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From Exposure To Effects: Examining The Cognitive Processes Underlying Effects Of "the Real Cost" Youth-Targeted Anti-Smoking Media Campaign

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Abstract
The goal of this dissertation is twofold: to assess anti-smoking campaign effects, and examine the ad-induced, cognitive processes that account for effective anti-smoking advertisements. The dissertation studies evaluate ads from "The Real Cost" anti-smoking campaign, a public education campaign aimed at reducing tobacco use among U.S. adolescents. Study 1 examines the relationship between self-reported recall of specific ads and anti-smoking belief endorsement in a nationally-representative sample of nonsmoking adolescents. To address limitations from Study 1, Study 2 evaluates the relationship between opportunities for exposure using Target Rating Points (TRPs), a measure of campaign reach and frequency, and anti-smoking belief endorsement in a nationally-representative sample of nonsmoking adolescents. Studies 3 and 4 employ functional magnetic resonance imaging (fMRI) to examine how anti-smoking ads are received and processed by the adolescent brain. Study 3 examines the relationships between ad-elicited neural response and subsequent ratings of perceived ad effectiveness and intention to share ads on social media in a sample of forty adolescent nonsmokers. Study 4 examines the moderating effect of ad-elicited brain response on the relationship between opportunities for campaign exposure and population-level ad recall. Analyses were conducted with a combined dataset representing: ad recall from a nationally-representative survey of adolescents; weekly, ad-specific TRPs; and ad-elicited neural response in brain regions implicated in social processing and memory encoding from a separate sample of adolescents.

From the studies that comprise this dissertation, we can conclude the following: 1) opportunities for exposure and recalled exposure to campaign ads associate with endorsement of ad-targeted beliefs, suggesting the campaign has been effective through the theorized pathway of effects 2) ads that are perceived as more effective elicit greater response in brain regions implicated in social processing, and 3) ad-induced neural response in social processing and memory encoding brain regions partially explains the relationship between opportunities for ad exposure and recalled exposure. Findings suggest that neural measures of ad processing may be an important tool for forecasting which ads will be more effective in a target audience. These conclusions have important implications for the future design and implementation of mass media campaigns.

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FROM EXPOSURE TO EFFECTS:

EXAMINING THE COGNITIVE PROCESSES UNDERLYING EFFECTS OF "THE REAL COST" YOUTH-TARGETED ANTI-SMOKING MEDIA CAMPAIGN

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ABSTRACT

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between opportunities for campaign exposure and population-level ad recall. Analyses were conducted with a combined dataset representing: ad recall from a nationally-representative survey of adolescents; weekly, ad-specific TRPs; and ad-elicited neural response in brain regions implicated in social processing and memory encoding from a separate sample of adolescents.

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CHAPTER 1. INTRODUCTION

Anti-smoking mass media campaigns have played an integral role in reducing the prevalence of tobacco use among youth in the United States (Allen et al., 2015; U.S. Department of Health and Human Services, 2012, 2014; Wakefield, Loken, & Hornik, 2010). Despite the progress that has been made, smoking remains the leading preventable cause of disease and death in this country (U.S. Department of Health and Human Services, 2012, 2014). Adolescents are among the populations most vulnerable to smoking initiation, as the vast majority of smokers initiate prior to turning 18 (U.S. Department of Health and Human Services, 2012, 2014). Thus, smoking prevention media campaigns that specifically target adolescent populations are crucial to continued declines in smoking prevalence.

The success of a mass media campaign hinges on its ability to elicit effects through the dissemination of campaign messages to a target audience, with exposure to messages influencing message-consistent beliefs and, ultimately, behaviors (Hornik, 2002; Wakefield, Loken, & Hornik, 2010). However, this simple distillation of the process—from implementation to effects—overlooks the important sub-processes that happen along the path from message dissemination to belief and behavior change. In particular, the cognitive processes that occur at the moment of message reception may have implications for the ultimate success of those messages. Through a series of studies, this dissertation examines the interrelationships between two elements of this overarching process—message dissemination and behavior-relevant belief endorsement—and the

intermediate cognitive processes, as shown in a schematic of the dissertation studies (Figure 1.1).

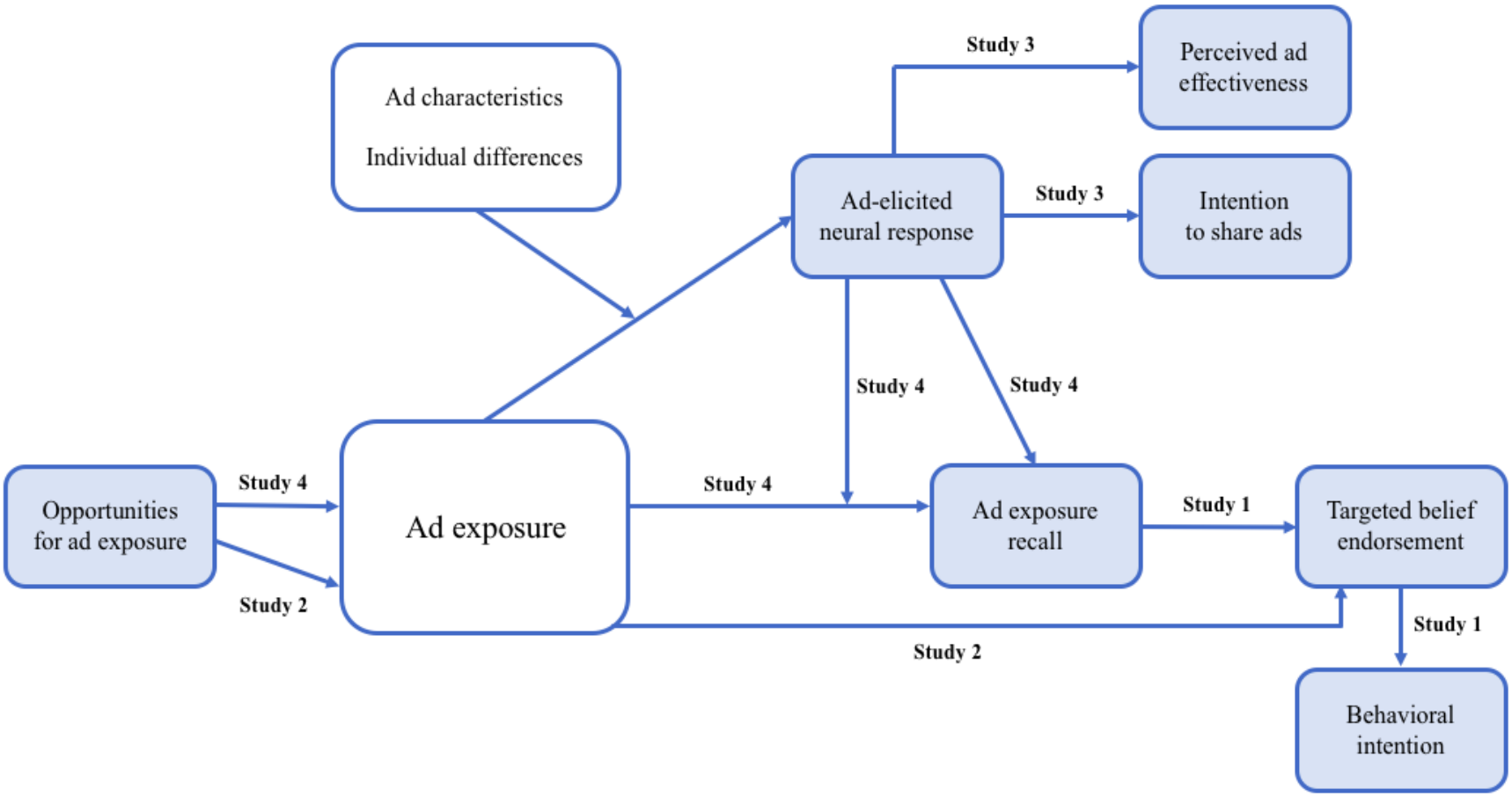


Figure 1.1 *Schematic of dissertation studies*

Note. Shaded boxes indicate variables examined in dissertation studies. Labeled arrows indicate relationships tested in each dissertation study. Transparent boxes indicate latent variables theorized to be involved in these processes.

The goal of this dissertation is twofold: (1) to provide evidence for anti-smoking campaign effects on recall and beliefs in the context of a specific youth prevention campaign, and (2) to understand the ad-induced, cognitive processes that account for effective anti-smoking campaign messages. Specifically, the dissertation studies focus on the effects of advertisements from "The Real Cost" anti-smoking campaign, the first nationally-funded public education campaign aimed at reducing tobacco use among U.S. youth aged 12 to 17. The strategy for The Real Cost campaign is to influence beliefs about the "real costs" of smoking that are associated with behavior through the dissemination of creative campaign messages (Duke et al., 2015). Here, I provide an overview of each dissertation study and the links between these studies.

Overview of Dissertation Studies

Previous research suggests The Real Cost campaign has reduced smoking initiation. During the first two years of the campaign, frequent exposure to campaign advertisements is estimated to have prevented 348,398 U.S. youths from initiating smoking (Farrelly et al., 2017). However, the evaluation led by Farrelly and colleagues did not examine the theorized pathway of campaign effects—through targeted beliefs associated with behavior. Studies 1 and 2 examine this pathway of effects by assessing the relationship between campaign exposure and campaign-targeted anti-smoking beliefs. Study 1 (Kranzler, Gibson, & Hornik, 2017) tests the relationship between self-reported recall of specific advertisements from The Real Cost campaign and endorsement of ad-targeted beliefs in a rolling, cross-sectional survey of a nationally-representative sample of nonsmoking youths aged 13-17 (TCORS dataset). To establish the specificity of these

effects, parallel analyses were conducted to examine the correlations between ad recall and anti-smoking beliefs that were not targeted by campaign ads; these recall/non-targeted belief correlations were then compared with recall/targeted belief associations to demonstrate the specificity of campaign effects. Consistent with the hypothesis of campaign effects, results indicate that recalled exposure to each of 4 campaign ads (but not a fake ad) was significantly associated with endorsement of ad-targeted beliefs, and that these associations were stronger than parallel recall/non-targeted belief correlations.

Though results from Study 1 offer evidence consistent with a claim of campaign effects through targeted beliefs, the claim is contingent on an inference derived from the cross-sectional association of self-reported campaign recall and self-reported beliefs. Inferences based on two self-reported measures may be subject to biases, such as reverse causal direction, that can threaten the validity of findings (Liu & Hornik, 2016; Slater, 2004). To address this limitation, Study 2 was conducted to evaluate the relationship between campaign exposure and targeted-belief endorsement using an exogenous measure of exposure—specifically, Target Rating Points (TRPs), a media-market measure of campaign reach and frequency. Study 2 tests the relationship between TRPs for advertisements from The Real Cost campaign (TRP dataset) and endorsement of ad-targeted beliefs in a nationally-representative sample of nonsmoking adolescents from a rolling, cross-sectional survey (TCORS dataset; Study 1). Analyses were conducted at the individual level, with past 4-week TRPs assigned to survey respondents on the basis of their survey interview date over 133 weeks. To establish the specificity of these effects (mirroring analyses in Study 1), parallel analyses were conducted to examine the

correlations between TRPs and non-targeted anti-smoking beliefs; these TRP/non-targeted belief correlations were then compared with TRP/targeted belief associations to demonstrate the specificity of campaign effects. Results demonstrate that for 2 of the 4 ad categories tested, past 4-week TRPs were significantly associated with endorsement of ad-targeted beliefs, and that these associations were stronger than parallel TRP/non-targeted belief correlations.

Studies 1 and 2 provide evidence consistent with a claim of large-scale campaign effects through targeted beliefs, demonstrating that opportunities for exposure and recalled exposure to campaign ads are associated with endorsement of ad-targeted beliefs. However, findings raise questions about the micro-level cognitive processes, occurring during the moment of message reception (and thus between opportunities for exposure and recalled exposure; see Figure 1.1), that associate with campaign effects. Studies 3 and 4 were conducted to investigate these ad-induced, psychological processes, and to assess whether they relate to small- and large-scale campaign effects. Specifically, we employed neuroimaging methods to examine how anti-smoking ads are received and processed by the adolescent brain, and used the neural response data in three ways. In Study 3, we demonstrate that neural response to the ads predicted two outcomes known to be related to distal campaign effects. In Study 4, we show that neural response to ads influences whether (opportunities for) exposure to ads produce recalled ad exposure.

To conduct Study 3, forty adolescent nonsmokers (aged 14-17) from the greater Philadelphia area (fMRI dataset) completed a functional magnetic resonance imaging (fMRI) scan, during which their brain response was measured while they viewed 12 ads

from The Real Cost campaign. We linked neural responses during ad reception with participants' subsequent ratings of perceived ad effectiveness, which has been shown to associate with actual effectiveness (Dillard, Shen, & Vail, 2007; Dillard, Weber, & Vail, 2007), and intentions to share ads on social media, in light of prior research demonstrating that interpersonal conversation about campaign ads influences campaign outcomes (Hafstad & Aaro, 1997; Hwang, 2012; Jeong & Bae, 2017).

Previous theoretical and empirical work from adult studies suggests that ads that prompt individuals to consider personal relevance, to engage in social processing (e.g., think about the mental states of others), and to consider the subjective value of an ad are more effective and more likely to be retransmitted (Baek, Scholz, O'Donnell, & Falk, 2017; Chua et al., 2011; Darke & Chaiken, 2005; Fishbein & Ajzen, 2011; Scholz et al., 2017). Thus, we hypothesized that neural response in brain regions previously implicated in self-relevance, social processing, and subjective valuation would be positively associated with both perceived ad effectiveness and sharing intention. Results from multilevel regression analyses demonstrated that perceived ad effectiveness was positively associated with ad-elicited neural activity in the social processing network and marginally associated with neural activity in the self-relevance network, whereas it was not associated with neural activity in the subjective valuation network. Conversely, sharing intention was not associated with neural activity in any of the hypothesized networks. Findings suggest that adolescents' ratings of ad efficacy may be attributable, in part, to their consideration of social factors when initially exposed to messages, such that

ads that inspire social processing may be more strongly associated with campaign outcomes.

Together, Studies 1-3 link campaign dissemination and the cognitive processes that occur at the moment of reception with measures of campaign efficacy. However, it is unclear whether these antecedent components of the message dissemination process work synergistically to produce campaign effects, raising the following question: Does neural response during ad exposure in a small group of participants partially explain large-scale campaign effects? To address this question, Study 4 aims to examine whether neural response to ads in a small group of adolescents enhances the prediction of population-level recalled exposure to campaign ads.

The success of a health campaign is contingent, in part, on its ability to achieve adequate exposure (Hornik, 2002; Randolph & Viswanath, 2004); however, opportunities for exposure are imperfect predictors of ad recall (Cowling, Modayil, & Stevens, 2010; Niederdeppe, 2005; Southwell, Barmada, Hornik, & Maklan, 2002). As shown in Study 3, capturing brain response during ad reception offers insights into the cognitive processes underlying memorable ads. Drawing on theories of message processing and empirical findings, the purpose of Study 4 is to examine the moderating effect of ad-elicited brain response on the relationship between opportunities for campaign exposure and ad recall. Prior literature suggests that two sets of brain regions are particularly important in affecting ad recall: regions related to social processing, thought to enhance the saliency of ads (in particular for adolescents) (Blakemore, 2008; Crone & Dahl, 2012), and regions related to memory encoding, which have been shown to index

encoding processes (Frankland & Bontempi, 2005) and theorized to associate with message recall (Lang, 2000). We thus hypothesized that neural response in these two sets of brain regions would moderate the relationship between opportunities for exposure and ad recall.

To conduct Study 4, we merged 3 datasets pertinent to The Real Cost youth-targeted anti-smoking campaign: past 30-day ad recall from a rolling national survey of adolescents (TCORS dataset; Studies 1 and 2), ad-specific Target Rating Points (TRPs), which measure campaign reach and frequency (TRP dataset; Study 2), and ad-elicited neural response in brain regions implicated in social processing and memory encoding from a separate sample of adolescents (fMRI dataset, Study 3). Survey respondents were assigned ad-specific past 4-, 8-, and 12-week TRP values based on their survey interview date, and ad-specific brain responses (averaged across neuroimaging participants) for each ad. In line with our hypotheses, multilevel regression models demonstrated that brain response in social processing and memory encoding regions moderates the relationship between opportunities for ad exposure and recalled exposure. Moreover, findings extend results from Study 3, which demonstrated that neural response in social processing regions associates with perceptions of ad effectiveness in the scanned participants themselves, to effects at a much larger scale. We discuss implications of this approach as a strategy for identifying messages that will "stick" with a target audience.

CHAPTER 2. THE RELATIONSHIP BETWEEN RECALLED CAMPAIGN EXPOSURE AND CAMPAIGN-TARGETED BELIEFS

Introduction

Smoking, the leading cause of preventable death in the United States, typically begins during adolescence, with 90% of smokers initiating smoking before age 18 (Centers for Disease Control and Prevention, 2014b). Despite a substantial decrease in smoking prevalence among youth over the last 15 years (Centers for Disease Control and Prevention, 2014a), projections based on current smoking rates estimate that 5.6 million of today's American youth will die prematurely due to a smoking-related illness (Centers for Disease Control and Prevention, 2014b). Efforts to prevent smoking initiation among youth remains an important public health issue.

The Real Cost Campaign

"The Real Cost" campaign, the first national youth prevention campaign sponsored by the Food and Drug Administration (FDA), seeks to reduce tobacco use intentions and behavior by educating at-risk youth about the harmful effects of tobacco use (Duke et al., 2015). The campaign targets youth, aged 12 to 17, who are susceptible nonsmokers or smoking experimenters. Prior to campaign initiation, formative research was conducted to identify the most promising message themes under the FDA's regulatory authority for use in campaign messages (Brennan, Gibson, Kybert-Momjian, Liu, & Hornik, 2017). Results indicated that three promising themes for a prevention campaign aimed at 13-17 year olds were *Addiction*, *Harmful Ingredients (found in cigarettes and in) Common Products*, and *Physical (Cosmetic) Effects.* Campaign

developers opted to target beliefs related to each of these promising themes, using campaign messages that highlight consequences of smoking that youth are concerned about, including a loss of control due to addiction, dangerous chemicals, and cosmetic health effects like tooth loss and skin damage [i.e., cosmetic effects] (Food and Drug Administration, 2015).

Between February 2014 and October 2015, the FDA purchased television advertising for The Real Cost program to attain 1,177 Target Rating Points (TRPs) for the first 8 weeks of the campaign and more than 300 TRPs per 4-week period thereafter, surpassing CDC guidelines for effective campaigns (Schar, Gutierrez, Murphy-Hoefer, & Nelson, 2006). Evidence from evaluation data collected from July 2014 to October 2014 suggests this ad buy translated into high ad awareness, with 89% of youth reporting they had seen at least one TV ad (Duke et al., 2015). Results from the first two published evaluations of The Real Cost campaign offer evidence in support of campaign efficacy. One evaluation shows a cross-sectional association between aided recall of campaign ads and increased risk perceptions about adverse health problems due to cigarette smoking (Huang et al., 2017). Another evaluation, conducted with longitudinal survey data, demonstrates that frequent recall of campaign advertisements resulted in decreased odds of subsequent smoking initiation, which accounted for an estimated 348,398 U.S. youths aged 11-18 who did not initiate smoking between February 2014 – March 2016 (Farrelly et al., 2017). Thus, there is evidence that the campaign has been effective at reducing smoking initiation. However, there is no evidence to suggest that exposure to campaign ads is associated with endorsement of the beliefs targeted by these ads, a pathway

through which the campaign was expected to influence smoking behavior (Duke et al., 2015). Evidence of specific relationships between campaign ad exposure and ad-targeted beliefs would bolster existing claims of campaign effects, reducing the likelihood that alternative explanations account for these effects.

Decades of smoking prevention research indicate that anti-smoking campaigns can increase young people's anti-smoking cognitions, which in turn predict smoking intentions and behavior (Australian Government Department of Health and Ageing, 2005; Freedman, Nelson, & Feldman, 2011; Goldade et al., 2012; U.S. Department of Health and Human Services, 2012). In their reviews of anti-tobacco campaigns, Allen et al. (2015) and Brennan et al. (2012) find several evaluations that have established associations between campaign exposure and smoking-relevant knowledge or beliefs on topics like health consequences and addiction. However, evaluations of campaigns that targeted beliefs in other topic areas, including cosmetic effects, do not show evidence of an effect (Brennan et al., 2012).

These findings suggest inconsistencies in the literature on the relationship between campaign exposure and campaign-targeted beliefs. However, it is unclear whether such inconsistencies can be attributed to the types of beliefs targeted, the ways in which exposure and belief endorsement have been measured, or to other persuasive elements of the campaigns such as superior production quality or campaign branding. In two previous studies with null findings pertinent to cosmetic effects, exposure and belief endorsement were measured in different ways. In one experimental study, advertisements that focused on the cosmetic effects of smoking were not associated with perceived

smoking risks (Pechmann, Zhao, Goldberg, & Reibling, 2003). However, these perceived risks were not specific to the themes targeted by advertisements, such as cosmetic effects; rather, they measured perceived severity of social disapproval risks due to smoking. In another study, recall of anti-smoking ads was not associated with knowledge about a cosmetic effect of smoking (Siegel & Biener, 2000). It is worth noting that in this study, ad recall reflected exposure to all anti-smoking advertisements, rather than exposure to specific ads targeting beliefs about the cosmetic effects of smoking.

Despite evidence that The Real Cost anti-smoking campaign has reduced smoking initiation, no one has tested the specific mechanisms through which the campaign was successful. This study aims to address one potential mechanism—an increase in the beliefs targeted by campaign advertisements—and offers evidence to suggest that this mechanism was successful for The Real Cost campaign in particular, and can be effective in the context of different anti-smoking themes more broadly.

Study Aims

Consistent with the integrative model of behavior prediction (Fishbein & Ajzen, 2011; Fishbein & Cappella, 2006; Fishbein & Yzer, 2003), The Real Cost campaign seeks to influence beliefs thought to underlie smoking intention and behavior, with an overarching goal of reducing intention to smoke and subsequent smoking behavior. Initial evidence indicates that the campaign succeeded in preventing smoking initiation. The present study then asks whether recall of television advertisements from The Real Cost campaign is related to the anti-smoking beliefs targeted by these ads. We hypothesized a specific positive association between recall of each ad and the belief targeted by that ad.

However, inferring campaign effects from merely showing that recall and targeted beliefs are associated is open to two major types of challenges: (a) the observed associations are the result of reversed causal direction, that is, anti-smoking beliefs lead respondents to better recall exposure to anti-smoking ads; or (b) the observed associations are merely a reflection of the influence of confounder variables affecting both anti-smoking beliefs and the likelihood of claiming recall of any anti-smoking ads. Comparing associations for campaign-targeted beliefs versus other anti-smoking beliefs allows us to distinguish the campaign effects hypothesis from the (selection and casual direction) alternative explanations for the observed associations. If these alternative explanations account for the observed associations, we would expect that ad recall would be similarly correlated with all anti-smoking beliefs, whether the campaign targeted them or not. Instead, we hypothesized that similar beliefs not specifically targeted by the campaign are less associated with ad recall.

