$, $p<0.02$ (Fusiform Gyrus, BA 20) and $r=0.82$, $p<0.0002$ (Medial Frontal Gyrus, BA 11).

Discussion

Using anti-tobacco PSAs as a model, we provide first evidence for differences in regional brain activation and recall as a function of ad format. As predicted in our primary hypothesis, the hiMSV PSAs produced less recognition than the loMSV PSAs. This behavioral indication of reduced cognitive processing of the content of the hiMSV PSAs is further supported by the corresponding imaging data; the hiMSV PSAs were associated with extensive activation in the occipital (including the fusiform gyrus) cortex and the parahippocampus, while the loMSV PSAs were accompanied by the higher prefrontal, temporal and posterior parietal activation. While the pattern of activation of PSA processing has not been established in prior research, our findings can be interpreted in light of the extensive literature on the functional neuroanatomy of reward, attention and learning. For example, current understanding of the role of the OFC emphasizes the integration of the incentive value and prediction of reward, which in turn, informs future behavior (Schoenbaum and Shaham, 2008). Superior and middle temporal structures are implicated in language processing, with the temporal poles emerging as an area of integration of somatic and affective information (Olson et al., 2007; Prince et al., 2005). Increased prefrontal activity encoding has also been reported with successful later spontaneous recall (Hannula and Ranganath, 2008). Thus, the activation pattern associated with loMSV PSAs is suggestive of deeper cognitive processing than the hiMSV PSAs. Moreover, the absence of differences between the loMSV and hiMSV in the anterior cingulate cortex and the higher posterior parietal activation in the loMSV PSA, suggests that higher MSV does not translate into increased attention.

The "limited capacity" and "dual processing" theories of communication, postulate that the competition between superficial PSA features and PSA message reduces the "deep" processing of message content and eventually, its impact (Lang, 2006; Petty and Cacioppo, 1986; Ragland et al., 2005). Our data, for the first time, demonstrate the neural basis of the concepts of limited capacity and dual processing of information, which until now, had only theoretical and behavioral support.

Compared to NV, PSAs activated the medial and lateral prefrontal and temporal cortices, the hippocampus, the fusiform and lingual gyri and the precuneus, in a remarkably robust and symmetrical fashion. The prefrontal and medial temporal activation is commonly observed during tests of endogenous attention and memory formation and retrieval (Buschman and Miller, 2007; D'Esposito, 2007; Knudsen, 2007; Murray and Ranganath, 2007). The addition of the fusiform

gyrus, the precuneus and the lateral and anterior temporal cortex makes the PSA-related activation similar to the pattern reported with the natural vision (Bartels et al., 2008; Cavanna and Trimble, 2006) and the comprehension and production of narrative speech (Awad et al., 2007) experiments. The PSAs were also better remembered than the NV (Table 1). Together, these data suggest that the PSAs may be associated with more cognitive processing than the non-PSAs. One possible interpretation of these findings is the effect of the personally relevant anti-tobacco message, which was present only in the PSAs. Another potential source of these findings is the differences in brain processing between ads and non-ads. The practical implication of our findings to PSA design is that the effort to secure attention may be at the expense of learning. While this may be acceptable for commercial advertising aimed at reaching audience's explicit memory with brand names, it is less so for the PSAs, aimed at central processing and ultimately behavioral change. Our findings should be interpreted with several limitations in mind. First, our sample was relatively small. Second, in the absence of a nonsmoker control group, we cannot determine whether the observed responses generalize to nonsmokers. Third, our post-exposure recall measure relied on the visual recognition of selected PSA and NV frames and did not assess the recall of PSA message. Finally, the existing MSV variable does not dissociate visual and auditory components of PSAs. Addressing this caveat would require refinements in the available validated instruments of PSA evaluation (Palmgreen et al., 2002).

In conclusion, personally relevant, televised anti-smoking PSAs low in "attention-grabbing" features generate more prefrontal and temporal activation and less recognition than their superficially more "engaging" counterparts. These data challenge the conventional assumption of the higher effectiveness of "attention-grabbing" ads and demonstrate the potential of using neuroimaging in the design and evaluation of anti-tobacco mass media public health communications. Further research is required to determine whether these findings generalize to other PSAs and commercial advertising media.