If ad recall is merely an artifact influenced by anti-smoking beliefs, or of confounders influencing both beliefs and recall, we would expect the association of beliefs and ad recall would be present even if we asked about recall of a fake ad. Contrarily, if recall of the campaign ads actually influence beliefs, then recall of a fake ad would not be associated with the ad-targeted beliefs. We address these risks by testing whether the ad recall-belief associations are specific to ad-targeted but not non-targeted beliefs, and by assessing the relationships between recall of a fake ad and ad-targeted beliefs. Furthermore, we control for a variety of factors that could be related to relationships between ad recall and smoking beliefs to account for possible third-variable

explanations. To add to the relevance of this evidence for assessing campaign promise, we hypothesized that endorsing anti-smoking beliefs targeted by The Real Cost campaign is positively associated with having no intention to smoke cigarettes, as suggested by formative campaign research (Brennan et al., 2017).

Methods

Sample

We obtained the data for this study from a large nationally-representative, ongoing observational study of 13-17 year olds, the goal of which is to examine whether exposure to tobacco-relevant content predicts subsequent tobacco-relevant beliefs, attitudes, and use behavior (R. C. Hornik & Lerman, 2013). As such, the 20-minute telephone survey includes questions pertinent to both general media use and exposure to specific tobacco-relevant media content, including recall of The Real Cost TV advertisements. Similarly, survey questions include both general smoking-relevant beliefs and those specifically targeted by The Real Cost ads.

This analysis is based on the first 132 weeks of survey data, which Social Science Research Solutions (SSRS) collected from June 18, 2014 through December 30, 2016. During the data collection period, a total of 4,964 respondents (age 13-17) completed the survey. The sampling plan included landline (30.2%) and cell phone (69.8%) recruitment, and an oversampling of households that indicated the presence of a person aged 13-17. SSRS obtained parental consent for participants aged 13-15[1] and respondent assent for all participants prior to survey administration. SSRS conducted surveys through a

[1] The Institutional Review Board at the University of Pennsylvania did not require parental consent for respondents aged 16-17.

combination of list-assisted and random-digit dialing frames, with a response rate of 22% (AAPOR response rate #3). The Institutional Review Board at the University of Pennsylvania approved this study.

Measures

Anti-smoking beliefs. The primary dependent variables are anti-smoking beliefs targeted by The Real Cost campaign TV advertisements (see Table 2.1). To assess beliefs, respondents were read the following statement: "The next set of questions is about tobacco cigarettes. I'll read a statement, then please tell me whether you strongly disagree, disagree, agree, or strongly agree with it." Respondents answered 13 belief items about the consequences of smoking tobacco cigarettes, asked in random order. Responses were coded as 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. To determine which belief was targeted by each ad, we analyzed the audiovisual content of each ad within the context of the overarching themes of the campaign. We assigned the three targeted beliefs listed in Table 2.1 to each The Real Cost ad on the basis of these characterizations. The other ten smoking-relevant beliefs not targeted by the ads addressed in this study are listed below Table 2.1. Respondents completed recall items prior to belief items to reduce the influence of belief items on recall responses.

Table 2.1 *Advertisements, targeted beliefs, and corresponding survey questions*

Advertisement (time aired)[a]	Survey Question Describing Advertisement: "A television ad where…	Recall[b] *Mean* (*SD*)	Percentage with any recall	Targeted Belief[c]	Survey Question Assessing Belief: "If I smoke every day…	Belief[d] *Mean* (*SD*)
Your Skin (74 weeks)	a girl tears off a piece of her skin to pay for a pack of cigarettes"	6.7 (13.6)	67.9 %	Wrinkle	I will get wrinkles"	3.09 (0.70)
Your Teeth (90 weeks)	a guy yanks out a tooth to pay for a pack of cigarettes"	6.0 (12.7)	63.9 %	Teeth	I will lose my teeth"	3.20 (0.68)
Bully (19 weeks)	a tiny man bullies young people into smoking cigarettes"	4.7 (10.8)	47.1 %	Control	I will be controlled by smoking"	3.29 (0.74)
Alison (9 weeks)	a girl in a cafeteria complains about cigarettes being bossy"	3.5 (8.5)	44.0 %	Control	I will be controlled by smoking"	3.29 (0.74)

Mouse[e]	a cartoon mouse becomes addicted to cigarettes"	1.2 (6.5)	16.9 %	N/A	N/A	N/A

[a] Weeks the ad aired between May 19, 2014 – December 30, 2016 (i.e., the time during which participants reported past 30-day recall).

[b] Recall is the number of times the ad was seen in the past 30 days.

[c] The 10 non-targeted beliefs are that as a result of daily smoking, respondents will develop headaches, develop sexual and/or fertility problems, develop cancer, get yellow fingers, become addicted to nicotine, look uncool, feel relaxed, enjoy life more, breathe in thousands of toxic chemicals, and be a turnoff to other people.

[d] Beliefs are rated on a 4-point scale where 4=*strongly agree* and 1=*strongly disagree*.

[e] Mouse is a fake ad that is not part of The Real Cost campaign but is included as a comparison.

SD = standard deviation.

Intention to smoke. The secondary dependent variable is self-reported intention to smoke in the next six months. To assess intention, respondents were asked the following question: "How likely is it that you will smoke a tobacco cigarette, even one or two puffs, at any time in the next six months? Would you say definitely will not, probably will not, probably will, or definitely will?" This item was adapted from the 2010 National Survey on Drug Use and Health (Resource Center for Minority Data, 2010). We dichotomized the smoking intention variable (1 = definitely will not and 0 = probably will not, probably will, or definitely will) to facilitate comparisons between the desired and undesired categories for this variable, as past work has shown that any level of susceptibility to smoking is predictive of future uptake (Jackson, 1998; Pierce, Choi, Gilpin, Farkas, & Merritt, 1996).

Aided recall of ads. The primary independent variables are self-reported, aided recall of TV advertisements from The Real Cost campaign modeled after previous campaign evaluations (e.g., Farrelly et al., 2002; Sly, Heald, & Ray, 2001). Respondents were first asked the following question: About how many times in the past 30 days have you seen or heard of each of the following? Subsequently, they were read brief descriptions of each advertisement (Table 2.1), and responses were coded between 0-100. The first four of these ads—Your Skin, Your Teeth, Bully, and Alison—are actual campaign ads, and the fifth, Mouse, is a description of a fake ad. For the first 4 weeks of the survey, respondents were asked about all five ads in random order. For the remaining 128 weeks, respondents were asked about two to three ads randomly selected from a pool of ads that included the larger set of airing The Real Cost ads and the fake Mouse ad. Ads

were removed from the pool of ads once they were continuously off the air for three months and were not scheduled to be rebroadcast.

Potential covariates. Potential covariates were selected a priori on the basis that 1) they might be associated with targeted beliefs, 2) they are temporally prior to ad exposure, and 3) they are not expected to mediate the relationship between ad recall and targeted beliefs. These include continuous covariates: respondents' age (13-17 years), sensation seeking (1-4, where 1 = low sensation seeker and 4 = high sensation seeker; Zuckerman, 2007), parental disapproval of smoking with different response items for users and non-users (1 = don't/wouldn't mind, 2 = would/disapprove a little, and 3 = would/disapprove a lot), grades (1 = mostly A's, 2 = mostly B's, 3 = mostly C's, 4 = mostly D's, and 5 = mostly F's), and average TV watching in a week (0-168 hours). Average hours per week of TV watching is assessed with two questions: average hours per weekday and average hours per weekend. Two binary covariates include sex and household cigarette use. Finally, two categorical covariates are race (reference category = non-Hispanic White) and parent education (reference category = high school degree or less).

Statistical Analysis Plan

Analyses were conducted on the subset of survey respondents (n = 4,831) who fell within the campaign's target population (13-17 year old nonsmokers or experimenters, defined as having smoked fewer than 100 cigarettes in their lifetime). Data were analyzed using Stata version 13.1 (StataCorp, 2013). Distributions of ad recall were highly skewed with greater levels of lower recall. In all The Real Cost ad analyses,

ad recall responses were log transformed, reducing the influence of the few cases reporting very high levels of exposure. Additionally, we excluded responses to recall items assessed more than two months after ads were continuously off-air. We chose this period of time because respondents were asked to report past 30-day recall of ads, and we anticipated lingering reports of ad recall beyond the 30-day period. Given the low proportion of respondents who reported any recall of the fake Mouse ad, this variable was dichotomized, such that 1 = any recall and 0 = no recall. We regressed targeted beliefs on logged recall variables, adjusting for potential confounders including age, sex, race, sensation seeking, and average weekly TV watching.

To assess the relative influence of recall on targeted versus non-targeted beliefs, we compared the standardized regression coefficient of the targeted belief predicted from recall of each specific ad with the 10 coefficients for non-targeted beliefs predicted in separate regressions from that same ad, controlling for the same set of covariates. We conducted two-sided sign tests for matched pairs to compare each recall/targeted belief association with the corresponding set of recall/non-targeted belief associations.

In line with criteria for evaluating the potential impact of national campaigns (Farrelly, Niederdeppe, & Yarsevich, 2003), we assessed whether endorsement of campaign-targeted beliefs is related to having no intention to smoke. We conducted separate logistic regressions for having no intention to smoke on each of the targeted beliefs, adjusted for confounders. We conducted similar regressions using the original, continuous version of the outcome variable (definitely do not intend to smoke – definitely intend to smoke) to ensure that the association between belief and intention remained

significant, regardless of whether a continuous or dichotomous outcome variable was used.

Responses to recall items that participants were not randomly assigned to answer were *missing completely at random* (MCAR; Allison, 2009). To account for this MCAR missing data, we conducted all regressions involving recall with maximum likelihood missing value (MLMV) estimation.[2] Additionally, we weighted analyses to adjust for sampling procedures and to be representative of the U.S. population of 13 – 17 year olds in terms of sex, age, region, parental education, and race/ethnicity.

Results

We present the unweighted and weighted demographic distributions of the study sample in Table 2.2. Respondents in the unweighted sample were approximately evenly distributed by age group (13-15 and 16-17) and sex (male and female). Just over half of respondents were non-Hispanic Whites (51.5%) and nearly a quarter were Hispanic (24.0%), with the remaining respondents reporting they were Black/African-American (13.2%) or other/more than one race (11.3%). One quarter of respondents' parents

[2] Generally, there were very low rates of missing data. However, the Wrinkle belief, Teeth belief, and parent education variables had missing values for more than 1% of responses. To test whether these missing cases influenced our results, we employed Manski-Horowitz logical bounds (Horowitz & Manski, 2006), separately replacing the missing values with the lowest and highest value on each variable and rerunning regression models. We recoded all missing values for the Wrinkle belief to "strongly disagree" in one model and "strongly agree" in another, completed the same procedure for the Teeth belief, and reran the regression models. Using the same approach, we created two new parent education variables in which missing values were separately replaced with the lowest and highest parent education value. We then ran two additional models for each ad recall/targeted belief pair, separately replacing parent education with the new bounded parent education variables. The results from all new models did not differ substantially from the original models. We believe this provides sufficient evidence that the missingness of these items did not affect study outcomes.

attained less than or equal to a high school degree (24.8%), and the remaining respondents' parents completed at least some college (75.2%).

Ad Recall

Among the four ads studied, Your Skin had the highest recall, with 67.9% of respondents who were asked this question reporting they had seen the ad at least once in the previous 30 days (Table 2.1). Sixty-four percent of respondents reported Your Teeth recall, while less than half of respondents reported Bully and Alison recall (47.1% and 44.0%, respectively). Fewer respondents, 16.9%, indicated that they had seen the fake Mouse ad. There was a monotonic relationship between ad recall and target rating points (TRPs), an exogenous measure of campaign reach and frequency, during the study period (Figure 2.1), suggesting that self-reported ad recall reflected opportunities for ad exposure.

Table 2.2 *Unweighted and weighted demographic distribution of the study sample (n = 4,831)*

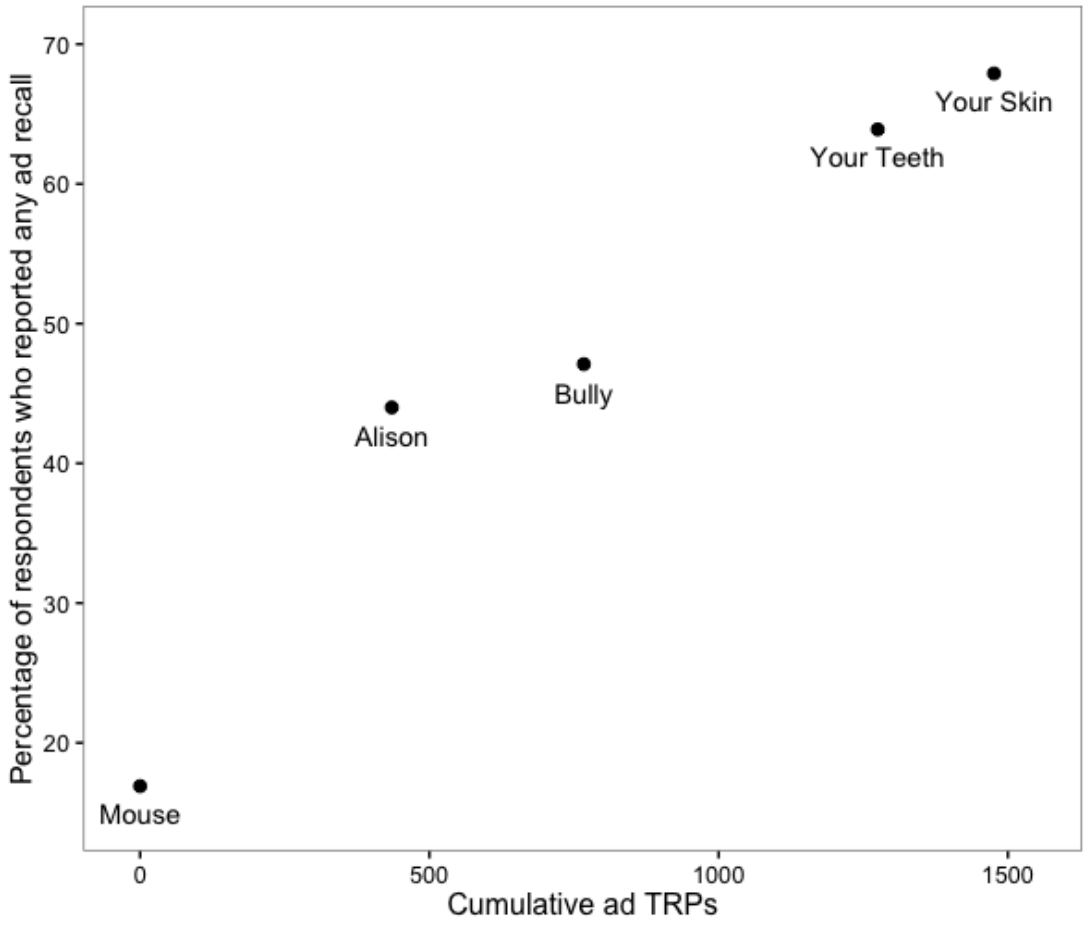
	Unweighted				Weighted		
	Frequency	Percentage	*Mean*	*SD*	Percentage	*Mean*	*SD*
Age			15.37	1.83		15.10	2.12
13-15	2,306	47.8			59.5		
16-17	2,521	52.2			40.4		
Sex							
Male	2,528	52.4			50.5		
Female	2,297	47.6			49.5		
Race							
White (non-Hispanic)	2,475	51.5			51.2		
Hispanic	1,154	24.0			22.1		
Black or African American (non-Hispanic)	635	13.2			14.1		
Other or more than one race	545	11.3			12.6		

Grades			4.36	0.77		4.33	0.80
Mostly A's (5)	2,413	50.7			49.1		
Mostly B's (4)	1,780	37.4			37.6		
Mostly C's (3)	467	9.8			10.9		
Mostly D's (2)	68	1.4			1.6		
Mostly F's (1)	35	0.7			0.8		
Sensation seeking (1-4)			2.41	0.52		2.40	0.52
Average weekly hours TV watching			24.0	21.2		24.4	21.6
Parent educational attainment							
Less than or equal to a high school degree	1,036	24.8			33.7		
Some college	654	15.7			22.7		
College degree	1,380	33.0			23.5		
Completed graduate school	1,109	26.5			20.1		
Parental disapproval of smoking			2.90	0.35		2.90	0.36

Don't/wouldn't mind (1)	77	1.6	1.7
Would/disapprove a little (2)	346	7.2	7.0
Would/disapprove a lot (3)	4,393	91.1	91.3
Household cigarette use			
No/Lives alone	3,603	75.5	73.0
Yes	1,168	24.5	27.0

Note. All analyses were conducted using weights representative of the U.S. population of 13-17 year olds. *SD* = standard deviation.

Figure 2.1 *Cumulative ad target rating points (TRPs) and percentage of respondents who reported any ad recall*



Association of Ad Recall with Targeted and Non-Targeted Beliefs

We regressed targeted beliefs on ad recall for each of the four targeted belief/ad recall pairs. Recall of all four of The Real Cost ads significantly predicted endorsement of the associated targeted belief (see Table 2.3). Recall of the ads Your Skin, Your Teeth, Bully, and Alison all showed associations with their targeted beliefs (Models 1-4, with standardized coefficients of 0.142, 0.112, 0.136, and 0.148, $p < .05$). As anticipated, there were no significant associations between recall of the fake Mouse ad and any of the three campaign-targeted beliefs (Table 2.4). Additionally, we tested for moderation of these associations by looking at the interactions between ad recall and two high-risk subgroups relative to their less risky peers, smoking experimenters (ever tried) and high sensation-seekers (top 25% of scores); none of these interactions were statistically significant.

In contrast, for each of The Real Cost ads, the average of the non-targeted belief and ad recall associations was less than half the magnitude of the comparable targeted belief association (0.059, 0.041, -0.017, and 0.020, respectively). To directly test whether the association of each ad with its targeted belief was larger than its association with the 10 non-targeted beliefs, we conducted a sign test, examining how many of the 10 associations of each ad with non-targeted beliefs were larger than the association of each ad with the targeted belief. The two-sided sign tests showed that for each of the 4 ads studied, ad recall/targeted belief associations were stronger than ad recall/non-targeted belief associations for all 10 comparisons ($Z = 2.0$, $p < .05$ across all ads). This finding supports our central hypothesis, that the recall-belief association is stronger for the

specific beliefs targeted by each campaign advertisement than for the non-targeted beliefs.

Table 2.3 *Multiple regression analysis of targeted beliefs on The Real Cost ad recall*

	Model 1 Wrinkle belief on Your Skin recall n = 1,558			Model 2 Teeth belief on Your Teeth recall n = 1,655			Model 3 Control belief on Bully recall n = 563			Model 4 Control belief on Alison recall n = 470		
	β	B	SE	β	B	SE	β	B	SE	β	B	SE
Ad recall	**.142*** **	.088	.022	**.112*** **	.068	.018	**.136***	.087	.042	**.148***	.104	.044
Age	**.034***	.011	.005	.019	.006	.005	.018	.006	.007	.026	.009	.007
Sex	-.009	-.012	.028	-.030	-.041	.026	**-.051****	-.076	.029	**-.044***	-.065	.030
Race (White=*Ref.*)												
Hispanic	**-.072****	-.124	.040	-.021	-.036	.036	**-.092*****	-.165	.042	**-.095*****	-.171	.042
Black/AA	**-.074****	-.151	.047	-.025	-.049	.046	-.039	-.082	.047	**-.051***	-.109	.053
Other race	.005	.010	.039	-.022	-.046	.043	-.034	-.075	.042	-.029	-.064	.043
Sensation seeking	-.031	-.043	.032	**-.084*****	-.112	.030	**-.086*****	-.123	.033	**-.092*****	-.131	.033

Parental Education (HS=*Ref.*)												
Some college	.015	.025	.048	.027	.045	.043	**.067***	.119	.049	**.058***	.103	.048
College degree	.036	.060	.040	.007	.011	.038	**.061***	.106	.045	**.055***	.096	.044
Graduate degree	**.070****	.124	.044	**.050***	.087	.042	**.083****	.154	.045	**.078****	.144	.046
Parent disapproval	**.069*****	.140	.037	**.102*****	.200	.039	**.075****	.159	.046	**.076****	.162	.047
Household cigarette use	-.009	-.014	.032	-.024	-.037	.033	-.021	-.035	.034	-.023	-.039	.035
Grades in school	.013	.012	.019	-.005	-.004	.019	**.050***	.047	.021	.037	.035	.020
TV watching	-.027	-.001	.001	.030	.001	.001	-.028	-.001	.001	-.017	-.001	.001

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). All analyses were weighted and used maximum likelihood estimation to account for values missing completely at random (MCAR). B = unstandardized coefficient. SE = standard error. β = standardized coefficient. *Ref.* = reference category. AA=African American. HS=high school or less.

Table 2.4 *Multiple regression analysis of targeted beliefs on fake mouse ad recall*

	Model 1 Wrinkle belief on Fake Mouse ad recall n = 1,727			Model 2 Teeth belief on Fake Mouse ad recall n = 1,742			Model 3 Control belief on Fake Mouse ad recall n = 1,765		
	β	B	SE	β	B	SE	β	B	SE
Ad recall	.026	.049	.057	.043	.079	.057	.050	.100	.056
Age	**.039****	.013	.004	.024	.008	.004	-.001	-.000	.005
Sex	-.015	-.022	.028	-.029	-.040	.026	**-.046***	-.069	.028
Race (White=*Ref.*)									
Hispanic	**-.065****	-.113	.039	-.016	-.026	.036	**-.093*****	-.168	.040
Black/AA	**-.063****	-.128	.046	-.010	-.021	.044	-.025	-.054	.044
Other race	.008	.018	.039	-.016	-.033	.044	-.030	-.067	.040
Sensation seeking	-.015	-.021	.031	**-.080*****	-.106	.030	**-.084*****	-.120	.032

Parental Education (HS=*Ref.*)									
Some college	.010	.018	.047	.029	.048	.043	.045	.080	.044
College degree	.030	.050	.039	.011	.018	.038	.043	.075	.040
Graduate degree	**.067****	.118	.043	**.054***	.093	.042	**.073****	.136	.042
Parent disapproval	**.087*****	.175	.035	**.106*****	.208	.039	**.071****	.150	.045
Household cigarette use	.005	.009	.031	-.010	-.016	.032	-.018	-.030	.033
Grades in school	.007	.006	.019	-.003	-.002	.019	.035	.033	.019
TV watching	-.015	-.000	.001	.036	.001	.001	-.006	-.000	.001

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). All analyses were weighted and used maximum likelihood estimation to account for values missing completely at random (MCAR). B = unstandardized coefficient. SE = standard error. β = standardized coefficient. *Ref.* = reference category. AA=African American. HS=high school or less.

Association of Targeted Beliefs with Having No Intention to Smoke

If the campaign was successful at changing the targeted beliefs, is there reason to think that the campaign would successfully reduce smoking initiation? Confirming the findings from formative analyses, results of logistic regression analyses adjusting for relevant confounders indicate that all three campaign-targeted beliefs are significantly associated with having no intention to smoke: Wrinkle belief (OR = 1.29, CI: 1.12, 1.49), Teeth belief (OR = 1.40, CI: 1.20, 1.64), and Control belief (OR = 1.27, CI: 1.11, 1.45). We conducted a sensitivity analysis using the continuous version of the intention variable to ensure that the aforementioned associations between beliefs and intention were not attributed to the dichotomized outcome variable; all three associations between beliefs and the continuous version of having no intention to smoke were statistically significant at $p < .01$.

Discussion

This study evaluated the relationship between recall of television advertisements from The Real Cost campaign, anti-smoking beliefs targeted by these ads, and having no intention to smoke. Results established significant, positive associations between recall of four campaign ads and the beliefs targeted by these ads, after adjustment for confounders. Specifically, results indicated relationships between Your Skin recall and the Wrinkle belief, Your Teeth recall and the Teeth belief, Bully recall and the Control belief, and Alison recall and the Control belief. Furthermore, these associations were larger than the association of ad recall with beliefs not targeted by The Real Cost campaign, supporting our central hypothesis. Also, the targeted beliefs were associated with having no intention

to smoke, suggesting that increasing endorsement of these beliefs may increase the likelihood that youths will have no intention to smoke.

Contrary to the null findings from evaluations of campaigns that targeted beliefs associated with cosmetic effects (Brennan et al., 2012), our results demonstrate associations between campaign exposure and beliefs about the negative cosmetic effects of smoking, suggesting that these beliefs can be influenced by campaign messages. These findings may indicate that ads from The Real Cost campaign are more persuasive than cosmetic effect ads from previous studies, or that ad exposure and ad-targeted belief endorsement have not been measured in a consistent way across studies. Indeed, in two previous studies with null findings pertinent to cosmetics effects, these variables were measured in different ways (Pechmann et al., 2003; Siegel & Biener, 2000). Thus, neither of these studies measured the relationship between exposure to ads that specifically target beliefs about the cosmetic effects of smoking and endorsement of those specific beliefs. This comparison underscores the importance of measuring such variables distinctly when examining the specific pathways through which campaign effects may occur.

Are these results enough to support a claim that The Real Cost campaign has been effective in influencing beliefs related to smoking? The strongest support comes from the specificity of the results. Our analyses show ad recall was less related to the non-targeted than the targeted anti-smoking beliefs; it is then less likely that observed recall-targeted belief associations are driven by reverse causation or third variable influence. Furthermore, the lack of association between recall of a fake Mouse ad and campaign-targeted beliefs also reduces such concerns. Moreover, our findings suggest that

endorsement of specific, targeted beliefs is related to having no intention to smoke. This structure of evidence is consistent with a claim of The Real Cost effects on campaign-targeted beliefs associated with intention.

Readers may be curious about how the two sets of results, the association of exposure and belief and of belief and intention might translate into an estimated magnitude of effect of exposure to each ad on intention, if we assume both relationships are causal. These estimates are generated through the following process: We first estimate what the expected belief scores would be for those who were not exposed, and for those who were highly exposed to the ad (defined as the mean recall plus one standard deviation), then use the regression of intention on the belief score to estimate the difference in predicted intention for individuals, contingent on those expected belief scores, translated into predicted probabilities. If the observed difference in belief between those unexposed and exposed to the ad is translated into an expected difference in having no intention to smoke, we would project an increase in having no intention to smoke of 5% for Your Teeth and Bully ads and 6% for Your Skin and Alison ads. These likely represent the maximum potential effect on intention of exposure to the individual ads, although they are likely to overestimate the actual effect.

Given recent evidence suggestive of campaign effects on smoking initiation (Farrelly et al., 2017) and the theoretical models upon which the campaign was developed (Duke et al., 2015), our findings are consistent with the idea that campaign ads indirectly reduced youth smoking initiation through ad-targeted beliefs. Though we have speculated about how the cross-sectional associations might translate into an effect of

exposure to each ad on intention, we do not think such cross-sectional data can support a formal analysis of whether ad-targeted beliefs mediated this relationship. We will need to wait for additional evidence to fully establish that beliefs targeted by The Real Cost campaign ads mediate the relationships between campaign exposure and smoking intention/behavior.

Limitations and Conclusion

There are several limitations to this study. Analyses were conducted with cross-sectional data, which limits our ability to draw causal inferences. Though the targeted belief specificity of the observed associations and the lack of association between recall of the fake Mouse ad and beliefs reduce concerns about unmeasured confounders, there is one circumstance where the specificity of the results does not eliminate the concern about reverse causation. If general anti-tobacco sentiment made it more likely that people would claim to recall the ads, then we would expect to see that all of the beliefs, targeted or not, would be associated with ad recall (and with fake ad recall), which is not what we found. However, if endorsement of specific beliefs only affected recall of ads targeted to those beliefs, but endorsement of non-targeted beliefs does not affect recall of target-belief linked ads, then reverse causation might still account for the observed pattern of associations. Recall measures rely on self-report and may not reflect actual ad exposure, or may exclude influential first exposures as recall items assess past 30-day exposure. Recall of the fake Mouse ad was dichotomized due to the low proportion of respondents who reported any recall; therefore, it is possible that we were unable to detect relationships between fake Mouse ad recall and campaign-targeted beliefs due to limited

variability. However, the fact that reported recall of the fake Mouse ad was so low suggests that respondents distinguished between fake and real ads, reflecting the validity of these measures. Finally, non-response bias may limit inferences about national populations made from study results; we attempted to address this bias by weighting the survey to known characteristics of the population.

According to Farrelly and colleagues (2003), criteria for evaluating the potential impact of national campaigns include establishing that higher levels of exposure are associated with targeted outcomes. Our results largely satisfy this criterion; for all four of The Real Cost ads studied, higher levels of recall were associated with targeted beliefs, which were in turn associated with having no intention to smoke. While there are always limitations to the interpretation of evaluations that rely on cross-sectional survey data, researchers do not always have the luxury of evaluating media campaigns with more robust types of data collected over time (e.g., repeated cross-sectional or longitudinal data). Our methodological approach offers a tool to support claims about media campaign effects within the confines of feasible data collection approaches.

The results from this study provide evidence consistent with published evaluations of The Real Cost campaign (Farrelly et al., 2017; Huang et al., 2017). Our analysis is the first to show discriminating associations between recall of The Real Cost anti-smoking campaign and targeted, rather than non-targeted, beliefs in a sample of adolescents. This study represents only a first step toward evaluating the pathway of effects through which The Real Cost campaign was expected to influence smoking behavior. Future research should examine whether campaign-targeted beliefs mediate the

relationship between campaign exposure and smoking behavior, which would offer additional evidence in support of campaign effects. Furthermore, future studies should incorporate exogenous measures of campaign exposure to complement self-reported campaign recall.

CHAPTER 3. THE RELATIONSHIP BETWEEN EXOGENOUS CAMPAIGN EXPOSURE AND CAMPAIGN-TARGETED BELIEFS

Introduction

Smoking is the leading preventable cause of disease and death in the U.S., responsible for more than 480,000 deaths per year (U.S. Department of Health and Human Services, 2014). Tobacco use is established primarily during adolescence, with approximately 90% of smokers having tried cigarettes before age 18 (U.S. Department of Health and Human Services, 1994, 2012, 2014); consequently, adolescents are at an increased risk of initiating and progressing to regular smoking relative to other segments of the population. Anti-smoking media campaigns can attenuate these risks by influencing young people's beliefs about the consequences of smoking, beliefs that predict reduced intention to smoke and decreased smoking behavior (Australian Government Department of Health and Ageing, 2005; Freedman et al., 2011; Goldade et al., 2012; U.S. Department of Health and Human Services, 2012). There is sufficient evidence to conclude that mass media campaigns, in concert with other tobacco control efforts, are responsible for preventing initiation and reducing the prevalence of tobacco use among youth (U.S. Department of Health and Human Services, 2014).

In February 2014, the Food and Drug Administration (FDA) launched "The Real Cost" national, youth-targeted smoking prevention media campaign. The overarching goal of the campaign is to educate youths aged 12–17 about the "real costs" of tobacco use, thereby influencing smoking-relevant beliefs underlying behavior (Duke et al., 2015). To date, several evaluations have demonstrated evidence consistent with a claim

of effects for The Real Cost campaign (Farrelly et al., 2017; Huang et al., 2017; Kranzler, Gibson, & Hornik, 2017). However, these studies employed respondent self-reported, aided recall of campaign ads as an indicator of campaign exposure, along with self-assessments of tobacco-related beliefs or behavior. This measurement approach is subject to several sources of bias and threats to the validity of the claims made on the basis of their outcomes.

Measures of Campaign Exposure

Self-reported exposure and outcomes are often assessed on the same survey instrument, and thus may not be independent of each other. Specifically, observed associations between self-reported exposure and outcomes may reflect reverse causal direction, or the influence of a third variable on both predictor and outcome (Liu & Hornik, 2016; Slater, 2004). The reverse causation explanation is of particular concern when analyses are conducted with cross-sectional data due to the absence of temporal ordering. Other validity threats associated with self-reported exposure include recall and social desirability biases. Respondents' inability to completely or accurately recall past exposure to campaign ads may influence their responses to aided recall measures. For example, when asked to report past 30-day ad exposure, a respondent may underreport if they better recall the frequency of ad exposures during the previous week, or overreport if they cannot distinguish exposures from 25 and 35 days previously. Additionally, self-reported recall may be influenced by an individual's propensity to respond to questions in a way that will be viewed favorably. Thus, threats to the validity of findings from these

evaluations of The Real Cost campaign call for additional research that incorporates measures of campaign exposure not assessed through self-report.

Exogenous Measures of Campaign Exposure

An alternative approach to evaluating the efficacy of a mass media campaign is to predict campaign outcomes using an exogenous measure of campaign exposure. Whereas self-report measures of exposure quantify individual differences in exposure, exogenous (or ecological) measures of exposure reflect *opportunities* for exposure based on the availability of messages in a specific environment. Exogenous exposure commonly involves comparing units that vary with geography or time: geographic variation occurs when certain geographic units, such as a state or media market, receive messages more frequently than others, whereas temporal variation compares units (still often geographically-based) whose campaign exposure varies over time (Niederdeppe, 2014).

There are several strengths associated with the use of exogenous measures of exposure in campaign evaluation research. Analyses based on exogenous exposure support stronger causal inferences than those that rely on self-reported campaign awareness or recall (Slater, 2004). Exogenous exposure is assessed independently of outcome measures, reducing concerns about reverse causal direction and third variable influence inherent in studies that incorporate endogenous measures of exposure (Liu & Hornik, 2016). The use of exogenous exposure can eliminate biases affiliated with self-reported exposure, including variation in ability to recall campaign exposure and social desirability bias (Liu & Hornik, 2016), thereby offering a measure less vulnerable to individual idiosyncrasies. Another advantage pertains to the route(s) through which

campaign messages influence outcomes; whereas self-reported exposure is likely to capture an individuals' direct exposure to a campaign, thereby potentially underestimating overall effects, a strength of exogenous exposure measures is their potential to capture campaign exposures that occur through both direct and indirect (personal, social and institutional) routes of exposure (Hornik & Yanovitzky, 2003).

Media Ratings and Tobacco-Relevant Outcomes

One category of exogenous campaign exposure−commercial media ratings−are typically quantified by Gross Rating Points (GRPs) and Target Rating Points (TRPs). GRPs measure a population's opportunities for exposure to media content, equal to the product of media content reach and frequency of exposure. TRPs quantify the same measure among targeted individuals (e.g., 13 – 17-year-olds) within a larger population (Farris, Bendle, Pfeifer, & Reibstein, 2010). Simply put, TRPs are an aggregate indicator of exposure within a targeted population over a specific period of time.

A substantial body of research has established relationships between tobacco-relevant media ratings (both GRPs and TRPs) and subsequent tobacco use outcomes among youth (Duke et al., 2014; Dunlop, Cotter, Perez, & Wakefield, 2013; Emery et al., 2005, 2012; Farrelly et al., 2012; Farrelly, Davis, Duke, & Messeri, 2009; Farrelly, Davis, Haviland, Messeri, & Healton, 2005; Nonnemaker et al., 2014; Pierce, Anderson, Romano, Meissner, & Odenkirchen, 1992; Sims et al., 2014; Wakefield et al., 2006; Wakefield et al., 2008; White, Durkin, Coomber, & Wakefield, 2013), providing evidence that media ratings indicative of exposure to tobacco-relevant content are associated with beliefs, attitudes, intentions, and behaviors related to tobacco use. To

date, only one study has examined the relationship between exogenous exposure to The Real Cost campaign and campaign outcomes (Duke et al., 2017). The study sample consisted of 1,680 susceptible nonsmokers and experimenters, aged 11-16 at baseline, from 75 U.S. media markets who completed the first 3 waves of a nationally-representative longitudinal survey of adolescents between November 2013 – July 2015. Multivariate logistic regression models were conducted to estimate the odds of endorsing campaign-targeted and non-targeted beliefs at the first and second follow-ups as a function of cumulative TRPs, ad-specific TRPs, and self-reported ad recall between survey waves. Results demonstrated that higher levels of campaign exposure, for cumulative TRPs, ad-specific TRPs, and self-reports, were associated with greater odds of endorsing 5 of 8 campaign-targeted beliefs from baseline to both follow-ups, controlling for covariates. Furthermore, parallel models demonstrated no association between exposure and endorsement of 12 of 14 non-targeted beliefs.

Findings suggest that exogenous measures of campaign exposure influenced tobacco-related beliefs theorized to precede behavioral outcomes, thereby supporting claims of campaign effects from other studies (Farrelly et al., 2017; Huang et al., 2017; Kranzler et al., 2017). However, the study by Duke et al. (2017) focused on the effects of geographic variation in TRPs rather than temporal variation in exposure. Thus, results are subject to the concern that an unmeasured confounder, a characteristic specific to a given media market, affected both average beliefs and the TRPs bought for that market and thus influenced their association. Furthermore, results illustrate the effects of exposure to only 6 advertisements disseminated during the first 18 months of the campaign. Over the

subsequent 18 months of the campaign, an additional 8 campaign ads were introduced into the rotation of ads, and the association between exposure to these ads and endorsement of beliefs they target has not yet been tested.

Current Study

To replicate the previous findings and to address limitations from previous studies, we have undertaken a new analysis with a different set of data and distinct analytical approach. The purpose of this study is to assess the efficacy of The Real Cost campaign by evaluating the relationship between week-to-week temporal variation in Target Rating Points (TRPs) for specific campaign ads that were available in the media environment and endorsement of the specific anti-smoking beliefs targeted by these ads in the campaign's target population. Our analyses employ an exogenous measure of campaign exposure to reduce concerns about reverse causal direction from previous self-report studies, and assess the effects of temporal variation, rather than geographic variation, in campaign exposure to reduce concerns about unmeasured market-level confounders influencing TRP/belief associations. We hypothesized that TRPs for The Real Cost campaign advertisements would be positively associated with endorsement of ad-targeted anti-smoking beliefs, assuming that exposure to the ad influenced the specific beliefs endorsed by that ad. This would be solid evidence for a Real Cost effect.

Still, a skeptic might wonder whether any observed over-time association between TRPs and beliefs was an artifact of time-varying external events affecting both investment in anti-smoking ads, and general anti-smoking beliefs. For example, if seasonally-varying concerns about smoking affected both the purchase of ad time, and

(because of additional media coverage of smoking) population concerns about smoking, this might enhance the TRP and belief association. However, if that were true, we would expect that exposure to anti-smoking advertisements would be associated with not just these specific beliefs targeted by ads but all anti-smoking beliefs. To address this alternative explanation, we also assessed whether TRPs associate with anti-smoking beliefs not targeted by campaign messages. We hypothesized that TRPs for The Real Cost campaign advertisements would be less associated with endorsement of anti-smoking beliefs not targeted by campaign ads than with ad-targeted beliefs.

Methods

Datasets

Data for this study was drawn from two datasets. Dataset #1 is a national observational survey of youth and young adults, undertaken by the University of Pennsylvania. The 20-minute survey measured knowledge, beliefs, intentions, and behaviors related to tobacco products and tobacco product use, including smoking-relevant beliefs targeted by The Real Cost campaign advertisements and similar beliefs not explicitly targeted by the campaign. The survey also measured respondents' typical media use patterns, sociodemographic characteristics, and tobacco use risk factors. Data was collected through a rolling, cross-sectional telephone survey from June 18, 2014 through December 24, 2016, administered to a nationally-representative sample of 13–25-year-olds. Study respondents were recruited by research firm Social Science Research Solutions (SSRS) through random digit dial (RDD) and list assisted sampling of

both landline and cell phone samples.[3] Each week, a unique sample of respondents was randomly selected from the population for survey participation. A total sample of 10,038 respondents completed the survey.[4] To align the study sample with the target population for The Real Cost campaign (12–17-year-old nonsmokers and smoking experimenters), the study sample has been limited to 13–17-year-olds who reported having smoked fewer than 100 cigarettes in their lifetime (n = 4,780).

Dataset #2 consists of national Target Rating Points (TRPs) for The Real Cost campaign. TRP data was provided by the Food and Drug Administration's (FDA) Center for Tobacco Products (CTP), which funds and oversees campaign implementation. National TRPs are provided on a weekly basis for each advertisement, starting on the Monday of each week since the campaign was initiated on Monday, February 10, 2014 and ending on Saturday, December 24, 2016; availability of weekly data permitted alignment of the TRP data with the survey sample.

Measures

Anti-smoking beliefs. The dependent variables are anti-smoking beliefs targeted by each campaign advertisement. Respondents were read a set of 13 belief statements about daily smoking and asked to indicate the extent to which they agreed or disagreed with each belief. Responses were provided on a 4-point scale, where strongly disagree = 1 and strongly agree = 4. Table 3.1 lists the names of each belief item, the corresponding

[3] Some survey respondents were recontacted 6 months after their initial interview to complete a follow-up survey. In this study, we focused only on responses from initial interviews.

[4] The American Association of Public Opinion Research (AAPOR) response rate 3 was estimated at 22%.

survey questions, and the classification of each belief as targeted or non-targeted by campaign ads. Beliefs targeted by campaign ads are the Wrinkle, Teeth, Control, and Chemical beliefs.

Target Rating Points. The independent variable is the total number of TRPs attained for each grouping of advertisements from The Real Cost campaign during 4-week intervals. Advertisements are grouped by their targeted beliefs (Wrinkle, Teeth, Control, and Chemical). Table 3.2 lists the names, descriptions, and targeted beliefs for each campaign ad. TRPs for ads within each targeted-belief group were combined, by week, into one TRP variable for each targeted belief. Weekly totals of TRPs were aggregated to form 4-week measures, based on 4-week periods receding from each week of interviews, for each targeted-belief TRP variable.

Table 3.1 *Names of smoking-relevant belief items, corresponding survey questions, and classification of beliefs (targeted vs. non-targeted by campaign ads)*

Name of belief item	Survey question ("If I smoke every day…")	Belief classification
Wrinkle	…I will get wrinkles.	Targeted
Teeth	…I will lose my teeth.	Targeted
Control	…I will be controlled by smoking.	Targeted
Chemical	…I will breathe in thousands of chemicals.	Targeted
Headache	…I will develop headaches.	Non-targeted
Sexual/fertility	…I will develop sexual and/or fertility problems.	Non-targeted
Cancer	…I will develop cancer.	Non-targeted
Yellow fingers	…I will get yellow fingers.	Non-targeted
Addiction	…I will become addicted to nicotine.	Non-targeted
Uncool	…I will look uncool.	Non-targeted
Turn off	…it will be a turn off to other people.	Non-targeted
Relaxed	…I will feel relaxed.	Non-targeted
Enjoy life	…I will enjoy life more.	Non-targeted

Note. Three additional belief items were administered to some survey respondents but are not used in these analyses: Friends ("If I smoke every day, I will gain friends"), Lungs ("If I smoke every day, I will develop smaller lungs"), and Brain ("If I smoke every day, it will change my brain"). The Friends belief was removed from the survey on July 17, 2014, and the Lungs and Brain beliefs were not added to the survey until October 19 and 26, 2017 (respectively). These belief items are excluded from analyses because they were not administered to most respondents, and the ads that targeted the Lungs and Brain beliefs were not introduced until October 2016.

Table 3.2 *Names, descriptions, and targeted beliefs for advertisements from The Real Cost campaign*

Ad name	Ad description	Ad-targeted belief
Your Skin	A girl tears off a piece of her skin to pay for a pack of cigarettes.	Wrinkle
Your Teeth	A guy yanks out a tooth to pay for a pack of cigarettes.	Teeth
Bully	A tiny man bullies a teenage young people into smoking cigarettes.	Control
Alison	A girl in a cafeteria complains about cigarettes being so bossy.	Control
Band	A tiny bully drags a drummer away from band practice to smoke.	Control
Dance	A tiny bully makes a teen leave his prom date for a smoke.	Control
Stay in Control	A girl gives up her freedom by signing a contract that turns into a cigarette.	Control
The 7,000	Swamp creatures turn into 7,000 toxic chemicals as a guy inhales cigarette smoke.	Chemical
Found it	A disgusting creature crawls into a teen's mouth before hiding in a cigarette pack.	Chemical
Science Class	A disgusting creature escapes while being dissected in a science class and crawls into a cigarette pack.	Chemical

Note. Four additional The Real Cost ads were aired during the study period: #ReasonsNotToSmoke, Any Reason, Hacked, and Straw City. The #ReasonsNotToSmoke and Any Reason ads are excluded from analyses because the survey did not assess the anti-smoking beliefs targeted by these ads. The Hacked and Straw City ads are excluded from analyses because they were not initially aired until October 2016.

Covariates. The randomly selected weekly samples of youth were designed to represent the population; there should be no association between TRPs in a given week and background characteristics of the sample. Nonetheless the weekly samples were small (around 35 per week) and there would likely be chance differences in background characteristics distributions across weeks. To detect ad effects more cleanly in the context of such differences, analyses controlled for a range of potential covariates. These include respondents' specific age (13-17 years), sex, race (non-Hispanic White/Caucasian, non-Hispanic Black/African-American, Hispanic, and multiple races/other), sensation seeking (1-4, where 1 = low sensation seeker and 4 = high sensation seeker) (Zuckerman, 2007), parent education (less than or equal to a high school degree, some college, college degree, and completed graduate school), parental disapproval of smoking with different response items for users (don't mind, disapprove a little, and disapprove a lot) and non-users (wouldn't mind, would disapprove a little, and would disapprove a lot), household cigarette use, grades (mostly A's, mostly B's, mostly C's, mostly D's, and mostly F's), TV watching over the past seven days (0-168 hours), and continuous interview week. Parent education is used as a proxy for socioeconomic status, and past 7-day TV watching behavior is used as a proxy for general TV watching behavior.

Analyses

Previous studies assessing the influence of exogenous measures of exposure to tobacco advertisements have typically used behavior (e.g., smoking initiation or prevalence, quit attempts) as the primary outcome measure. Across these studies, exposure aggregated over varying periods of time (e.g., 3 months versus 12 months) has

predicted different behavioral outcomes (Emery et al., 2005; Wakefield, Spittal, Yong, Durkin, & Borland, 2011), suggesting that the effects of exposure may vary according to the length of the exposure period and/or the outcome being measured.