Acknowledgments

References

Awad, M., Warren, J.E., Scott, S.K., Turkheimer, F.E., Wise, R.J., 2007. A common system for the comprehension and production of narrative speech. J. Neurosci. 27, 11455–11464.
Bandettini, P.A., Wong, E.C., Hinks, R.S., Tikofsky, R.S., Hyde, J.S., 1992. Time course EPI of human brain function during task activation. Magn. Reson. Med. 25, 390–397.
Bartels, A., Zeki, S., Logothetis, N.K., 2008. Natural vision reveals regional specialization to local motion and to contrast-invariant, global flow in the human brain. Cereb. Cortex 18, 705–717.
Biener, L., McCallum-Keeler, G., Nyman, A.L., 2000. Adults' response to Massachusetts anti-tobacco television advertisements: impact of viewer and advertisement characteristics. Tob. Control 9, 401–407.
Buschman, T.J., Miller, E.K., 2007. Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. Science 315, 1860–1862.
Cavanna, A.E., Trimble, M.R., 2006. The precuneus: a review of its functional anatomy and behavioural correlates. Brain 129, 564–583.
Chattopadhyay, A., Laborie, J.-L., 2005. Managing brand experience: the market contact audit (TM). J. Advert. Res. 45, 9–16.
Cohen, J.D., 1988. Statistical Power Analysis for the Behavioral Sciences, 2nd ed. Lawrence Erlbaum Associates, Hillsdale, NJ.
D'Esposito, M., 2007. From cognitive to neural models of working memory. Philos. Trans. R. Soc. Lond., B Biol. Sci. 362, 761–772.
D'Silva, M.U., Palmgreen, P., 2007. Individual differences and context: factors mediating recall of anti-drug public service announcements. Am. J. Health Commun. 21, 65–71.
Dale, A.M., 1999. Optimal experimental design for event-related fMRI. Hum. Brain Mapp. 8, 109–114.
Emery, S.L., Szczypka, G., Powell, L.M., Chaloupka, F.J., 2007. Public health obesity-related TV advertising: lessons learned from tobacco. Am. J. Prev. Med. 33, S257–263.
Erk, S., Spitzer, M., Wunderlich, A.P., Galley, L., Walter, H., 2002. Cultural objects modulate reward circuitry. NeuroReport 13, 2499–2503.

Fishbein, M., Hall-Jamieson, K., Zimmer, E., von Haeften, I., Nabi, R., 2002. Avoiding the boomerang: testing the relative effectiveness of antidrug public service announcements before a national campaign. Am. J. Public Health 92, 238–245.

Foerde, K., Knowlton, B.J., Poldrack, R.A., 2006. Modulation of competing memory systems by distraction. Proc. Natl Acad. Sci. U. S. A. 103, 11778–11783.

Hahn, B., Ross, T.J., Stein, E.A., 2006. Neuroanatomical dissociation between bottom-up and top-down processes of visuospatial selective attention. NeuroImage 32, 842–853.

Hannula, D.E., Ranganath, C., 2008. Medial temporal lobe activity predicts successful relational memory binding. J. Neurosci. 28, 116–124.

Harrington, N., Lane, D.R., Donohew, L., Zimmerman, R.S., Norling, G.R., An, J.-H., Cheah, W.H., McClure, L., Buckingham, T., Garofalo, E., Bevins, C.C., 2003. Persuasive strategies for effective anti-drug messages. Commun. Monogr. 70, 16–38.

Helme, D.W., Donohew, R.L., Baier, M., Zittleman, L., 2007. A classroom-administered simulation of a television campaign on adolescent smoking: testing an activation model of information exposure. J. Health Commun. 12, 399–415.

Ibrahim, J.K., Glantz, S.A., 2007. The rise and fall of tobacco control media campaigns, 1967–2006. Am. J. Public Health 97, 1383–1396.

Indovina, I., Macaluso, E., 2007. Dissociation of stimulus relevance and saliency factors during shifts of visuospatial attention. Cereb. Cortex 17, 1701–1711.

IOM, 2007. In: Bonnie, R. (Ed.), Ending the Tobacco Problem: A Blueprint for the Nation. Institute of Medicine, Washington, DC 20055.

Jenkinson, M., Smith, S., 2001. A global optimisation method for robust affine registration of brain images. Med. Image Anal. 5, 143–156.

Jenkinson, M., Bannister, P., Brady, M., Smith, S., 2002. Improved optimization for the robust and accurate linear registration and motion correction of brain images. NeuroImage 17, 825–841.

Kang, Y., Cappella, J., Fishbein, M., 2006. The attentional mechanism of message sensation value: interaction between message sensation value and argument quality on message effectiveness. Commun. Monogr. 73, 351–378.

Knudsen, E.I., 2007. Fundamental components of attention. Annu. Rev. Neurosci. 30, 57–78.

Kwong, K.K., Belliveau, J.W., Chesler, D.A., Goldberg, I.E., Weisskoff, R.M., Poncelet, B.P., Kennedy, D.N., Hoppel, B.E., Cohen, M.S., Turner, R., et al., 1992. Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation. Proc. Natl. Acad. Sci. U. S. A. 89, 5675–5679.

Lancaster, J.L., Woldorff, M.G., Parsons, L.M., Liotti, M., Freitas, C.S., Rainey, L., Kochunov, P.V., Nickerson, D., Mikiten, S.A., Fox, P.T., 2000. Automated Talairach atlas labels for functional brain mapping. Hum. Brain Mapp. 10, 120–131.