The current study assesses the relationship between ad exposure and a different class of outcome variable—ad-targeted beliefs. Given that changes in beliefs associated with behavior are theorized to precede actual behavior (Fishbein, 2008; Fishbein & Ajzen, 2011), it is feasible that it takes less time for campaign exposure to influence beliefs than behavior. Thus, one might expect that TRPs aggregated over a shorter period (relative to studies of behavioral effects) would relate to endorsement of campaign-targeted beliefs. We also speculate that the belief effects of ads focused on a single message will happen quicker than effects tied to multi-message campaigns.

In previous work that examined the relationship between self-reports of ad recall and belief endorsement (Kranzler et al., 2017), we demonstrated that past 30-day recall of ads was significantly associated with targeted belief endorsement, suggesting that past 30-day ad exposure is a relevant period for detecting effects. Based on these findings, we chose to test whether past 4-week TRPs predicted targeted belief endorsement,[5] as well as non-targeted belief endorsement. Though we anticipated potential indirect effects on non-targeted beliefs, we expected them to be smaller than the direct effects of TRPs on the beliefs directly targeted by the ads.

We note that Duke et al. (2017) previously demonstrated that cumulative ad TRPs over a much longer period, approximately 7-9 months, were associated with belief

[5] We used 4-week periods in lieu of 30-day periods, as TRP data is provided on a weekly basis.

endorsement. However, the authors used media markets and not units of time as their units of analysis, and were forced to use this extended time period because it was the elapsed time between each survey wave. Although this finding did raise the possibility that longer-term campaign exposure can influence targeted beliefs, we thought there was substantive justification for detecting belief effects after a four-week period, and there was practical justification as well; we only had 36 months of available data.

Analysis Plan

Prior to conducting analyses, we aggregated the TRP data as follows. TRPs for ads within each targeted-belief group (e.g., all ads that target the Control belief) were summed by campaign week (*trpweek*), generating 4 new TRP variables. For each belief-specific TRP variable, weekly TRPs were aggregated to form past 4-week summed measures, based on 4-week periods prior to and including each *trpweek*.[6] In the survey dataset, respondents were assigned *trpweek* values consistent with the campaign week during which they completed the survey. Finally, the TRP and survey datasets were merged by *trpweek*, such that past 4-week aggregated TRPs for each ad or set of ads were assigned to each respondent by interview week. To ease interpretation of regression results, all TRP variables were scaled to 1 = 1,000 TRPs.

To assess associations between TRPs for each targeted-belief group of ads and endorsement of ad-targeted anti-smoking beliefs, we estimated a series of regression

[6] It is possible that respondents interviewed earlier in each campaign week had fewer opportunities for exposure to weekly ads than respondents interviewed later in the week. To account for these differences in exposure opportunities, 4-week periods receding from each week of interviews began halfway through the corresponding campaign week (*trpweek*).

models in which past 4-week TRPs for each ad or set of ads were separately used to predict respondents' endorsement of the corresponding ad-targeted belief, controlling for potential covariates. These analyses allowed us to test the primary hypotheses.

To permit comparison of these TRPs and targeted belief associations and the associations between TRPs and endorsement of non-targeted anti-smoking beliefs (see Table 3.1 for all beliefs), we estimated a parallel series of regression models. The models were identical to those used in the preceding set of analyses, however the outcome variables were non-targeted anti-smoking beliefs. Consistent with previous work that examined the relationship between ad recall and belief endorsement (Kranzler et al., 2017), the standardized regression coefficient of the targeted belief predicted from past 4-week TRPs for each ad or set of targeted-belief ads was compared with the 9 coefficients for non-targeted beliefs predicted in separate regressions from those same past 4-week TRPs. Specifically, we conducted two-sided sign tests for matched pairs to compare each TRP/targeted belief association with the corresponding set of TRP/non-targeted belief associations.

Results

The demographic distributions of the study sample are presented in Table 3.3. Respondents were approximately evenly distributed by age group (13-15 and 16-17) and sex (male and female). Approximately half of respondents were white (51.5%) and the majority of respondents' parents attained at least a college degree (59.7%).

Table 3.3 *Demographic distributions of the study sample (n = 4,780)*

	Frequency	Percentage	*Mean*	*SD*
Age			15.35	1.40
13-15	2,285	47.8		
16-17	2,495	52.2		
Sex				
Male	2,499	47.7		
Female	2,275	52.4		
Race				
White (non-Hispanic)	2,449	51.5		
Hispanic	1,146	24.1		
Black or African American (non-Hispanic)	628	13.2		
Other or more than one race	536	11.3		
Sensation seeking			2.41	0.52
Parent educational attainment				
Less than or equal to a high school degree	1,027	24.8		
Some college	643	15.5		

College degree	1,369	33.1		
Completed graduate school	1,100	26.6		
Parental disapproval of smoking			2.90	0.35
Don't/wouldn't mind (1)	76	1.6		
Would/disapprove a little (2)	343	7.2		
Would/disapprove a lot (3)	4,346	91.2		
Household cigarette use				
No/Lives alone	3,562	75.5		
Yes	1,159	24.6		
Grades			4.36	0.77
Mostly A's (5)	2,385	50.6		
Mostly B's (4)	1,765	37.5		
Mostly C's (3)	461	9.8		
Mostly D's (2)	67	1.4		
Mostly F's (1)	34	0.7		
Average weekly hours TV watching			23.95	21.16

Note. SD = standard deviation.

Univariate Distributions of Ad-Targeted Beliefs and TRPs

On average, respondents reported agreement with each ad-targeted belief. Respondents most strongly endorsed the Chemical belief (M = 3.47, SD = 0.65), followed by the Control belief (M = 3.29, SD = 0.74), Teeth belief (M = 3.20, SD = 0.68), and Wrinkle belief (M = 3.09, SD = 0.70). There was considerable variation in past 4-week TRPs across the four targeted-belief TRP categories. On average, respondents had fewer opportunities for exposure to ads targeting the Teeth and Wrinkle beliefs, with mean 4-week TRP values of 38.24 (SD = 32.59) and 41.46 (SD = 41.63), respectively. Conversely, there were greater opportunities for exposure to ads targeting the Chemical and Control beliefs, with mean 4-week TRP values of 70.00 (SD = 57.82) for Chemical TRPs and 132.20 (SD = 63.04) for Control TRPs.

Association of Ad-Targeted Beliefs and TRPs

We regressed targeted beliefs on past 4-week TRPs for each of the four targeted-belief/TRP pairs, controlling for the aforementioned covariates. Past 4-week TRPs significantly predicted belief endorsement for two of the four targeted-belief categories (see Table 3.4). Specifically, TRPs for Control-targeted ads were associated with the Control belief (b = 0.421, p = .048, 95% CI [0.004, 0.839]); results indicate that an additional 1,000 Control-targeted TRPs available in the previous 4 weeks were associated with an increase of 0.42 on the Control belief scale. Similarly, TRPs for Chemical-targeted ads were associated with the Chemical belief (b = 0.572, p = .018, 95% CI [0.098, 1.046]); results indicate that an additional 1,000 Chemical-targeted TRPs available in the previous 4 weeks were associated with an increase of 0.57 on the

Chemical belief scale.[7] TRPs for Wrinkle-targeted and Teeth-targeted ads were not significantly associated with their respective targeted beliefs (Wrinkle: b = -0.135, p = .641, 95% CI [-0.703, 0.433]; Teeth: b = -0.088, p = .799, 95% CI [-0.765, 0.589]).

Association of Non-Targeted Beliefs and TRPs

We then estimated a series of regression models in which past 4-week TRPs for ads in each targeted-belief category (Wrinkle, Teeth, Control, and Chemical) were separately used to predict the anti-smoking beliefs not targeted by the campaign, controlling for the same set of covariates (see Table 3.5 for standardized regression coefficients). We conducted sign tests to examine how many of the 9 associations of each TRP variable with non-targeted beliefs were less positive than the association of that TRP variable with its targeted belief (Table 3.5). Two-sided sign tests indicated that for past 4-week TRPs targeting the Control and Chemical beliefs, TRP/targeted belief associations were stronger than TRP/non-targeted belief associations for all comparisons (Z = 2.66, p = .004). In other words, past 4-week TRPs for ads targeting the Control and Chemical beliefs were more strongly associated with their targeted belief (respectively) than with anti-smoking beliefs not targeted by the campaign. For TRPs targeting the Wrinkle and Teeth beliefs, TRP/targeted belief associations were not significantly larger than TRP/non-targeted belief associations.

[7] To assess whether relationships between past 4-week TRPs and belief endorsement are nonlinear, we estimated parallel regression models in which a categorical version of each TRP variable was used to predict the targeted belief, adjusting for the same covariates. We then conducted likelihood-ratio tests for each class of targeted belief (Control and Chemical), comparing estimates from the continuous predictor regression model with those from the model with a categorical predictor. Likelihood-ratio test results indicated that for both Control and Chemical beliefs, regression models with continuous TRP predictor variables are better fit to the data than models with categorical TRP variables.

Table 3.4 *Multiple regression analysis of targeted beliefs on past 4-week Target Rating Points for advertisements from The Real Cost campaign*

	Model 1 Wrinkle belief on Wrinkle TRPs n = 3,890			Model 2 Teeth belief on Teeth TRPs n = 3,931			Model 3 Control belief on Control TRPs n = 3,965			Model 4 Chemical belief on Chemical TRPs n = 3,326		
	β	B	SE	β	B	SE	β	B	SE	β	B	SE
Past 4-week TRPs	-.008	-.130	.290	-.004	-.087	.345	**.036***	**.423**	**.214**	**.051***	**.572**	**.242**
Age	.017	.009	.008	-.005	-.002	.008	-.012	-.006	.009	.016	.008	.008
Sex	**-.042****	**-.058**	**.022**	-.028	-.038	.022	**-.052***	**-.076**	**.023**	**-.040***	**-.051**	**.022**
Race (White=*Ref.*)												
Hispanic	**-.055****	**-.091**	**.030**	-.016	-.025	.029	**-.069*****	**-.121**	**.031**	**-.061****	**-.093**	**.030**
Black/AA	**-.047****	**-.096**	**.035**	-.013	-.026	.034	-.024	-.053	.036	-.035	-.066	.034
Other race	-.016	-.035	.037	-.012	-.026	.036	-.021	-.048	.038	-.001	-.002	.037

Sensation seeking	**-.046****	**-.062**	**.022**	**-.098*****	**-.130**	**.021**	**-.090*****	**-.129**	**.023**	**-.060****	**-.074**	**.022**
Parental education (HS=*Ref.*)												
Some college	.013	.026	.037	.015	.029	.036	.031	.063	.038	.025	.045	.037
College degree	.040	.059	.031	.015	.022	.030	**.059****	**.092**	**.032**	**.061****	**.084**	**.031**
Graduate degree	**.075*****	**.118**	**.033**	**.044***	**.068**	**.032**	**.081*****	**.135**	**.034**	**.096*****	**.139**	**.033**
Parent disapproval												
(Would/disapp. a lot=*Ref.*)												
Don't/wouldn't mind	**-.059*****	**-.329**	**.089**	**-.101*****	**-.557**	**.087**	**-.059*****	**-.356**	**.094**	**-.062*****	**-.307**	**.085**
Would/disapp. a little	**-.069*****	**-.184**	**.043**	**-.086*****	**-.223**	**.042**	**-.056*****	**-.158**	**.045**	**-.059****	**-.143**	**.043**
Household cigarette use	-.002	-.004	.027	-.012	-.019	.026	**-.036***	**-.062**	**.028**	.025	.038	.027
Grades in school	**.034***	**.032**	**.015**	-.001	-.001	.015	**.036***	**.035**	**.016**	**.045***	**.038**	**.015**
TV watching	-.011	-.000	.001	**.050****	**.002**	**.001**	.009	.000	.006	.015	.000	.001
Interview week	-.005	-.000	.000	**.035***	**.001**	**.000**	.028	.001	.000	.026	.001	.000

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).
B = unstandardized coefficient. SE = standard error. β = standardized coefficient. *Ref.* = reference category. AA = African American. HS = high school or less.

Table 3.5 *Standardized regression coefficients from regression analyses of past 4-week Target Rating Points (TRPs) predicting targeted and non-targeted belief endorsement, and results from two-sided sign tests*

Past 4-week Target Rating Points (TRPs)		Non-targeted beliefs									Two-sided sign tests	
	Targeted belief	Headache	Sexual/ fertility	Cancer	Yellow fingers	Addiction	Uncool	Turn off	Relaxed	Enjoy life	Z	*p*
Wrinkle TRPs	-.008	.011	-.022	.006	-.007	-.003	-.019	.005	.013	-.025	0.02	.508
Teeth TRPs	-.004	-.006	.014	.018	.005	.011	.016	.034	.005	-.013	0.92	.180
Control TRPs	.036	.013	.022	-.002	-.023	.027	-.001	-.010	-.032	.009	**2.66**	**.004**
Chemical TRPs	.051	-.003	.008	-.001	.008	.004	-.001	-.015	-.000	.037	**2.66**	**.004**

Note. Standardized regression coefficients were derived from separate regression equations that controlled for the following potential covariates: age, sex, race, sensation seeking, parent education, parental disapproval of smoking, household cigarette use, grades, past 7-day TV watching, and continuous interview week. Two-sided sign tests were calculated by assessing how often the standardized regression coefficients for each TRP/targeted belief association were more positive than the 9 TRP/non-targeted belief associations within each TRP belief category.

Discussion

This study evaluated the relationships between exogenous exposure to TV advertisements from The Real Cost campaign, operationalized as past 4-week Target Ratings Points (TRPs), and endorsement of both targeted and non-targeted anti-smoking beliefs. As hypothesized, results established significant, positive associations between past 4-week TRPs and belief endorsement for ads that separately targeted Control and Chemical beliefs, lending support to a claim that the campaign has been effective at influencing campaign-targeted beliefs. Furthermore, for both Control- and Chemical-targeted ads, past 4-week TRPs were less associated with endorsement of beliefs not targeted by The Real Cost campaign than ad-targeted beliefs. These results suggest that an alternative explanation for these findings—that external events affected both broadcast of anti-smoking ads and all anti-smoking beliefs, producing an association between TRPs and the targeted beliefs—is unlikely. If that were the case, we would have expected effects on all beliefs, not only those targeted by the ads. Since the effects we found are specific to the targeted beliefs, this is a less viable explanation for the pattern of results.

Our findings build on previous research (Duke et al., 2017) which demonstrated that higher market levels of TRPs, both across the campaign and for ads targeting specific beliefs, were associated with greater odds of endorsing 5 of 8 campaign-targeted beliefs. Similar to Duke et al. (2017), our analyses demonstrated differential associations of TRPs with ad-targeted beliefs relative to non-targeted beliefs. Moreover, as our results reflect relationships between temporal (rather than geographic) variation in TRPs and beliefs from a randomly-selected sample within the targeted population, these results are less

subject to the concern that an unmeasured confounder, such as a characteristic specific to a geographically-defined group, influenced the association between TRPs and beliefs. It is also worth noting the different time periods for campaign exposure between the two sets of analyses. Whereas results from the Duke et al. (2017) study demonstrated that cumulative ad TRPs over approximately 7-9 months associated with belief endorsement, we were able to demonstrate belief effects from only 4 weeks of exposure, a considerably shorter time frame. Our results may indicate that for Control- and Chemical-targeted ads, minimal periods of exposure were necessary to influence ad-targeted beliefs.

Contrary to our hypotheses, results did not demonstrate significant relationships between past 4-week TRPs and belief endorsement for ads that separately targeted Wrinkle and Teeth beliefs. Additionally, past 4-week TRPs for these ads were not differentially associated with ad-targeted beliefs relative to TRP associations with beliefs not targeted by The Real Cost campaign. There are several potential explanations for these findings. First, it is possible that respondents did not attain sufficient exposure to these ads to change their corresponding beliefs. Indeed, mean past 4-week TRPs were lower for ads targeting Wrinkle and Teeth beliefs (38.24 and 41.46, respectively) than for those targeting Chemical and Control beliefs (70.00 and 132.20, respectively). Fewer opportunities for exposure to these classes of ads may have resulted in less actual exposure, thereby accounting for the observed lack of effects.

An alternative explanation for these null results is that respondents were not exposed to these specific ads for sufficiently long periods of time to change their corresponding beliefs. Though the previous study demonstrated associations between

TRPs targeting these beliefs and belief endorsement in the context of this campaign (Duke et al., 2017), TRPs were aggregated over approximately 7- to 9-month periods prior to belief measurement, whereas in the present study TRPs were aggregated over 4-week periods. It is possible that certain characteristics of these ads or the beliefs they target, both of which constitute beliefs about the cosmetic effects associated with smoking, require longer periods of exposure for effects to take hold. Some previous research on the relationship between campaign exposure and beliefs about the cosmetic effects of smoking (for other campaigns) has shown null effects (Pechmann et al., 2003; Siegel & Biener, 2000). However, other research relying on self-reports of recall of The Real Cost's "Your Skin" and "Your Teeth" ads did show a specific association with the related beliefs (Kranzler et al., 2017). Thus, while beliefs about the cosmetic effects of smoking may hold promise for influencing smoking behavior (Brennan et al., 2017), ads that target these beliefs may require longer periods of exposure to influence message-consistent belief change.

Lastly, our null results may have been influenced by the number of ads within each targeted-belief ad category. Over the course of the study period, a total of 5 ads targeting the Control belief and 3 ads targeting the Chemical belief were aired; conversely, there was only one ad each targeting the Wrinkle and Teeth beliefs (see Table 3.2). It is possible that the Control- and Chemical-targeted ads influenced beliefs because the introduction of new ads drew fresh attention to their themes over the course of the study, whereas the Wrinkle- and Teeth-targeted ads were less influential due to a lack of novelty and wear-out of attention over time.

Limitations and Conclusion

There are several limitations to this study. TRPs represent opportunities for exposure available in the media environment during a specified period of time, and thus may not index actual exposure to advertisements. However, given previous work demonstrating relationships between exposure opportunities and self-reported recall, both for previous campaigns (Cowling et al., 2010; Niederdeppe, 2005; Richardson, McNeill, et al., 2014; Southwell et al., 2002) and at the aggregate level for The Real Cost campaign (Kranzler et al., 2017), there is empirical support for a claim that TRPs represent actual ad exposure. TRPs index reach and frequency of campaign exposure on a national scale; thus, results may over- or underestimate effects for individual respondents based on the TRPs available in their specific media market. Beliefs were assessed via self-report measures and may have been influenced by response bias. Non-response bias may limit inferences about national populations made from study results. Finally, analyses controlled for potential covariates but did not employ survey weights. Survey weights for this dataset were developed at the quarterly level, rather than the weekly level, to adjust for some of the same covariates listed in the Methods section. Due to this time interval mismatch, we expected that survey weights would inflate standard errors without providing much additional effective adjustment.

In conclusion, findings from this study add to a growing body of research supporting a claim of effects for The Real Cost campaign. Specifically, results lend support to the notion that campaign exposure, assessed independently of outcomes, influenced beliefs targeted by campaign ads that constitute the pathway through which

campaign effects were theorized to occur (Duke et al., 2015). Broadly, these results contribute to the campaign evaluation literature by suggesting that campaign-targeted beliefs may be influenced by exposure to advertisements over a shorter period of time than previously expected, and that the length of the exposure necessary to elicit belief change may be contingent on the beliefs being targeted. Future research should further examine the relationship between the length of the exposure period and belief change, and whether recalled exposure mediates the relationship between opportunities for exposure and belief endorsement.

CHAPTER 4. ADOLESCENT NEURAL RESPONSES TO ANTI-SMOKING CAMPAIGN MESSAGES, PERCEIVED EFFECTIVENESS, AND SHARING INTENTION

Introduction

Tobacco use is a major public health threat throughout the world and the leading cause of preventable death and disease in the United States (U.S. Department of Health and Human Services, 2014). Initiation of smoking typically begins during adolescence, with 90% of smokers having initiated tobacco use before age 18 (U.S. Department of Health and Human Services, 2014). Anti-smoking campaigns can influence young people's anti-smoking cognitions, which in turn predict campaign effects, including reduced intention to smoke and decreased smoking behavior (Allen et al., 2015; U.S. Department of Health and Human Services, 2014). Interpersonal communication about media content provides an important link between mass media messages and message effects (Jeong & Bae, 2017; Katz & Lazarsfeld, 1955; Southwell & Yzer, 2007; Southwell & Yzer, 2009). Anti-smoking campaigns can prompt conversations about campaign messages, which can influence targeted campaign outcomes for anti-smoking campaigns targeting adults and adolescents (Hafstad & Aaro, 1997; Hwang, 2012). Less is known about the message-induced psychological and neural processes that make messages effective and shareworthy among adolescents, a key target audience for anti-smoking campaigns.

One promising approach to improve our understanding of these mechanisms is to examine how anti-smoking messages are received and processed by the adolescent brain, and to link neural responses during message receipt to subsequent message effects.

Neuroimaging, and functional magnetic resonance imaging (fMRI) in particular, offers a means for probing implicit cognitive processes in real time, and has been used to study the neural mechanisms associated with effective health messages, including messages from anti-smoking campaigns (for a review, see Whelan, Morgan, Sherar, Orme, & Esliger, 2017). However, little research has examined adolescent neural response to anti-smoking messages. In the current study, we measured neural response in a sample of adolescents, and investigated the relationship between message-induced brain response and two outcomes of interest: perceived message effectiveness and sharing intention. Perceived message effectiveness can be defined as judgments of the effectiveness of a particular message (i.e., the extent to which the message is deemed convincing, informative, attention-grabbing, and/or memorable). Sharing intention is defined as an individual's intention to retransmit information through interpersonal communication channels.

Current theoretical accounts of the mechanisms underlying effective and shareworthy messages are based primarily on empirical evidence from adult studies. However, theoretical and empirical research on adolescents suggest that the cognitions that drive message effects in adolescents may differ from those in adults. The period of adolescence, which coincides with pubertal onset, represents a period of remarkable development in the adolescent brain (Crone & Dahl, 2012). Neural development is accompanied by sociocultural changes, as an increased awareness of and receptivity to social signals exert substantial influence on individuals' thoughts and actions (Blakemore & Mills, 2014; Crone & Dahl, 2012). Adolescents demonstrate both a shift from self-

oriented to social-oriented behavior (Eisenberg & Fabes, 2006) and an enhanced desire for autonomy as they become increasingly independent (Steinberg & Silverberg, 1986). In light of these developmental changes, it is unclear what neurocognitive processes drive message effects in adolescents. Here, we review literature about the neural correlates of effective and shareworthy messages in adults and neurodevelopmental considerations in adolescents to highlight what is already known about these processes and how they may present during adolescence.

Self-Relevance and Message Effectiveness

A great deal of communication research has identified characteristics of effective health messages. One strategy for maximizing message effects involves increasing the personal relevance of messages (e.g., through message tailoring), which in turn enhances motivation to process health information (Rimer & Kreuter, 2006). This increased motivation, generated by personal relevance, can lead to greater message elaboration and persuasive effects (Petty & Cacioppo, 1986). More broadly, messages that are rated as self-relevant (they contain content that is deemed personally relevant [Strecher, Shiffman, & West, 2006]) or prompt enhanced activation in brain regions implicated in self-related processing (Chua et al., 2011; Cooper, Tompson, O'Donnell, & Falk, 2015; Falk et al., 2016) are more effective in changing health behaviors. In particular, judgments about self-relevance have been shown to engage specific regions of the brain, namely the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC; Murray, Schaer, & Debbané, 2012). Several studies have identified links between neural activity in the MPFC during message exposure and targeted outcomes, including calls to a smoking

quitline (Falk, Berkman, & Lieberman, 2012), clicks in an anti-smoking email campaign (Falk et al., 2016), smoking reduction (Falk, Berkman, Whalen, & Lieberman, 2011), and smoking cessation (Chua et al., 2011). This link is thought to stem from MPFC's role in integrating multiple cognitive and affective inputs to arrive at a summary judgment of how valuable and self-relevant a piece of information might be to a given individual (Falk & Scholz, 2018).

In one such study, adult smokers viewed anti-smoking advertisements during an fMRI scan (Falk et al., 2011), and completed self-report ratings of the ads. Expired carbon monoxide (CO), a biological measure of recent smoking, was measured at baseline and one month post-scan. Results demonstrated that neural activity in MPFC and ad-specific self-report ratings (intention to quit, self-efficacy to quit, and self-relevance of ads) predicted independent variance in changes in CO, suggesting that MPFC may capture an implicit form of self-relevance not indexed by these self-reports. In another study (Chua et al., 2011), smokers interested in quitting completed an fMRI scan during which they viewed tailored, untailored, and neutral smoking cessation messages. Participants then completed a web-based tailored smoking cessation program and a follow-up interview 4 months later to assess smoking status. Analyses indicated that brain regions including the dorsomedial prefrontal cortex (DMPFC; a subregion of the MPFC), precuneus, and angular gyrus were preferentially engaged by both tailored messages and self-related processing. Relative to a neutral condition, mean neural response in the MPFC during exposure to tailored smoking cessation messages significantly predicted the odds of quitting smoking. These findings complement other

communication research demonstrating that messages with higher personal relevance have a greater influence on health behavior than comparison or control conditions (Noar, Benac, & Harris, 2007).

Together, these findings suggest that self-related considerations during message exposure, as indexed by response in specific regions of the brain, may partially influence health behavior change. Furthermore, neural response to messages can complement self-report measures of campaign efficacy by explaining additional variance in campaign effects. However, as detailed below, these findings were all obtained in adult samples, and scant research has tested the link between neural response to campaign messages and messages effects among adolescents. Despite evidence that self-relevant processing in adolescents is also indexed in the MPFC (Pfeifer et al., 2009), it is unclear whether the same form of self-related processes are as central to messages that are influential for adolescents. In light of the developmental changes characteristic of adolescence that may influence self-related considerations (Crone & Dahl, 2012; Eisenberg & Fabes, 2006; Steinberg & Silverberg, 1986), a lack of research in this domain warrants an examination of whether adolescent neural response in regions involved in self-relevant processing associate with message effectiveness.

Social Processing and Message Effectiveness

Theories of behavior change highlight the role of normative beliefs—perceptions about peer engagement in a particular behavior—in predicting behavioral outcomes across populations (Fishbein & Ajzen, 2011). Among adolescents in particular, there is empirical support for this theorized relationship in the domain of tobacco use research

(Liu et al., 2017) and particularly in studies of message effects (Ho, Poorisat, Neo, & Detenber, 2014; Moran & Sussman, 2014; Paek, 2008). Taken together, findings suggest that people take the perspectives, beliefs, and behaviors of their peers into account when forming their own intentions to engage in a particular behavior, and that this normative information can be obtained through exposure to health messages. The influence of normative beliefs and behaviors are especially heightened among adolescents (Brown, Clasen, & Eicher, 1986), suggesting that adolescent' consideration of normative information, as relayed through health messages, may exert substantial influence on subsequent message effects.

Neuroimaging research has identified a group of brain regions implicated in mentalizing, or the ability to understand the mental states of others (Frith & Frith, 2006), and social processing more broadly, which includes interpreting social feedback, considering the repercussions of others' actions, and anticipating the social consequences of one's own actions (Blakemore, 2008). This social processing system, comprised of regions within the dorsal, middle, and ventral components of the medial prefrontal cortex (DMPFC, MMPFC, and VMPFC), precuneus (PC), bilateral temporal parietal junction (TPJ), and right superior temporal sulcus (rTPS), was activated in a large sample of participants while they considered others' beliefs (Dufour et al., 2013). In adolescents, activation of regions within this system scales with receiving social feedback (Welborn et al., 2015), incorporation of peer feedback into product recommendations (Cascio, O'Donnell, Bayer, Tinney, & Falk, 2015), and viewing photos that are liked by peers (Sherman, Payton, Hernandez, Greenfield, & Dapretto, 2016). Neural response in these

brain regions may also index self-relevant processing in adolescents; previous research that has shown greater activity in brain regions relevant to social processing in adolescents, relative to adults, when prompted to self-reflect (Pfeifer et al., 2009); suggesting that adolescents incorporate others' perspectives into their own self-concept. Given theories and research that link social norms with message effects (Cialdini et al., 2006; Goldstein, Cialdini, & Griskevicius, 2008), and the prospect that adolescents use social information in determining self-relevance (Pfeifer et al., 2009), neural response in the social processing system may be important in determining perceived message effectiveness in adolescents.

In the few studies that have examined the neural processes underlying perceived message effectiveness, findings offer evidence consistent with the notion that effective ads inspire social thought. In one recent study, young adults viewed anti-drug public service announcements (PSAs) during an fMRI scan, then rated their perceived message effectiveness of each ad (Donohew et al., 2017). Results demonstrated that greater neural activation in the left temporal pole and dorsomedial prefrontal cortex, regions previously linked to social processing and mentalizing (Dufour et al., 2013; Olson, Plotzker, & Ezzyat, 2007), while viewing anti-drug messages was associated with higher ratings of perceived message effectiveness. Findings suggest that ads that elicit socio-cognitive processing may be perceived as more effective; however, the results were specific to young adults and may or may not not translate to adolescent samples. In another study, adolescents viewed anti-drug PSAs and nondrug ads during an fMRI scan and rated the perceived convincingness of these ads (Ramsay, Yzer, Luciana, Vohs, & MacDonald,

2013). Participants demonstrated increased activity in brain regions involved in self-related, social, and emotional processing, including the amygdala and a region of the MPFC, while viewing PSAs relative to nondrug ads. Furthermore, individual differences in neural response to messages in the lateral prefrontal cortex, a brain region implicated in executive control functions, was correlated with aggregates of participants' self-reported perceived convincingness of these PSAs. Findings demonstrate that among adolescents, messages that are rated as persuasive engage activation in brain regions involved in self-related, social, and emotional processing and executive control.

Though results offer evidence somewhat consistent with prior theoretical and empirical research regarding the role of normative information on health behavior, they provide insufficient evidence with which to make claims about the neural correlates of persuasive messages in adolescents. Considering the central role of normative information as a determinant of adolescent behavior (Liu et al., 2017) and the extent to which adolescence is marked by social and neural development (Blakemore, 2008; Crone & Dahl, 2012), a lack of conclusive evidence regarding the link between social processing and perceived message effectiveness warrants additional adolescent research.

Positive Value and Message Effectiveness

More broadly, messages that are more effective might also prompt positive valuation, or consideration of the worth of the information contained in the messages, thus engaging the value system in their receivers including the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS) (Bartra, McGuire, & Kable, 2013). Indeed, several major theories have argued that helping a message recipient find personal value in

messages is key to behavior change (Darke & Chaiken, 2005; Fishbein & Ajzen, 2011; Glanz, Rimer, & Viswanath, 2008). Theories of behavior change, such as the Theory of Reasoned Action and Health Belief Model, operate on the premise that beliefs about the benefits of engaging in (or abstaining from) a behavior are key predictors of behavioral outcomes (Fishbein & Ajzen, 2011; Rosenstock, 1974). According to these theories, we would expect messages that prompt individuals to consider the value of engaging in a behavior to influence their behavioral performance.

Likewise, activity in brain regions that compute the expected value of outcomes, including the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS), have been associated with positive message effects (Cooper et al., 2015; Falk, Berkman, Mann, Harrison, & Lieberman, 2010; Falk et al., 2015; Vezich, Katzman, Ames, Falk, & Lieberman, 2017). In adolescents, this value system is particularly sensitive to social inputs (for a review see Telzer, 2016) and may aid in determining the extent to which adolescents perceive messages to be valuable.

The Role of Self-Relevance, Social Processing, and Valuation in Sharing

The sharing of campaign content may increase the effectiveness of an anti-smoking campaign (Hafstad & Aaro, 1997; Hwang, 2012) through the diffusion of messages to individuals who would otherwise be unexposed to the campaign or by reinforcing the social norms pertinent to a campaign message (Jeong et al., 2015). Consequently, we are also interested in neurocognitive processes associated with adolescents' desires to share about the campaign. Preliminary neuroimaging studies have linked activation in regions within the social processing system to the successful

transmission of ideas and recommendations, and emphasize the role of activity in the communicator's DMPFC (Falk, Morelli, Welborn, Dambacher, & Lieberman, 2013; Falk, O'Donnell, & Lieberman, 2012) and TPJ (Cascio et al., 2015; Falk et al., 2013; Falk et al., 2012) in this process. These findings are complemented by evidence that neural activity in regions implicated in self-related processing during message exposure, including MPFC and PCC, as well as positive valuation, including VMPFC and VS, are associated with greater enthusiasm for sharing ideas (Falk et al., 2012) and greater intention and success in propagating messages (Falk et al., 2013) in adults. Neural activity in self-relevance, social processing and value systems during exposure to health news headlines was positively related to self-reported intention to share (Baek et al., 2017) and population-level measures of actual sharing behavior (Scholz et al., 2017). Together, these findings suggest that activity in these brain regions may index an intention to share and successful transmission of content.

Perceived Message Effectiveness and Sharing in Adolescents

Are the psychological processes evident in adults key to perceived message effectiveness and sharing intent in adolescents? As touched on above, despite initial findings in adults, no prior fMRI study has examined perceived message effectiveness and sharing intention in the same cohort, nor explored these processes in a sample of adolescents. Observed differences between adolescent and adult neural response in brain regions within these systems (Barkley-Levenson & Galván, 2014; Pfeifer, Lieberman, & Dapretto, 2007; Pfeifer et al., 2009; Pfeifer & Blakemore, 2012; Richards, Plate, & Ernst, 2013) raise questions about the nature of neural activity in adolescents' self-relevance,

social processing and value systems and how it relates to their intention to share content on social media. More broadly, adolescence is a key period in which sensitivity to social cues is heightened and rapid changes occur in social and brain development. The increased influence of peers leads adolescents to alter their behavior as a means to gain social acceptance (Steinberg & Monahan, 2007), as the rewards and threats that are most salient to adolescents are typically social in nature (Crone & Dahl, 2012). The hormonal changes that stimulate adolescent pubertal maturation are accompanied by complex social-cognitive changes (for a review, see Crone & Dahl, 2012). One relevant social-cognitive process is the ability to mentalize, or make inferences about the mental states of others (Frith & Frith, 2006). The ability to mentalize develops during childhood, but during adolescence individuals exhibit a more marked shift from self-oriented to social-oriented behavior (Eisenberg & Fabes, 2006). As such, self and social cognitions may contribute differently to perceptions of campaign effectiveness, and ultimate valuation of ideas, in adolescents relative to other groups that have been studied.

Current Study

The goal of the current study was to understand the neural processes underlying the perceived effectiveness of ads and how these processes may relate to adolescents' sharing of ads on social media. Neuroimaging methods afford the measurement of multiple processes, simultaneously, during exposure to messages in real time, thus providing information about the cognitive mechanisms associated with message effects that take hold in real time as participants are exposed to messaging. By contrast, self-report measures must either actively interrupt the process of natural exposure or can offer

retrospective, summary reports of individuals' thoughts and feelings about a message during the exposure period (as we use as the outcomes in this study). Here, we were particularly interested in understanding the message-induced cognitive processes during exposure that are associated with later perceiving a message to be effective and shareworthy, thus combining the strengths of different tools (neuroimaging and self-reports of subjective experience). We focused our study on adolescents for two central reasons. Most of the research that has examined the neural correlates of effective and shareworthy messages has been conducted in adults, and thus there is a lack of adolescent research in this domain. Furthermore, adolescents are an important target population for health campaigns; though adolescence is associated with increased health risks given the tendency to engage in risky behaviors (Albert, Chein, & Steinberg, 2013), it also presents opportunities to enhance long-term health outcomes through educational and preventive efforts (Kleinert, 2007).

To examine the aforementioned relationships, we combined measures of adolescent neural response to advertisements from "The Real Cost" national anti-smoking campaign with subsequent ratings of perceived ad effectiveness and intention to share these ads on social media. The Real Cost campaign, launched in February 2014, is an ongoing, national campaign funded by the U.S. Food and Drug Administration (FDA) that aims to prevent adolescent non-smokers from initiating smoking by educating youth about the "real costs" of smoking (Duke et al., 2015). The campaign targets anti-tobacco beliefs that are expected to influence behavior, including the loss of control due to

smoking addiction, the dangerous chemicals found in cigarettes, and the negative health and cosmetic effects associated with smoking.

Considering theories and empirical research relevant to the neural correlates of effective and shareworthy messages in adults, and developmental considerations in adolescents, we pre-registered hypotheses that neural activity in these self-relevant, social, and value systems during ad exposure would be positively associated with participants' evaluations of the efficacy of the messages. Specifically, we hypothesized that in a sample of adolescents, a composite measure of perceived ad effectiveness would scale with neural activity in all three systems during exposure to the ads. Further, we hypothesized that neural activity in these systems during message exposure would be positively related to participants' intention to share ads, and preregistered this hypothesis.[8] Specifically, we anticipated that the more likely an individual was to share a message on social media, the stronger the neural response to the message would be in these sets of brain regions.

Methods

Participants

Forty-four adolescent non-smokers between the ages of 14-17 from the greater Philadelphia area were recruited to participate in this fMRI study. All participants provided informed assent and parental consent was obtained in accordance with the procedures of the Institutional Review Board at the University of Pennsylvania. One participant was excluded from the study due to scheduling issues and three participants

[8] Hypothesis preregistration document can be accessed via https://osf.io/gz5uv/.

were excluded from data analyses due to excessive head motion (n=1), discomfort in the scanner (n=1), and lack of variance in sharing ratings (n=1).

Eligibility Screening

To be included in the study, participants had to report that they were non-smokers, defined as not having smoked in the previous 30 days and a lifetime history of having smoked fewer than 100 cigarettes, and were required to meet standard fMRI eligibility criteria, including having no metal in their bodies and no history of psychiatric or neurological disorders. We oversampled high sensation seekers (a combined score of at least 12 out of 16 on the Brief Sensation Seeking Scale [BSSS-4]) as they are at greater risk of smoking initiation (Sargent, Tanski, Stoolmiller, & Hanewinkel, 2010); thus, eligibility was contingent upon sensation seeking as assessed during the eligibility screen. Potential participants of all sensation-seeking levels were eligible to participate. Participants were recruited until a cap was met for each subgroup (low-moderate and high sensation seekers. This resulted in a study sample with 21 high sensation seekers and 19 low-moderate sensation seekers.

Pre-Scan Tasks

During the week prior to the fMRI scan session, participants completed a web-based baseline questionnaire to assess prior exposure to The Real Cost ads, demographic information (e.g., age, sex, race), as well as smoking-relevant cognitions and behaviors and individual difference measures not addressed here. At the in-person scanning session, prior to the fMRI scan, participants completed a practice run of the fMRI task in which they viewed a preparation countdown and an ad from The Real Cost campaign, rated

their intention to share the ad, then closed their eyes and reimagined the ad. The practice run was conducted with a Real Cost ad not included in study stimuli.

Stimuli

The stimuli for this study consisted of 12 anti-smoking advertisements from the FDA's The Real Cost smoking prevention campaign. Each 30-second, high quality audiovisual advertisement was professionally produced. Examples of the content of these ads include a teenage girl who tears off a piece of her skin in exchange for cigarettes, a teenage boy who yanks out one of his teeth in exchange for cigarettes, and a teenage girl who complains about cigarettes being "bossy," as if describing a boyfriend. See Table 4.1 for descriptions of each ad used in this study and links to the campaign page and sample videos.

fMRI Task

During the ad viewing task (Figure 4.1), participants viewed, rated their intention to share, and reimagined each of 12 ads from The Real Cost campaign. For each ad, participants first viewed a 4-second preparation countdown and were then instructed to view one of the 30-second Real Cost ads, presented in random order. Subsequently, participants were instructed to rate their intention to share the ad using an MRI-compatible button box. Lastly, participants were asked to close their eyes and instructed to reimagine the ad over a 10-second period.[9] Each participant completed the preparation

[9] The reimagine task was administered during the fMRI scan for purposes orthogonal to the current study (to understand the neural mechanisms underlying how people reimagine messages). As this task was beyond the scope of the current investigation, we did not examine brain response during the reimagine task in the current study.

countdown, view, sharing rating, and reimagine tasks in the same order for all 12 ads, however the order in which ads were presented was randomized.

Table 4.1 *Names and descriptions of 12 advertisements from The Real Cost campaign*

Ad name	Ad description
Alison	A girl in a cafeteria complains about cigarettes being so bossy.
Any Reason	A girl won't smoke because she doesn't want to break up her finger puppets.
Band	A tiny bully drags a drummer away from band practice to smoke.
Bully	A tiny man bullies young people into smoking cigarettes.
Dance	A tiny bully makes a teen leave his prom date for a smoke.
Found it	A disgusting creature crawls into a teen's mouth before hiding in a cigarette pack.
#ReasonsNotToSmoke	A skater doesn't smoke because he can't fit a pack of cigarettes in his skinny jeans.
Science Class	A disgusting creature escapes while being dissected in a science class and crawls into a cigarette pack.
Stay in Control	A girl gives up her freedom by signing a contract that turns into a cigarette.
The 7,000	Swamp creatures turn into 7,000 toxic chemicals as a guy inhales cigarette smoke.
Your Skin	A girl tears off a piece of her skin to pay for a pack of cigarettes.
Your Teeth	A guy yanks out a tooth to pay for a pack of cigarettes.

Note. Links to the campaign page and sample videos are listed below:
https://www.fda.gov/TobaccoProducts/PublicHealthEducation/PublicEducationCampaigns/TheRealCostCampaign/default.htm
https://www.youtube.com/user/KnowTheRealCost/videos

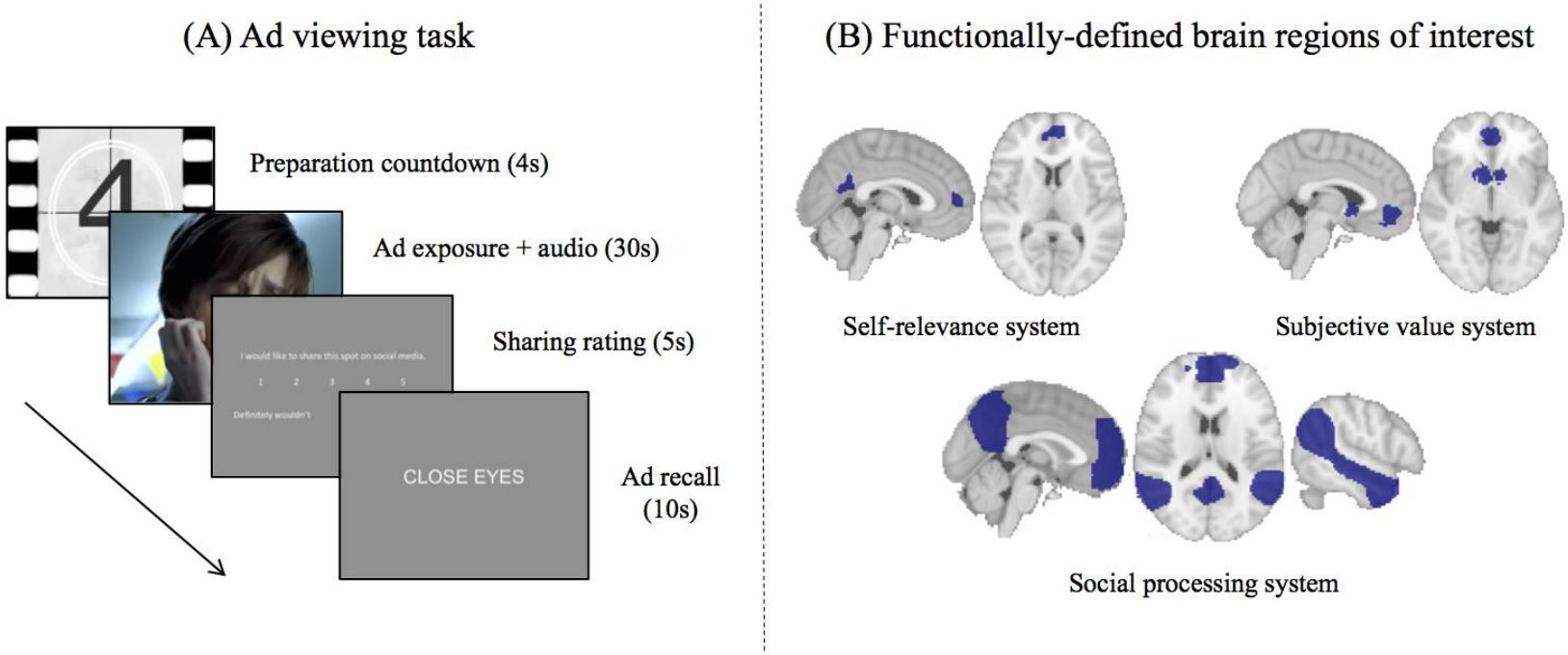


Figure 4.1 *Ad viewing task and functionally-defined brain regions of interest*

(A) The ad viewing task was completed as part of the fMRI scan. For each of 12 ads, participants first viewed a 4-second preparation countdown and were then instructed to view one of the 30-second Real Cost ads, presented in random order. Subsequently, participants were instructed to rate their intention to share the ad using an MRI-compatible button box. Lastly, participants were asked to close their eyes and instructed to reimagine the ad over a 10-second period. Each participant completed the preparation countdown, view, sharing rating, and reimagine tasks in the same order for all 12 ads, however the order in which ads were presented was randomized. (B) The self-relevance system is comprised of the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC),

the subjective value system is comprised of the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS), and the social processing system is comprised of the right temporal parietal junction (rTPJ), left temporal parietal junction (lTPJ), dorsal, middle, and ventral components of the medial prefrontal cortex (DMPFC, MMPFC, and VMPFC), precuneus (PC), and right superior temporal sulcus (rSTS). Each set of regions was treated as a system (self-relevance, social processing, and subjective value) in all analyses.

After the scanning session, participants completed a web-based questionnaire that included perceived effectiveness items for the ads shown in the scanner. For each ad, participants were shown 3 screenshots of the ad and asked to indicate their level of agreement with 7 statements pertinent to ad effectiveness. Participants completed this task in random order for all 12 Real Cost ads.