Lang, A., 2006. Using the limited capacity model of motivated mediated message processing to design effective cancer communication messages. J. Commun. 56, S57–S80.

McClure, S.M., Li, J., Tomlin, D., Cypert, K.S., Montague, L.M., Montague, P.R., 2004. Neural correlates of behavioral preference for culturally familiar drinks. Neuron 44, 379–387.

Morgan, S.E., 2003. Associations between message features and subjective evaluations of the sensation value of antidrug public service announcements. J. Commun. 53, 512–526.

Murray, L.J., Ranganath, C., 2007. The dorsolateral prefrontal cortex contributes to successful relational memory encoding. J. Neurosci. 27, 5515–5522.

Olson, I.R., Plotzker, A., Ezzyat, Y., 2007. The enigmatic temporal pole: a review of findings on social and emotional processing. Brain 130, 1718–1731.

Palmgreen, P., Donohew, L., Lorch, E., Rogus, M., Helm, D., Grant, N., 1991. Sensation seeking, message sensation value, and drug use as mediators of PSA effectiveness. Health Commun. 3, 217–227.

Palmgreen, P., Stephenson, M.T., Everett, M.W., Baseheart, J.R., Francies, R., 2002. Perceived message sensation value (PMSV) and the dimensions and validation of a PMSV scale. Health Commun. 14, 403–428.

Petty, R., Cacioppo, J., 1986. Communication and Persuasion: Central and Peripheral Routes to Attitude Change. Springer Verlag, New York.

Pomerleau, C.S., Carton, S.M., Lutzke, M.L., Flessland, K.A., Pomerleau, O.F., 1994. Reliability of the Fagerstrom Tolerance Questionnaire and the Fagerstrom Test for Nicotine Dependence. Addict. Behav. 19, 33–39.

Prince, S.E., Daselaar, S.M., Cabeza, R., 2005. Neural correlates of relational memory: successful encoding and retrieval of semantic and perceptual associations. J. Neurosci. 25, 1203–1210.

Ragland, J.D., Gur, R.C., Valdez, J.N., Loughead, J., Elliott, M., Kohler, C., Kanes, S., Siegel, S.J., Moelter, S.T., Gur, R.E., 2005. Levels-of-processing effect on frontotemporal function in schizophrenia during word encoding and recognition. Am. J. Psychiatry 162, 1840–1848.

Rossiter, J.R., Silberstein, R.B., 2001. Brain-imaging detection of visual scene encoding in long-term memory for TV commercials. J. Advert. Res. 41 Mar–Apr 2001.

Russell, C.A., Belch, M., 2005. A managerial investigation into the product placement industry. J. Advert. Res. 45, 73–92.

Schoenbaum, G., Shaham, Y., 2008. The role of orbitofrontal cortex in drug addiction: a review of preclinical studies. Biol. Psychiatry 63, 256–262.

Smith, S.M., 2002. Fast robust automated brain extraction. Hum. Brain Mapp. 17, 143–155.

Stephenson, M., Southwell, B., 2006. Sensation Seeking, the activation model, and mass media health campaigns: current findings and future directions for cancer communication. J. Commun. 56, S38–S56.

Strasser, A.A., Cappella, J.N., Jepson, C., Fishbein, M., Tang, K.Z., Han, E., Lerman, C., 2009. Experimental evaluation of anti-tobacco PSAs: effects of message content and format on physiological and behavioral outcomes. Nicotine Tob. Res. doi:10.1093/ntr/ntn026.

Talairach, J., Tournoux, P., 1988. Co-planar Stereotaxic Atlas of the Human Brain. An Approach to Cerebral Imaging. Thieme Medical Publishers, New York, 3-Dimensional Proportional System.

Uncapher, M.R., Rugg, M.D., 2005. Effects of divided attention on fMRI correlates of memory encoding. J. Cogn. Neurosci. 17, 1923–1935.

Wakefield, M., Szczypka, G., Terry-McElrath, Y., Emery, S., Flay, B., Chaloupka, F., Saffer, H., 2005. Mixed messages on tobacco: comparative exposure to public health, tobacco company- and pharmaceutical company-sponsored tobacco-related television campaigns in the United States, 1999–2003. Addiction 100, 1875–1883.

Wakefield, M., Terry-McElrath, Y., Emery, S., Saffer, H., Chaloupka, F.J., Szczypka, G., Flay, B., O'Malley, P.M., Johnston, L.D., 2006. Effect of televised, tobacco company-funded smoking prevention advertising on youth smoking-related beliefs, intentions, and behavior. Am. J. Public Health 96, 2154–2160.

Woolrich, M.W., Ripley, B.D., Brady, M., Smith, S.M., 2001. Temporal autocorrelation in univariate linear modeling of FMRI data. NeuroImage 14, 1370–1386.