In previous research examining the neural underpinnings of effective health messages, the outcomes of interest have most commonly been operationalized as behavioral intentions or actual behavior (Baek et al., 2017; Cooper et al., 2015; Falk et al., 2011). In the present study, however, we opted to use perceived ad effectiveness in lieu of intentions to smoke or smoking behavior for several reasons. We recruited adolescent non-smokers for this study, so as to align our study sample with the target population of The Real Cost campaign (12 – 17-year-old non-smokers and smoking experimenters); as such, they reported no smoking behavior and very low intention to smoke. With virtually no variation in these variables, we would have been unable to detect any differences in these outcomes as a function of neural activity with the sample size available for a neuroimaging experiment. Given findings from studies indicating that perceived effectiveness is substantially associated with actual effectiveness (Dillard, Weber, & Vail, 2007) and a causal antecedent to it (Dillard, Shen, & Vail, 2007), we focused on participants' perceived ad effectiveness ratings as a primary outcome of interest.

Measures

Perceived Ad Effectiveness. The first dependent variable was participants' perceived effectiveness of ads from The Real Cost campaign. Participants were shown each of the following statements and asked to indicate their agreement on a 5-point scale (1 = Strongly disagree, 5 = Strongly agree): "This ad is worth remembering," "This ad grabbed my attention," "This ad is powerful," "This ad is informative," "This ad is meaningful," and "This ad is convincing." Responses to one additional statement, "This ad is terrible," were excluded from analyses to align the perceived effectiveness scale with that used in the FDA-funded campaign evaluation. Results from analyses based on the 6- and 7-item perceived effectiveness scales were not substantively different.

We assessed participants' ratings of perceived ad effectiveness by averaging their responses to 6 perceived effectiveness items for each ad (Cronbach's $\alpha = 0.92$). Across all 12 Real Cost ads, participants rated them as moderately effective ($M = 3.55$, $SD = 1.00$). Mean perceived effectiveness varied both within and between ads. Within ads, mean perceived effectiveness across participants ranged from 2.83 ($SD = 1.06$) to 4.12 ($SD = 0.82$). In other words, some ads were generally perceived to be more effective than other ads. Within participants, mean perceived effectiveness across ads ranged from 2.06 ($SD = 1.42$) to 4.67 ($SD = 0.48$). That is, some participants generally rated ads as more effective than other participants. We calculated intra-class correlation coefficients (ICC) to determine the proportion of individual variance in perceived effectiveness ratings accounted for by between-subject and between-ad differences (Bliese, 2016). Results indicated that 20% of the variance in perceived effectiveness ratings was explained by between-subject differences, indicating that perceived effectiveness varied more within

subjects than between subjects ([ICC1] = 0.20). Similarly, 17% of the variance in perceived effectiveness ratings was explained by between-ad differences, indicating that perceived effectiveness varied more within ads than between ads ([ICC1] = 0.17). In other words, there was variation in which ads different people preferred, and participants provided a range of ratings across ads.

Intention to Share. The second dependent variable was participants' intention to share ads from The Real Cost campaign on social media. After viewing each ad, participants were shown the statement "I would like to share this spot on social media" and asked to indicate their agreement on a 5-point scale (1 = Definitely wouldn't, 5 = Definitely would). Participants reported moderate intention to share ads on social media across all 12 Real Cost ads (M = 3.07, SD = 1.28). Intention to share varied both within and between ads. Within ads, mean intention-to-share ratings ranged from 2.70 (SD = 1.20) to 3.62 (SD = 1.14). That is, some ads were rated as more shareworthy than others. Within participants, mean intention-to-share ratings ranged from 1.25 (SD = 0.45) to 4.75 (SD = 0.45). In other words, across all ads, some participants had greater intention to share ads relative to their peers. Intra-class correlations coefficients indicated that 37% of the variance in intention-to-share ratings was attributed to between-subject differences, indicating that intention to share varied more within than between subjects ([ICC1] = 0.37). Conversely, only 2% of the variance in intention-to-share ratings was explained by between-ad differences, indicating that intention to share varied almost entirely within ads, rather than between ads ([ICC1] = 0.02). In other words, although some individuals were mildly biased to share more or less across ads, participants generally varied in which ads they preferred to share.

fMRI Data Acquisition

All neuroimaging data were acquired using a 3 Tesla Siemens Magnetom MRI scanner equipped with a 32-channel head coil at the Center for Functional Neuroimaging at the University of Pennsylvania. One functional run was acquired for each participant (735 volumes per run). Functional images were recorded using a multiband sequence (TR = 1000 ms, TE = 32 ms, flip angle = 60 deg, 56 axial slices, FOV = 208 mm, slice thickness = 2.5 mm; voxel size = 2.5 x 2.5 x 2.5 mm). We also acquired a high-resolution T1-weighted image using an MP-RAGE sequence (TR = 1850.0 ms, 160 slices, voxel size = 0.9 x 0.9 x 1.0 mm) for use in coregistration and normalization. To allow for the stabilization of the BOLD signal, the first 6 volumes of each run were immediately discarded during the scan.

Pre-registered Region of Interest Selection

In line with a set of pre-registered hypotheses, we selected a series of a priori theory-driven regions of interest (ROIs) that belong to three systems. Specifically, our analyses focused on activity in the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC; see Figure 4.1), as defined by a meta-analysis of self-relevant processing (Murray et al., 2012), the right temporal parietal junction (rTPJ), left temporal parietal junction (lTPJ), dorsal, middle, and ventral components of the medial prefrontal cortex (DMPFC, MMPFC, and VMPFC), precuneus (PC), and right superior temporal sulcus (rSTS; see Figure 4.1), as defined by a large-scale study of mentalizing (Dufour et al., 2013), and the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS; see Figure 4.1), as defined by a meta-analysis of the neural correlates of subjective value

(Bartra et al., 2013). We treated each set of regions as a system (self-relevance, social processing, and subjective value) in all analyses.

Analyses

fMRI Data Preprocessing

Functional data were pre-processed and analyzed using FSL and Statistical Parametric Mapping (SPM12, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). Data were corrected for differences in the time of slice acquisition using sinc interpolation, spatially realigned to correct for head motion, and co-registered to the structural image. Data were then normalized to the skull-stripped Montreal Neurological Institute (MNI) template provided by FSL (FMRIB Software Library; MNI152_T1_1mm_brain.nii). Functional images were smoothed using a Gaussian kernel (8 mm full width at half maximum).

fMRI Data Extraction and Analyses

We first adopted a region of interest approach to investigate the relationship between parameter estimates of neural activity during ad exposure and, separately, self-reports of perceived ad effectiveness and sharing intention. Analyses were conducted using sets of a priori theory-driven regions of interest implicated in self-relevant processing, social processing, and subjective valuation (as defined in Methods; see Figure 4.1).

The fMRI data were modeled using the general linear model (GLM) as implemented in SPM8 (SPM8, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). At the first level, a separate regressor was defined during the viewing period (30 seconds) for each of the 12 ads, resulting in 12 ad-specific

regressors for each participant. The same procedure was employed during the reimagine period (11 seconds), resulting in an additional 12 ad-specific regressors for each participant. The preparation countdown task periods were captured in a single regressor. The six rigid-body translation and rotation parameters derived from spatial realignment were also included as nuisance regressors in all first-level models.

We extracted parameter estimates from these sets of regions during the viewing period using the MarsBar toolkit from SPM (Brett, Anton, Valabregue, & Poline, 2002) and converted them to percent signal change, resulting in 12 values for each brain system for each participant. These values were combined with perceived effectiveness and sharing ratings by participant and ad in R (R Core Team, 2015). Prior to analyses, we standardized (z-scored) mean neural activity and self-report data across subjects and used standardized variables in all regression models. We used the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2016) in R to create mixed-effect multilevel models in which neural response in each system (self-relevance, social processing, and subjective value) was used to separately predict each outcome of interest (perceived effectiveness and intention-to-share ratings). In all models, participants and ads were treated as random effects, with random intercepts to account for non-independence of repeated measures within subjects,[10] and analyses controlled for age, sex, race, and prior recall of each The Real Cost ad as assessed during the baseline questionnaire.

[10] We tested whether allowing both slopes and intercepts to vary at the participant and ad levels improved model fit. Original models specified random intercepts at both participant and ad levels. We created models that also included (1) random slopes for participants, (2) random slopes for ads, and (3) random slopes for both participants and ads. We then conducted analysis of variance (ANOVA) to compare each of these models with the original reduced model, for each ROI and outcome of interest. Using Bayesian information criteria (BIC) as our criterion for model selection, we determined that these

Subsequently, we conducted exploratory whole-brain analyses to determine brain regions outside of hypothesized regions of interest in which neural activity during ad exposure scaled with subsequent ratings of perceived ad effectiveness and sharing intention (i.e., whole brain models in which participant ratings are treated as predictor variables and the brain is treated as the outcome variable). Two additional models were built for each subject with a single regressor for the viewing period for all ads with participants' standardized (1) perceived effectiveness and (2) sharing ratings used as parametric modulators of brain activity. An additional regressor was used to capture the reimagine period and six movement nuisance regressors were used. Data were high-pass filtered with a cutoff of 128 seconds in all models.

Parametric modulation analyses of the effects of variation in perceived effectiveness ratings on neural response during each ad exposure, described above, were combined using a random effects model in SPM. As described above, we built individual models for each participant, modeling the period of exposure to each ad in one regressor, a parametric modulator of perceived effectiveness, and a final regressor modeling other periods of no interest to this analysis (preparation countdown, sharing rating, and reimagining). These individual maps were combined in a random effects analysis at the group level. The resulting image maps were cluster corrected using 3dClustSim (version AFNI_16.2.02) at $p = .005$, $k > 504$, corresponding to $p = .05$, corrected. Likewise, parallel models were built using a parametric modulator of standardized sharing rating.

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models were not a better fit to the data as compared with the original models, and hence opted for the more parsimonious models.

Results

Demographic Distributions

The study sample was comprised of 40 adolescents aged 14-17, with a mean age of 16.1 years (SD = 0.94). The sample was approximately evenly distributed by sex, with 21 females (52.5%). There was variation in participants' race, with 13 White (23.5%), 13 Black/African American (23.5%), and 8 Asian participants (20%), and 6 participants of Other or multiple races (15%). Sensation-seeking scores ranged from 7-16, with a mean of 11.7 (SD = 1.88). Among low-moderate sensation seekers, the mean score was 10.05 (SD = 1.03), and among high sensation seekers, the mean score was 13.19 (SD = 1.03). High sensation seekers scored significantly higher on the Brief Sensation Seeking Scale (BSSS-4) than low-moderate sensation seekers ($t = 9.64$, $p < .001$).

Neural Activity During Ad Exposure and Perceived Ad Effectiveness

We first examined perceived ad effectiveness as a function of neural activity within self-relevance, social processing and value regions of interest during ad exposure (Table 4.2). Within the social processing system during ad exposure, neural activity was significantly associated with mean perceived effectiveness ($\beta = .12$, $t(390) = 2.37$, $p = .019$, 95% CI [0.019, 0.213]). By contrast, neural activity in the self-relevance system was marginally associated with mean perceived effectiveness ($\beta = .10$, $t(348) = 1.89$, $p = .060$, 95% CI [-0.003, 0.196]), and neural activity in the value system did not predict mean perceived effectiveness ($\beta = .05$, $t(400) = 1.02$, $p = .308$, 95% CI [-0.048, 0.149]). We conducted a parallel set of analyses in which we controlled for age, sex, race, prior ad recall, and sensation seeking (high versus low or moderate). Results indicated that, in all models, the coefficient for sensation seeking was non-significant and the coefficients for

all other variables did not differ substantively from the original models. Exploratory whole brain analyses, cluster corrected using 3dClustSim at $p < .005$, $k > 504$, corresponding to $p < .05$ corrected, did not produce any other activations that survived whole brain correction.

Neural Activity During Ad Exposure and Intention to Share

We next examined intention-to-share ratings as a function of neural activity in the self-relevance, social processing, and subjective value regions of interest during ad exposure (Table 4.3). Neural activity during ad exposure in the hypothesized regions of interest within the self-relevance (β = -.06, $t(408) = -1.16$, $p = .246$, 95% CI [-0.164, 0.044]), social processing (β = .01, $t(421) = 0.26$, $p = .792$, 95% CI [-0.086, 0.113]), and subjective value (β = -.07, $t(435) = -1.35$, $p = .178$, 95% CI [-0.171, 0.030]) systems was not significantly associated with intention to share ads. We conducted a parallel set of analyses in which we controlled for age, sex, race, prior ad recall, and sensation seeking (high versus low or moderate). Results indicated that, in all models, the coefficient for sensation seeking was non-significant and the coefficients for all other variables did not differ substantively from the original models. Additionally, no regions of interest within these systems survived more stringent correction within a whole brain analysis.

Table 4.2 *Results from separate multilevel regression models assessing the relationship between neural activity in self-relevance, social processing, and subjective value systems during ad exposure and mean perceived effectiveness*

	B (SE)	*β*	*df*	*t*	*p*
Self-relevance[a]	0.19† (0.10)	0.10	348	1.89	0.060
Age	0.03 (0.09)	0.03	34	0.36	0.724
Sex	-0.32† (0.16)	-0.16	34	-1.98	0.056
Black	0.28 (0.20)	0.13	35	1.42	0.164
Asian	-0.19 (0.22)	-0.08	35	-0.85	0.404
Other/multiple	0.32 (0.26)	0.11	34	1.24	0.222
Ad recall	0.18* (0.09)	0.09	470	2.02	0.044
Social processing[b]	**0.32* (0.13)**	**0.12**	**390**	**2.37**	**0.019**
Age	0.02 (0.09)	0.02	34	0.22	0.826
Sex	-0.29† (0.16)	-0.15	34	-1.78	0.084
Black	0.28 (0.20)	0.13	34	1.39	0.173
Asian	-0.17 (0.23)	-0.07	35	-0.73	0.469
Other/multiple	0.31 (0.26)	0.11	34	1.18	0.246
Ad recall	0.19* (0.09)	0.09	470	2.09	0.037
Subjective value[c]	0.12 (0.12)	0.05	400	1.02	0.308
Age	0.03 (0.09)	0.03	34	0.37	0.718
Sex	-0.29† (0.16)	-0.15	34	-1.79	0.082
Black	0.27 (0.20)	0.13	36	1.35	0.185
Asian	-0.19 (0.26)	-0.07	35	-0.82	0.417
Other/multiple	0.33 (0.26)	0.12	34	1.28	0.209
Ad recall	0.19* (0.09)	0.10	471	2.10	0.037

Note. Separate regression models were estimated for each system (3), controlling for age, sex, race (reference category = White), and prior recall of each The Real Cost ad. Parallel analyses excluding control variables (not shown) produced similar results. SE = standard error. † $p < .10$, * $p < .05$

[a] The self-relevance system is comprised of the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC).
[b] The social processing system is comprised of the bilateral temporal parietal junction (TPJ), dorsal, middle, and ventral components of the medial prefrontal cortex (DMPFC, MMPFC, and VMPFC), precuneus (PC), and right superior temporal sulcus (rSTS).
[c] The subjective value system is comprised of the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS).

Table 4.3 *Results from separate multilevel regression models assessing the relationship between neural activity in self-relevance, social processing, and subjective value systems during ad exposure and intention to share ads*

	B (SE)	*β*	*df*	*t*	*p*
Self-relevance[a]	-0.16 (0.14)	-0.06	408	-1.16	0.246
Age	0.02 (0.14)	0.01	34	0.14	0.893
Sex	-0.37 (0.25)	-0.14	34	-1.49	0.147
Black	0.67* (0.30)	0.25	35	2.20	0.035
Asian	-0.13 (0.34)	-0.04	35	-0.39	0.701
Other/multiple	0.79* (0.39)	0.22	34	2.03	0.050
Ad recall	0.11 (0.11)	0.04	430	0.94	0.349
Social processing[b]	0.05 (0.17)	0.01	421	0.26	0.792
Age	0.01 (0.14)	0.01	34	0.10	0.919
Sex	-0.39 (0.24)	-0.15	34	-1.57	0.125
Black	0.71* (0.30)	0.26	35	2.36	0.024
Asian	-0.13 (0.34)	-0.04	35	-0.38	0.706
Other/multiple	0.77† (0.39)	0.21	34	1.97	0.057
Ad recall	0.10 (0.11)	0.04	432	0.90	0.371
Subjective value[c]	-0.21 (0.16)	-0.07	435	-1.35	0.178
Age	0.02 (0.14)	0.02	34	0.15	0.885
Sex	-0.39 (0.24)	-0.15	34	-1.61	0.117
Black	0.64* (0.30)	0.23	36	2.11	0.042
Asian	-0.13 (0.34)	-0.04	35	-0.40	0.693
Other/multiple	0.80* (0.39)	0.22	34	2.07	0.046
Ad recall	0.11 (0.11)	0.04	433	0.92	0.356

Note. Separate regression models were estimated for each system (3), controlling for age, sex, race (reference category = White), and prior recall of each The Real Cost ad. Parallel analyses excluding control variables (not shown) produced similar results. SE = standard error. † $p < .10$, * $p < .05$

[a] The self-relevance system is comprised of the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC).
[b] The social processing system is comprised of the bilateral temporal parietal junction (TPJ), dorsal, middle, and ventral components of the medial prefrontal cortex (DMPFC, MMPFC, and VMPFC), precuneus (PC), and right superior temporal sulcus (rSTS).
[c] The subjective value system is comprised of the ventromedial prefrontal cortex (VMPFC) and ventral striatum (VS).

Discussion

The present study assessed the relationships between adolescents' neural activity during exposure to ads from The Real Cost anti-smoking campaign and two outcomes relevant to campaign ads: perceived ad effectiveness, and the intention to share ads on social media. Mean perceived ad effectiveness was positively associated with neural activity in the social processing system and marginally associated with neural response in the self-relevance system. However, perceived effectiveness was not associated with neural activity in the subjective value system. Conversely, intention to share ads on social media was not associated with neural activity in the social processing, self-relevance, or subjective value systems.

Our findings are consistent with the idea that the mental processes responsive to effective messages in adolescents are more focused on social processing than self-related cognitions. Substantial research with adult samples has demonstrated that effective messages elicit activity in brain regions implicated in self-relevance and value, and that messages that are likely to be shared elicit value, self-relevant, and social processing. Our results suggest a more central role for socio-cognitive effects than has previously been emphasized, which may reflect adolescents' heightened sensitivity to social cues in both decision-making (Crone & Dahl, 2012) and judgments of self-relevance (Pfeifer et al., 2009).

Perceived Effectiveness

Our data suggest that adolescents' ratings of message efficacy may be attributable, in part, to their consideration of social factors when they are initially exposed to messages, rather than more self-focused considerations observed in adults.

Whereas effective health messages evoke a neural response in the MPFC (implicated in self-relevance and value) in adult samples (Cooper et al., 2015; Chua et al., 2011; Falk et al., 2012, 2011), our findings indicate a marginal, positive relationship between perceived message effectiveness and brain response in the self-relevance system, and no relationship with activity in the value system. Thus, message efficacy may be driven by different processes in adolescents than in adults. Indeed, studies of message effects suggest that greater weight is placed on social factors in adolescents. In particular, studies of the effects of anti-substance use messages on adolescents have shown that a range of social factors influence the relationship between message exposure and message-relevant outcomes. These social factors include peer group identification (Moran & Sussman, 2014), social norms about substance use (Ho et al., 2014), and actual substance use by peers (Paek, 2008). These findings also echo social components from prominent theories of behavior change, which posit that behavioral outcomes are influenced by normative beliefs about a behavior—both perceptions of who is or is not engaging in the behavior—and perceptions of others' approval or disapproval of the behavior (Fishbein & Ajzen, 2011). Thus, our data highlight the idea that social factors and information about peers' preferences may be especially important to the perceived effectiveness of campaign materials in adolescents.

Another possibility is that self-reported perceived effectiveness may rely more heavily on social considerations than objectively-measured behavior change. Despite the aforementioned link between the neural response in MPFC and targeted health outcomes (Chua et al., 2011; Falk et al., 2016, 2012, 2011), one previous study of the neural correlates of self-reported perceived message effectiveness in youth and young adults did

not show a link between MPFC or any other regions implicated in social processing in adults and self-reported perceived effectiveness in adolescents (Weber, Huskey, Mangus, Westcott-Baker, & Turner, 2015). However, with only limited studies of the neural correlates of perceived effectiveness, our data provide a reference point to which future research can be compared.

There are several implications of these findings for the development of influential media campaigns and more broadly in relation to how adolescents respond to social and self-relevant cues. The first implication pertains to the design of effective messages. One popular approach to message design is tailoring, or the customization of messages to match individual characteristics in a population (Kreuter & Skinner, 2000). Evidence points to the efficacy of tailoring: a meta-analysis of 57 tailored health behavior change interventions conducted largely in adult samples (mean age of 45) indicated that tailored messages had a greater influence on health behavior than comparison or control conditions (Noar et al., 2007). These past findings suggest that messages are more effective when they incorporate self-relevant content. Given evidence that messages rated as more self-relevant (Chua et al., 2011; Strecher et al., 2006) and those that elicit greater neural activity in brain regions implicated in self-relevance (Cooper et al., 2015; Falk et al., 2016) are more apt to influence behavioral outcomes, we can infer that self-relevant content may drive self-relevant cognitions, which in turn contribute to the efficacy of the messages in adults.

In the current study, messages that were perceived to be more effective were associated with brain activity in the social processing system rather than brain regions implicated in self-relevant thought. One possibility is that a form of "social tailoring" that

focuses on peer norms or takes them into account may be especially impactful in adolescents. Future research should examine whether messages that elicit specific socially-focused, and self-relevant thoughts in adolescents are perceived as effective when the intended audience is adolescents. Alternatively, self-relevant messages may prompt socio-cognitive processing in the form of reflected appraisals (i.e., what others will think of me if I like this). Though the ability to mentalize develops during childhood, during adolescence individuals exhibit a marked shift from self-oriented to social-oriented behavior (Eisenberg & Fabes, 2006). During this process, the tendency for self-relevant messages to elicit social cognitive processing may reflect adolescents' struggles to disentangle the "self" from the "social," given their reduced tendency to differentiate between their perception of what others think about them and what others actually think about them (Elkind, 1967). Our findings warrant additional research to elucidate the mechanisms that account for self-relevant and social thoughts as they relate to effective messages.

Intention to Share

Contrary to our hypotheses, we find that brain activity in hypothesized regions of interest within the self-relevance, social processing, and subjective value systems is not associated with sharing intentions. Our findings diverge from previous research by Scholz et al. (2017) and Baek et al. (2017), which showed a positive relationship between neural activity in the self-relevance, social processing, and subjective value systems used here, in response to health articles and adults' self-reported intention to share health news articles with others.

There are several potential explanations for our null findings. One possibility is that for adolescents, self-relevant, social, and subjective value processing during message exposure is not predictive of intention to share messages on social media. That is, the extent to which ads inspire adolescents to think more about themselves, others, and their subjective value may have no bearing on message retransmission. Our hypothesis that ad-induced neural processing in these brain regions drives adolescent sharing was based, in part, on parallel findings from adult studies (Baek et al., 2017; Scholz et al., 2017). However, our results may signal that adolescents hold different motivations for sharing than adults.

Another possible explanation for these findings is specific to the outcome in question—self-reported intention to share ads on social media. Recent neuroimaging research examining the psychological processes underlying information sharing has shown that self-disclosure (Tamir & Mitchell, 2012), and information sharing more broadly (Tamir, Zaki, & Mitchell, 2015), are intrinsically rewarding. Findings from the latter of these studies, conducted with young adults (aged 18-28), highlight the role of the ventral striatum (VS) and VMPFC in these processes. Though the VS is implicated in reward processing in both adolescents and adults, neural response in this region differs by age group according to the specific type of processing involved. When receiving rewards, adolescents consistently demonstrate increased response in the VS. However, in anticipation or expectation of rewards, adolescents tend to show less activation in the VS relative to adults (Richards et al., 2013). Thus, even if the act of sharing is deemed rewarding, considering one's intention to share information may constitute the anticipation of a reward (as compared with engaging in the act of sharing), and this could

explain the lack of association between adolescents' sharing intention ratings and brain response in the reward system.

An alternative explanation for these findings is that the relationship between adolescent brain response to ads and sharing intention is contingent on developmental or motivational differences. Adolescence is characterized by changes in social development (Crone & Dahl, 2012), and the increasing influence of peers may prompt adolescents to change their behavior in an effort to gain social acceptance (Steinberg & Monahan, 2007). Concurrently, adolescence is characterized by a desire for autonomy, as children become increasingly independent (Steinberg & Silverberg, 1986). The act of sharing information with others involves considering how it will reflect upon oneself and influence others (Berger, 2014). Thus, differences in the relative influence of these developmental phenomena could alter the relationship between neural response to ads and their intention to share them with others on social media. Additionally, it is unclear what specific motivations prompt adolescents in our sample to share anti-smoking messages. It is feasible that adolescents are more inclined to share messages that contain particular content, such as information that would reflect positively upon the sharer or be particularly relevant for the receiver. These considerations warrant additional research to examine the role of adolescent sharing motivation on the link between brain response and sharing intention.

Furthermore, our null findings may stem from greater variability in adolescents, relative to adults, in the brain systems examined in this study. Adolescence is characterized by developmental changes that affect brain structure and function (Crone & Dahl, 2012). According to one account of adolescent development, brain regions

implicated in social and emotional processing mature more quickly than those involved in cognitive control (Steinberg, 2010). It is possible that different rates of maturation across study participants led to greater variation in neural activation in corresponding regions of the brain. Indeed, in a recent study that examined the moderating effect of development on the neural correlates of social influence processing and conformity, adolescents demonstrated significantly more variability in neural response in regions involved in social influence relative to adults (Cascio, 2017). Variability in brain activation within our study sample could make it more difficult to detect the expected relationships between brain response in self-relevance, social, and value processing systems and sharing intention. Lastly, the small number of ads in our stimuli (12) and variability across ads may have limited our power to detect true effects. Our measure of sharing intention was based on a single item that lacked specificity about intention to share on a specific social media platform; these factors may have added noise to our findings, potentially impeding our ability to detect true effects.

Conclusion

Projections based on current smoking rates estimate that 5.6 million of today's American youth will die prematurely due to a smoking-related illness (U.S. Department of Health and Human Services, 2014), underscoring the vital importance of adolescent smoking prevention. Over the past 15 years, a number of mass media smoking-prevention campaigns have been broadcast via mass media channels to target this demographic, and evaluations of this work have largely pointed to their success in influencing smoking-relevant beliefs and behaviors (Allen et al., 2015). Despite progress in this domain, questions remain about the neural mechanisms that account for a link between campaign

exposure and targeted outcomes in adolescents, which may influence message design and dissemination. Our findings shed light on the neural underpinnings of adolescents' perceptions of ad effectiveness, potentially highlighting a stronger role for social processes than self-focused processes and subjective valuation, while raising questions about what might account for sharing among adolescents. Future research should examine whether individual differences can better explain the relationship between ad-induced brain response and sharing intention, and whether engagement of these three systems during message exposure predicts actual sharing behavior in adolescence. Furthermore, future research should examine whether neural activity in self-relevance, social processing, and subjective value systems in this group predicts population-level measures of ad effectiveness.

CHAPTER 5. AD-ELICITED BRAIN RESPONSE MODERATES THE RELATIONSHIP BETWEEN EXOGENOUS AD EXPOSURE AND POPULATION-LEVEL AD RECALL

Introduction

Millions of dollars are spent each year on mass media campaigns (Holtgrave, Wunderink, Vallone, & Healton, 2009; Villanti, Curry, Richardson, Vallone, & Holtgrave, 2012; Xu et al., 2015), which can exert substantial influence on the performance of health-promoting and avoidance of health-harming behaviors (Wakefield et al., 2010). Yet, identifying which messages are most likely to shift population-level behaviors is a difficult task (O'Keefe, 2018). As a prerequisite, the success of a health campaign hinges on its ability to achieve adequate exposure (Hornik, 2002; Randolph & Viswanath, 2004). Sufficient exposure is necessary, in part, because campaign messages are crafted to prompt cognitive processing of message content, thereby influencing message-consistent beliefs, intentions, and behaviors (Cappella, 2006; Fishbein & Cappella, 2006; Lang, 2000). However, dissemination of messages does not guarantee that they will be attended to, processed, and stored by the target audience. The extent to which messages engage viewers can influence the depth of persuasion and endurance of effects (Cappella, 2006; Petty & Cacioppo, 1986). The current investigation tests whether messages that elicit specific brain responses in relatively small groups of people produce greater depth of encoding at the population level.

Specifically, we focus on message recall, which is a function both of opportunities for exposure and depth of encoding (i.e., given that a person has been exposed to a message, do they encode it in a way that enables later recall). Opportunities for exposure

to campaign advertisements in the media environment correlate with self-reported ad recall (Cowling et al., 2010; Kranzler et al., 2017; Niederdeppe, 2005; Richardson, Langley, et al., 2014; Southwell et al., 2002), reflecting the fact that ad exposure is one necessary input to subsequent recall. However, not all message exposures result in recall, and empirically, opportunities for exposure are imperfect predictors of recall (Cowling et al., 2010; Richardson, Langley, et al., 2014). In other words, even given equal exposure, some messages may be remembered better than others, and variability in message memorability may result from how different messages are processed and encoded into memory.

Message Processing, Storage, and Retrieval

Theories of message processing posit that ad recall can be conceptualized as a function of how an ad is processed and stored in the brain, given the opportunity for exposure. The Limited Capacity Model of Motivated Mediated Message Processing (LC4MP) holds that for messages to be recalled, they must be encoded and stored in memory (Lang, 2000). During encoding, the information presented in a mediated message is transformed into a mental representation in working memory, which may then be stored in long-term memory. According to LC4MP, a message must be sufficiently engaging to prompt encoding. Furthermore, information in encoded mental representations is not processed equally during storage; information that can more readily be linked with previously stored information is stored more thoroughly. The ability to retrieve information (e.g., an ad) when cued is thought to index how thoroughly a piece of information was stored (Lang, 2000). Thus, retrieval or recall of a message is critically dependent on the extent to which it engages its viewer.

Messages that contain certain characteristics are more apt to be recalled and more strongly associated with subsequent message effects (Donohew, Palmgreen, & Duncan, 1980; D'Silva & Palmgreen, 2007; Lang, Bolls, Potter, & Kawahara, 1999; Palmgreen & Donohew, 2010; Stephenson & Southwell, 2006). One common thread across theories of media effects and behavior change is that social inputs are key determinants of effects. Theories and empirical research link social norms with message effects (Cialdini et al., 2006; Cialdini & Trost, 1998; Goldstein et al., 2008; Rimal & Real, 2005), and social influence is a core tenet of prominent behavior change theories (Fishbein & Ajzen, 2011; Glanz et al., 2008). Together, these findings imply that messages that feature social information and prompt individuals to consider social consequences may be especially influential.

Social considerations are particularly salient for adolescents, a key target audience for health campaigns. Adolescence is marked by rapid changes in social and brain development (Crone & Dahl, 2012) and a shift from self-oriented to social-oriented behavior (Eisenberg & Fabes, 2006). During this developmental period, individuals become increasingly more sensitive to social cues to the extent that perceived social rewards and threats can exert substantial influence on their actions (Crone & Dahl, 2012; Steinberg & Monahan, 2007). Given the prominent role that social considerations play in adolescent thoughts and actions, the expectation or anticipation of social consequences may enhance the saliency of messages for this population, thereby influencing the extent to which they are encoded and recalled. Thus, messages that prompt adolescents to think about social outcomes may lead to enhanced message encoding.

Brain Response During Message Exposure

One promising approach for assessing whether a given ad elicits social information processing across people, and in turn whether message encoding takes place, is to measure brain response to messages in real time during message exposure. Functional magnetic resonance imaging, or fMRI, allows researchers to track unobtrusively how messages engage regions of the brain that have previously been implicated in specific psychological processes. By measuring changes in neural response, this method can elucidate the cognitive processes that occur during exposure to memorable messages without having to rely on introspection.

Previous research has demonstrated that brain response during message exposure can predict message effects at both the individual and population levels. The majority of this research has examined the effects of anti-smoking messages on smoking-relevant outcomes. At the individual person level, message-elicited neural response in regions associated with self-related processing and subjective valuation have been shown to associate with subsequent self-reports and biological indicators of smoking reduction (Cooper, Tompson, O'Donnell, & Falk, 2015; Falk, Berkman, Whalen, & Lieberman, 2011; Wang et al., 2013) and smoking cessation (Chua et al., 2011). At the population level, neural response to stimuli in a relatively small group of participants has been shown to predict large-scale health-related outcomes, such as the retransmission of health information or the success of anti-smoking campaign messages (Falk et al., 2016; Falk, Berkman, & Lieberman, 2012; Scholz et al., 2017). Yet these studies have not documented the neural processes associated with large-scale message recall, or linked brain activity in small groups to population-level message recall.

Brain Response and Message Encoding

Prior literature suggests that two sets of brain regions are particularly important in affecting message recall: regions related to social processing, and regions related to memory encoding. The LC4MP posits that a message must be sufficiently engaging to prompt encoding (Lang, 2000); thus, messages that are particularly salient may be more apt to engage attention and encoding processes. In line with this perspective, we first focused on brain regions implicated in social processing, such as recognizing other people and evaluating their mental states, given that social processing is thought to enhance the saliency of messages. This class of cognitions, which includes "mentalizing" or understanding the mental states of other people (Frith & Frith, 2006), is consistently associated with neural response in the bilateral temporal parietal junction; dorsal, middle, and ventral regions of the medial prefrontal cortex; precuneus; and the right superior temporal sulcus (Dufour et al., 2013).

Second, we focused on brain regions directly involved in memory formation, within the medial temporal lobes, including the hippocampus. Numerous studies demonstrate that hippocampal activation correlates with memory encoding (Frankland & Bontempi, 2005; Greicius et al., 2003; Lepage, Habib, & Tulving, 1998; Schacter & Wagner, 1999). Though some theories suggest the hippocampus plays a permanent role in memory storage and retrieval, most models posit that memories are initially encoded and stored in the hippocampus, and that over time these newer memories become integrated with pre-existing memories stored in a broadly-distributed cortical network (Frankland & Bontempi, 2005). Messages that elicit greater neural response in memory

encoding regions should index stronger message encoding and might predict subsequent message recall.

Current Study

Message recall is contingent on opportunities for exposure—without the availability of messages in one's environment, they cannot be processed, stored, and subsequently recalled. Unsurprisingly, then, there is evidence that opportunities for message exposure correlate with message recall. In addition, we argue that the extent to which a given message prompts message encoding across people, indexed by neural activation in key regions during message exposure in test groups, moderates the relationship between opportunities for exposure and message recall at the population level. In the current study, we test the idea that messages that more strongly engage brain regions involved in motivating and indexing message encoding in relatively small groups of people, should be better recalled, given available exposure in larger groups. According to this logic, we would expect that the effect of opportunities for exposure on recall will be larger for messages that elicit greater versus lesser neural response in the hypothesized regions of interest.

The current study examines whether message-elicited responses in brain regions associated with social processing and memory encoding in a group of adolescents in Philadelphia moderate the relationship between opportunities for national campaign exposure and message recall in a national survey of adolescents. Prior to examining moderation hypotheses, we first tested the following hypothesis concerning the main effects of opportunities for exposure on message recall:

H1: There is a positive relationship between opportunities for message exposure and message recall.

Next, we tested the following moderation hypotheses:

H2: Message-induced neural response in social processing regions moderates the relationship between opportunities for message exposure and message recall, such that greater neural response is associated with a more positive relationship between exposure and recall.

H3: Message-induced neural response in memory encoding regions moderates the relationship between opportunities for message exposure and message recall, such that greater neural response is associated with a more positive relationship between exposure and recall.

To demonstrate that these moderation effects are not the result of general increases in brain activity during message exposure, we also examined the moderating effects of neural response in a region not expected to be relevant to message recall—the supplementary motor cortex, which is implicated in the planning and execution of voluntary movement (Nachev, Kennard, & Husain, 2008). We did not expect to observe a relationship between activity in this region and message encoding or processing, and thus anticipated that neural response in this region would not moderate the relationship between exposure opportunities and message recall.

Methods

Datasets

This study focuses on effects of advertisements from "The Real Cost" anti-smoking campaign, the first nationally-funded public education campaign aimed at reducing tobacco use among U.S. youth aged 12 to 17 (Duke et al., 2015). Data for this study were drawn from three datasets.

Survey dataset. The first dataset is a national observational survey of youth and young adults, undertaken by Tobacco Center of Regulatory Science (TCORS) at The University of Pennsylvania. This survey was administered as part of a larger project to examine whether population-level exposure to tobacco-relevant content in the public communication environment predicts subsequent tobacco-relevant beliefs, attitudes and use behavior. The 20-minute survey measured knowledge, beliefs, intentions, and behaviors related to tobacco products and tobacco product use, and recalled exposure to specific advertisements from The Real Cost campaign. The survey also measured respondents' typical media use, including general TV-watching behavior, sociodemographic characteristics, and tobacco use risk factors.

Data were collected through a rolling, cross-sectional telephone survey from June 18, 2014 to June 20, 2017, administered to a nationally-representative sample of 13- to 25-year-olds. Study respondents were recruited by research firm Social Science Research Solutions (SSRS) through random digit dial (RDD) and list assisted sampling of both landline and cell phone samples. A total sample of 11,847 respondents completed the survey (American Association of Public Opinion Research response rate #3 = 22%). To align the study sample with the target population for The Real Cost campaign (12- to 17-

year-old nonsmokers and smoking experimenters), the study sample has been limited to 13- to 17-year-olds who reported having smoked fewer than 100 cigarettes in their lifetime (n = 5,110).

TRP dataset. The second dataset consists of national television Target Rating Points (TRPs) for The Real Cost campaign. TRPs measure the opportunity for exposure to media content in a targeted population (e.g., 12- to 17-year-olds) over a specified period of time, equal to the product of media content reach and frequency of exposure (Farris et al., 2010). For example, if a campaign purchased 100 TRPs for a specific advertisement over a one-week period, this could reflect 100% of the targeted population having the opportunity to be exposed to the ad once per week, 1% of the targeted population having the opportunity to be exposed to the ad 100 times per week, or a similar combination of reach and frequency for which the product is equal to 100 (Southwell et al., 2002). TRP data were provided by the Food and Drug Administration's (FDA) Center for Tobacco Products (CTP), which funds and oversees campaign implementation. National TRPs are provided on a weekly basis for each advertisement, starting on the Monday of each week since the campaign was initiated on Monday, February 10, 2014 and ending on Sunday, June 25, 2017.

FMRI dataset. The third dataset is comprised of neural responses to ads from The Real Cost campaign (fMRI study) in a sample of 14- to 17-year-old nonsmokers (n = 40), collected from December 3, 2015 – June 9, 2016 in Philadelphia, PA. Study participants first completed a web-based questionnaire to assess prior recall of campaign ads, demographic information (e.g., age, sex, race), as well as smoking-relevant cognitions and behaviors and individual difference measures not included in the current study. At

the in-person scanning session, participants viewed ads from The Real Cost campaign during an fMRI scan while their brain response was measured (see Figure 5.1 for details about the study task), then answered questions about their perceived effectiveness of each ad. The data used in this study consists of neural response within (1) social processing regions, (2) memory encoding regions, and (3) the motor cortex across study participants for each of 12 campaign ads.

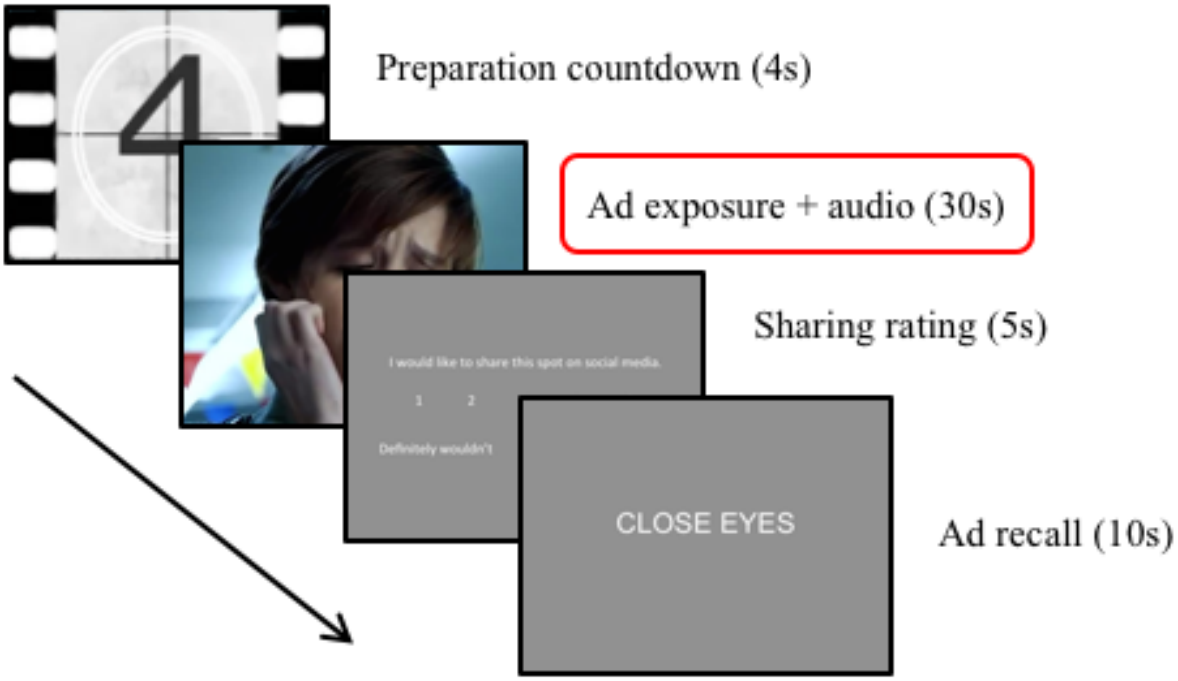

Figure 5.1 *Brief overview of fMRI study task.*

Participants first viewed a 4-second preparation countdown and were then instructed to view one of the 30-second The Real Cost ads. Subsequently, participants were instructed to rate their intention to share the ad on social media. Lastly, participants were asked to close their eyes and instructed to reimagine the ad in their mind's eye. Each participant completed the preparation countdown, view, sharing rating, and reimagine tasks in the same order for all 12 ads, however the order in which ads were presented was randomized. The current study focuses on neural response during the ad exposure period (outlined in red); sharing ratings and neural response during the sharing and reimagine portions of this task are not assessed in the current study.

Study Design

The dependent variable is self-reported recall of 12 ads from The Real Cost campaign across 5,110 respondents as assessed by the TCORS survey (Survey dataset). Respondents were first asked the following question: About how many times in the past 30 days have you seen or heard of each of the following? Subsequently, they were read brief descriptions of each ad (Table 5.1) and responses were coded between 0–100. For the first 4 weeks of the survey, respondents were asked about all ads currently airing in random order. For the remainder of the data collection period, respondents were asked about 2–3 ads randomly selected from a pool of ads that included the larger set of The Real Cost ads that were currently airing. Ads were removed from the pool of ads once they were continuously off-air for 3 months and were not scheduled to be rebroadcast.

Table 5.1 *Names and descriptions of 12 advertisements from The Real Cost campaign*

Ad name	Ad description
Alison	A girl in a cafeteria complains about cigarettes being so bossy.
Any Reason	A girl won't smoke because she doesn't want to break up her finger puppets.
Band	A tiny bully drags a drummer away from band practice to smoke.
Bully	A tiny man bullies young people into smoking cigarettes.
Dance	A tiny bully makes a teen leave his prom date for a smoke.
Found it	A disgusting creature crawls into a teen's mouth before hiding in a cigarette pack.
#ReasonsNotToSmoke	A skater doesn't smoke because he can't fit a pack of cigarettes in his skinny jeans.
Science Class	A disgusting creature escapes while being dissected in a science class and crawls into a cigarette pack.
Stay in Control	A girl gives up her freedom by signing a contract that turns into a cigarette.
The 7,000	Swamp creatures turn into 7,000 toxic chemicals as a guy inhales cigarette smoke.
Your Skin	A girl tears off a piece of her skin to pay for a pack of cigarettes.
Your Teeth	A guy yanks out a tooth to pay for a pack of cigarettes.

Note. These descriptions were used to assess past 30-day ad recall in both the Survey dataset and fMRI dataset. Survey respondents and study participants were instructed to indicate how many times in past 30 days they had seen or heard each television ad and were provided ad descriptions.

The independent variable is the total number of national television TRPs attained for each of 12 ads from The Real Cost campaign during 4-week, 8-week, and 12-week intervals prior to and including the week during which respondents were interviewed (TRP dataset).[11] Weekly totals of ad-specific TRPs were aggregated to form 4-, 8-, and 12-week measures. The 4-week time frame was selected because it is closely aligned with the past 30-day time frame used to assess ad recall. Additionally, we conducted analyses with TRPs aggregated over 8 and 12 weeks because we anticipated lingering reports of ad recall beyond the 30-day period, and because prior evidence shows increasing effects with longer exposure (Richardson, Langley, et al., 2014; White et al., 2013).

The moderating variables are the mean neural response in (1) social processing regions, (2) memory encoding regions, and (3) the motor cortex during exposure to each of 12 ads from The Real Cost campaign (fMRI dataset; see Figure 5.2). Neural response is operationalized as percent signal change in each region or set of regions. The social processing and memory encoding regions were identified using the Neurosynth database (http://neurosynth.org). This database contains neural activation coordinates for a large volume of fMRI studies based on the occurrence of words or phrases in the text of articles, producing mappings between brain activity and a range of cognitive states. We identified these regions using reverse inference brain maps that correspond with the occurrence of the word "mentalizing" (for social processing regions) and the phrase "memory encoding" (for memory encoding regions). The brain map for social processing

[11] It is possible that respondents interviewed earlier in each campaign week had fewer opportunities for exposure to weekly ads than respondents interviewed later in the week. To account for these differences in exposure opportunities, 4-, 8-, and 12-week periods receding from each week of interviews start halfway through the corresponding campaign week (*trpweek*).

regions (Figure 5.2, panel A) represents 5,569 neural activation coordinates across 124 studies; the brain map for memory encoding regions (Figure 5.2, panel B) represents 4,313 neural activation coordinates across 124 studies.[12] The supplementary motor cortex (Figure 5.2, panel C) consists of a single brain region constructed in the Wake Forest University PickAtlas toolbox in SPM.

[12] Brain maps were downloaded from neurosynth.org on February 2, 2018.

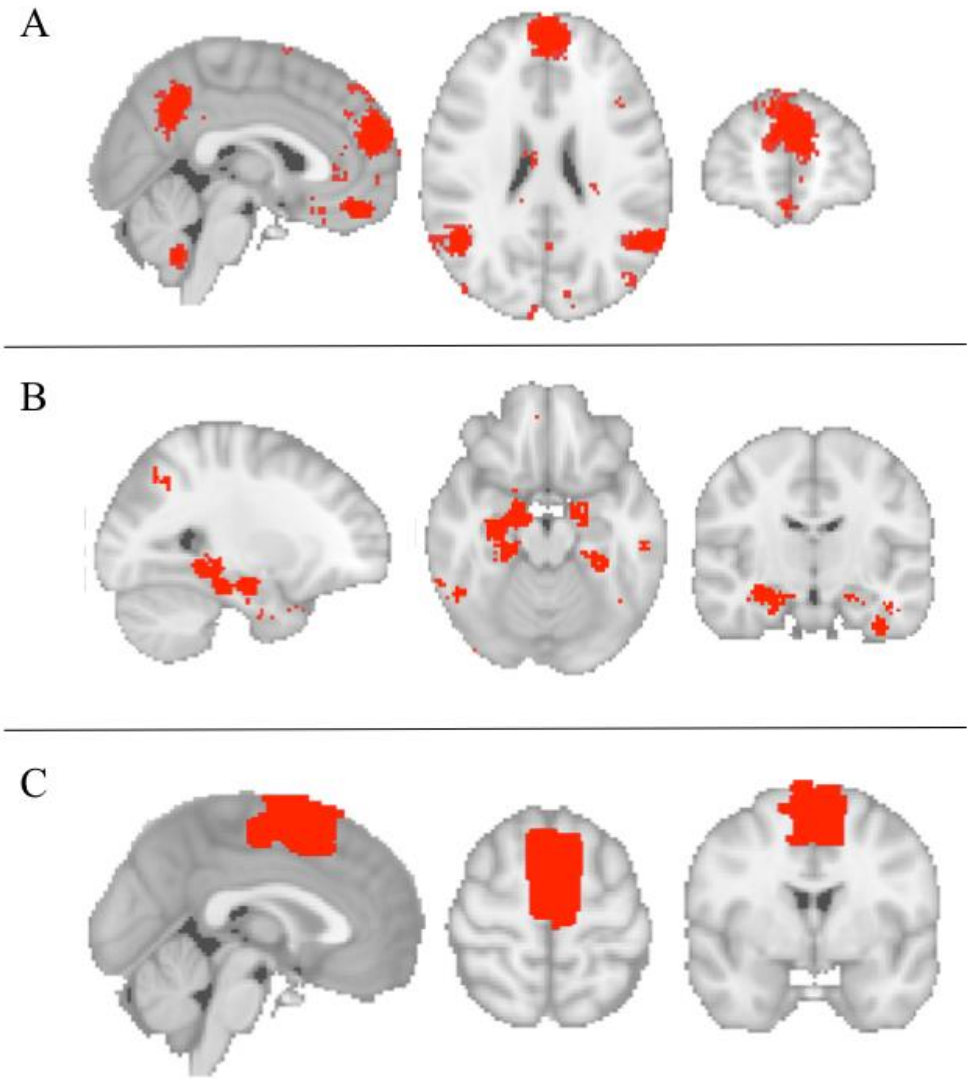

Figure 5.2. *Brain regions of interest.*

Neural response was measured in A) social processing regions, B) memory encoding regions, and C) the supplementary motor cortex. The social processing and memory encoding regions were identified using the Neurosynth database (http://neurosynth.org) using reverse inference brain maps that correspond with the occurrence of the word "mentalizing" and the phrase "memory encoding," respectively. The motor cortex was constructed in the Wake Forest University PickAtlas toolbox in SPM.

As the dependent and independent variables were drawn from different datasets, we did not expect any variables to confound the relationship between TRPs and ad recall. However, to reduce noise from individual-level variables that may associate with ad recall, our analyses controlled for the following potential covariates from the Survey dataset: respondents' age (13-17 years), sex, race (non-Hispanic White/Caucasian, non-Hispanic Black/African-American, Hispanic, and multiple races/other), sensation seeking (1-4, where 1 = low sensation seeker and 4 = high sensation seeker) (Zuckerman, 2007), parental disapproval of smoking with different response items for users and non-users (1 = don't/wouldn't mind, 2 = would/disapprove a little, and 3 = would/disapprove a lot), household cigarette use, parent education (less than high school, high school, some college, college degree, and completed graduate school), TV watching over the past seven days (0-168 hours), and interview week. Parent education was used as a proxy for socioeconomic status, and past 7-day TV watching behavior was used as a proxy for general TV watching behavior.

The Analytic Combined Dataset

Prior to conducting analyses, we combined the data, such that each respondent in the main Survey dataset had a separate data row for each ad recall item completed, with variables specifying the ad name and the recall value associated with that ad, as well as covariate scores, as reported by each respondent. Respondents were then assigned scores representing the TRPs for that ad that aired 4, 8, and 12 weeks prior to and including the week of the interview. Finally, fMRI data about the relevant ad (aggregated across the scanned sample for each ad) was merged into the ad-specific respondent data row and all variables were mean centered.

The fMRI scores were estimates of neural response to each ad in (1) social processing regions, (2) memory encoding regions, and (3) the motor cortex during exposure to each of 12 The Real Cost ads (compared to rest). We first extracted parameter estimates separately from the social processing, memory encoding, and motor cortex regions for each ad exposure and each fMRI participant using the MarsBar toolkit from SPM (Brett et al., 2002), then converted these estimates to percent signal change relative to baseline; this procedure resulted in 12 social processing, 12 memory encoding, and 12 motor cortex values for each fMRI participant. To account for the potential influence of prior ad exposure on neural response measures within the fMRI sample, we estimated multilevel regression models (one each for the social processing regions, memory encoding regions, and motor cortex) in which ad-specific neural response was regressed on fMRI participants' past 30-day ad recall (assessed with items listed in Table 5.1), controlling for past 4-week TRPs and time since the ad first aired (based on the fMRI scan date) and clustering at the participant and ad levels. This analysis yielded neural response residuals for these sets of brain regions for each participant and each ad. We used these neural response residuals to calculate the mean neural response in (1) social processing regions, (2) memory encoding regions, and (3) the motor cortex across all 40 study participants for each ad (fMRI2 dataset), creating a measure of the extent to which each ad collectively elicited brain response in each region or set of regions after removing the potential influence of prior ad exposure.[13]

[13] Neural response residuals were estimated with models that controlled for fMRI participants' past 4-week TRPs, prior ad recall, and days since each ad was first aired. We tested whether controlling for past 8- or 12-week TRPs in these residual models influenced study results. As results did not differ substantively, we report results using residuals from models that controlled for fMRI participants' past 4-week TRPs.

Analysis Plan

Prior to conducting moderation analyses, we first assessed the main effect of ad-specific TRPs on ad recall (H1). We estimated mixed-effect multilevel models with the *lmer* and *lmerTest* package (Kuznetsova et al., 2016) in R, separately regressing past 30-day ad recall on (1) past 4-week TRPs, (2) past 8-week TRPs, and (3) past 12-week TRPs. Respondents and ads were treated as random effects, with random intercepts to account for non-independence of repeated measures within respondents and ads.

To assess whether brain response in social processing regions during exposure to The Real Cost ads moderates the association between TRPs and ad recall (H2), we estimated mixed-effect multilevel models, separately regressing past 30-day ad recall on the interaction between mean neural response residuals in social processing regions and (1) past 4-week TRPs, (2) past 8-week TRPs, and (3) past 12-week TRPs. Similarly, to assess whether brain response in memory encoding regions during exposure to The Real Cost ads moderates the association between TRPs and ad recall (H3), we estimated mixed-effect multilevel models, separately regressing past 30-day ad recall on the interaction between mean neural response residuals in memory encoding regions and (1) past 4-week TRPs, (2) past 8-week TRPs, and (3) past 12-week TRPs.

Finally, to reduce the threat that results stem simply from global increases in brain activity, we assessed whether brain response in a region not expected to be relevant to message recall—the motor cortex—during exposure to The Real Cost ads moderates the association between TRPs and ad recall. We estimated mixed-effect multilevel models, separately regressing past 30-day ad recall on the interaction between mean neural response in the motor cortex and (1) past 4-week TRPs, (2) past 8-week TRPs, and (3)

past 12-week TRPs. All models included main effects of TRPs and aggregate neural response derived from the fMRI sample for each ad, on ad recall in the national survey. Respondents and ads were treated as random effects, with random intercepts to account for non-independence of repeated measures within respondents and ads. To reduce noise from individual-level variables that may associate with ad recall, analyses controlled for potential covariates listed in the Methods section.

Results

The demographic distributions in the Survey study sample are presented in Table 5.2. Respondents were approximately evenly distributed by sex (male and female) and age group (13-15 and 16-17), with a mean age of 15.34 (*SD* = 1.40). Approximately half of respondents (50.2%) were White, a quarter of respondents (24.7%) Hispanic, and a quarter of respondents split between Blacks/African Americans (13.2%) and those reporting Other/More than one race (11.8%). The majority of respondents' parents completed at least some college, with 59.8% of parents having attained at least a college degree and only a quarter of parents (24.6%) having completed less than or equal to a high school degree. The demographic distributions for the fMRI sample are presented in Table 5.3.

Table 5.2 *Demographic distributions of the Survey study sample (n = 5,110)*

	Frequency	Percentage	*Mean*	*SD*
Age			15.34	1.40
13-15	2,426	47.5		
16-17	2,684	52.5		
Sex				
Male	2,670	52.3		
Female	2,435	47.7		
Race				
White (non-Hispanic)	2,555	50.2		
Hispanic	1,257	24.7		
Black or African American (non-Hispanic)	674	13.2		
Other/more than one race	603	11.8		
Sensation seeking			2.42	0.52
Parent educational attainment				
Less than or equal to a high school degree	1,092	24.6		
Some college	688	15.5		
College degree	1,457	32.9		
Completed grad school	1,194	26.9		

Parental disapproval of smoking			2.90	0.35
Don't/wouldn't mind	77	1.5		
Would/disapprove a little	365	7.2		
Would/disapprove a lot	4,653	91.3		
Household cigarette use				
No/Lives alone	3,809	75.4		
Yes	1,243	24.6		
Average weekly hours TV watching			23.95	21.36

Note. SD = standard deviation. In the parental disapproval of smoking subcategories, categories are scored as follows: 1 = Don't/wouldn't mind, 2 = Would/disapprove a little, and 3 = Would/ disapprove a lot.

Table 5.3 *Demographic distributions of the fMRI sample (n = 40)*

	Frequency	Percentage	*Mean*	*SD*
Age			16.1	0.94
14-15	10	25.0		
16-17	30	75.0		
Sex				
Male	19	47.5		
Female	21	52.5		
Race				
White	13	23.5		
Black or African American	13	23.5		
Asian	8	20.0		
Other/more than one race	6	15.0		
Sensation seeking			2.93	0.47
Parent educational attainment				
Less than or equal to a high school degree	17	42.5		
Some college	7	17.5		
College degree	7	17.5		
Completed grad school	9	22.5		

Note. SD = standard deviation

On average, Survey respondents recalled seeing The Real Cost ads approximately 5 times during the previous 30 days (M = 4.92, SD = 11.37). There was considerable variation in recall across ads, with ad-specific mean recall ranging from 1.14 (SD = 2.91) – 6.80 (SD = 13.78). There was also considerable variation in past 4-, 8-, and 12-week TRPs. Opportunities for exposure to each ad over these 3 time periods ranged from 0 – 220 TRPs (M = 52.17, SD = 44.12), 0 – 421 TRPs (M = 106.66, SD = 71.59), 0 – 589.25 TRPs (M = 159.39, SD = 99.80), respectively.[14] Mean neural response residuals in each set of brain regions, representing percent signal change in blood flow relative to baseline, varied across ads, with a range of -0.034 – 0.034 (M = 0.001, SD = 0.018) in social processing regions, -0.036 – 0.021 (M = 0.002, SD = 0.015) in memory encoding regions, and -0.040 – 0.046 (M = 0.001, SD = 0.023) in the motor cortex.

Association Between TRPs and Ad Recall

First, we estimated mixed-effect multilevel models to test the main effect of ad-specific TRPs on ad recall (H1). Results demonstrated positive relationships between past 30-day recall and TRPs for all time periods, with significant effects for past 8-week (β = 0.026, p = .011, 95% CI [0.006, 0.045]), and 12-week (β = 0.022, p = .028, 95% CI [0.003, 0.042]) TRPs. The relationship between ad recall and TRPs was nonsignificant for past 4-week TRPs (β = 0.002, p = .806, 95% CI [-0.015, 0.019]).[15]

[14] Due to the skewed distributions of ad recall and TRPs, we tested whether data transformations influenced outcomes. We employed a log transformation to the recall variable and square root transformations to the TRP variables. As these transformations produced results that did not differ substantively from those conducted with the raw variables, we opted to report analyses with the untransformed variables to facilitate interpretation of results.

[15] Study 2 demonstrated a positive relationship between past 4-week TRPs and belief endorsement. In the current study, however, past 4-week TRPs were not significantly

Ad-level Neural Response in Social Processing and Memory Encoding Regions in the fMRI Sample as Moderators of the Association Between TRPs and Ad Recall in the National Survey

We estimated mixed-effect multilevel models to examine the moderating effect of neural response in social processing regions on the association between TRPs and ad recall (H2). Results demonstrated a significant, positive effect for the interaction between aggregate neural response to the ads in the fMRI sample, within social processing regions and past 4-week (β = 0.023, p = .013, 95% CI [0.005, 0.041]), 8-week (β = 0.041, p < .001, 95% CI [0.023, 0.059]), and 12-week TRPs (β = 0.037, p < .001, 95% CI [0.019, 0.055]) on ad recall (see Table 5.4). Results were similarly robust when covariates were omitted from each model. Thus, ads that elicited a greater response in social processing regions showed a stronger relationship between TRPs and ad recall relative to ads that elicited a lesser response, as shown in Figure 5.3. For example, for ads that elicited high versus low brain response in social processing regions, respondents with the opportunity to be exposed to 500 TRPs for each ad over the preceding 12 weeks recalled approximately 2.5 more exposures.

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associated with past 30-day ad recall. This discrepancy may be attributed to the different ways in which TRPs were aggregated in each study. In Study 2, TRPs were aggregated over time (previous 4 weeks) and within each targeted-belief category (Wrinkle, Teeth, Control, and Chemical). In the current study, TRPs were aggregated over time (previous 4 weeks) for each of 12 ads.

Table 5.4 *Results from mixed-effect multilevel regression models testing the moderating effect of mean neural response in social processing regions on the association between past 4-, 8-, and 12-week TRPs and past 30-day ad recall, controlling for potential covariates*

	Model 1 Past 4-Week TRPs				Model 2 Past 8-Week TRPs				Model 3 Past 12-Week TRPs			
	β	SE	t	p	β	SE	t	p	β	SE	t	p
TRPs	.000	.011	0.06	.954	**.039****	**.013**	**2.90**	**.004**	**.038****	**.013**	**2.84**	**.004**
Mean neural response in social processing regions	-.017	.037	-0.45	.664	-.013	.036	-0.35	.737	-.011	.036	-0.30	.775
TRPs*mean neural response in social processing regions	**.023***	**.009**	**2.49**	**.013**	**.041*****	**.009**	**4.40**	**.000**	**.037*****	**.009**	**4.03**	**.000**
Age	.027	.015	1.79	.073	.028	.015	1.80	.072	.028	.015	1.84	.066

Sex	**-.035***	**.015**	**-2.41**	**.016**	**-.035***	**.015**	**-2.43**	**.015**	**-.036***	**.015**	**-2.44**	**.015**
Race (White=*Ref.*)												
Hispanic	**.033***	**.016**	**2.02**	**.043**	**.033***	**.016**	**1.99**	**.046**	**.033***	**.016**	**1.99**	**.047**
Black/African American	**.074*****	**.015**	**4.78**	**.000**	**.074*****	**.015**	**4.80**	**.000**	**.075*****	**.015**	**4.82**	**.000**
Other/multiple races	.020	.015	1.32	.188	.020	.015	1.31	.190	.020	.015	1.31	.190
Sensation seeking	**.059*****	**.015**	**3.95**	**.000**	**.058*****	**.015**	**3.91**	**.000**	**.058*****	**.015**	**3.89**	**.000**
Parent disapproval												
(Would/disapprove a lot=*Ref.)*												
Don't/wouldn't mind	-.013	.015	-0.85	.395	-.012	.015	-0.79	.429	-.012	.015	-0.77	.440
Would/disapprove a little	**-.034***	**.014**	**-2.32**	**.020**	**-.033***	**.014**	**-2.31**	**.021**	**-.033***	**.014**	**-2.30**	**.022**

Household cigarette use	**.045****	**.015**	**3.01**	**.003**	**.046****	**.015**	**3.04**	**.002**	**.046****	**.015**	**3.03**	**.002**
Parental education (HS=*Ref.*)												
Some college	-.030	.017	-1.75	.080	-.030	.017	-1.70	.090	-.030	.017	-1.71	.087
College degree	-.036	.019	-1.89	.059	-.035	.019	-1.86	.063	-.036	.019	-1.88	.061
Graduate degree	**-.039***	**.019**	**-2.06**	**.040**	**-.038***	**.019**	**-2.01**	**.045**	**-.039***	**.019**	**-2.02**	**.043**
TV watching	**.099*****	**.015**	**6.79**	**.000**	**.098*****	**.015**	**6.76**	**.000**	**.099*****	**.015**	**6.78**	**.000**
Interview week	-.029	.017	-1.72	.085	-.004	.018	-0.21	.831	-.004	.018	-0.21	.835

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).
β = standardized coefficient. SE = standard error. *Ref.* = reference category. HS = high school degree or some high school.

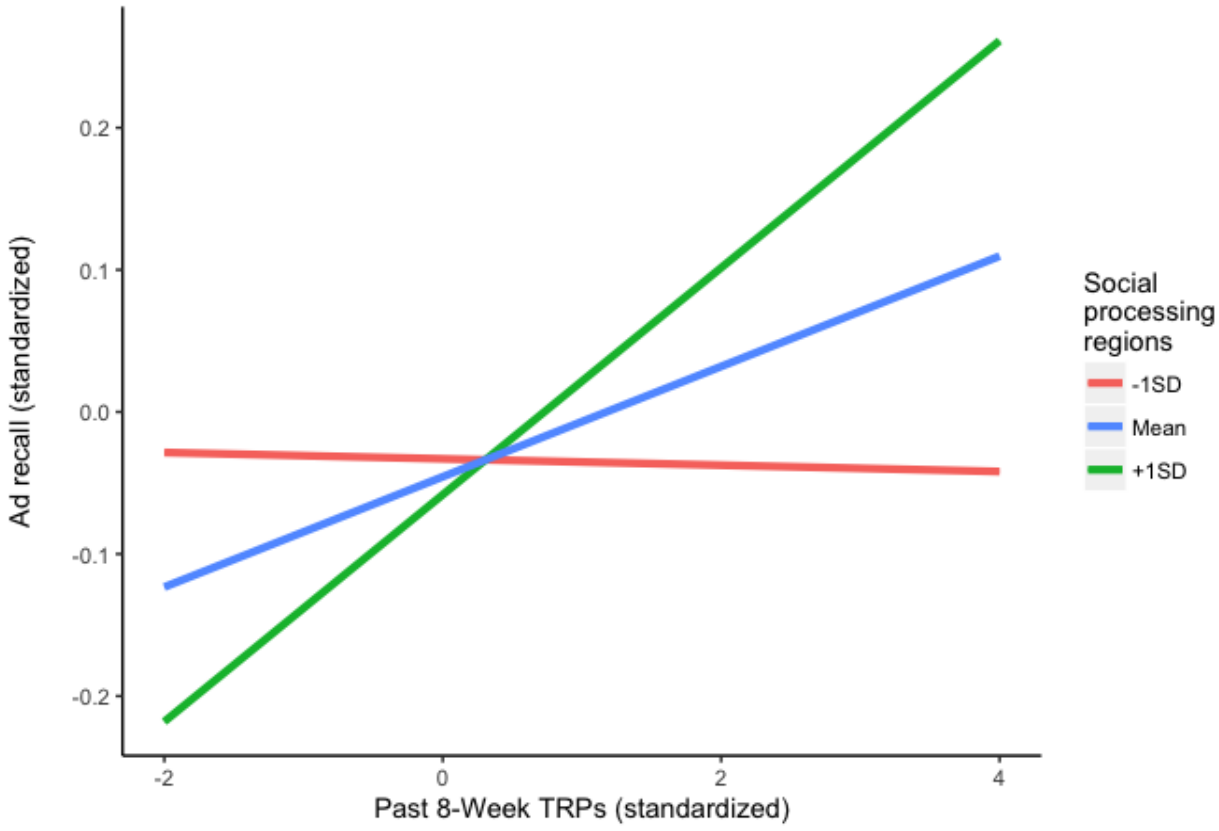


Figure 5.3. *Association between past 8-week TRPs and past 30-day ad recall at varying levels of ad-elicited neural response in social processing regions*

Note. SD = standard deviation. The blue line illustrates the relationship between TRPs and ad recall for ads that elicited mean levels of neural response in social processing regions. The red and green lines illustrate the relationship between TRPs and ad recall for ads that elicited neural response in social processing regions equal to one standard deviation below and above, respectively, the mean neural response.

Next, we estimated parallel models to examine the moderating effect of neural response in memory encoding regions (H3). Results demonstrated a positive effect for the interaction between aggregate neural response to the ads in the fMRI sample in memory encoding regions and past 4-week (β = 0.013, p = .149, 95% CI [-0.005, 0.031]), 8-week (β = .049, p < .001, 95% CI [0.027, 0.071]), and 12-week TRPs (β = .043, p < .001, 95% CI [0.019, 0.067]) on ad recall (see Table 5.5), though this effect was only significant for past 8- and 12-week TRP models. Results were similar when covariates were omitted from each model. That is, ads that elicited a greater response in memory encoding regions showed a stronger relationship between TRPs and ad recall relative to ads that elicited a lesser response, as shown in Figure 5.4. For example, for ads that elicited high versus low brain response in memory encoding regions, respondents with the opportunity to be exposure to 500 TRPs for each ad over the preceding 12 weeks recalled approximately 3 more exposures.

Table 5.5 *Results from mixed-effect multilevel regression models testing the moderating effect of mean neural response in memory encoding regions on the association between past 4-, 8-, and 12-week TRPs and past 30-day ad recall, controlling for potential covariates*

	Model 1 Past 4-Week TRPs				Model 2 Past 8-Week TRPs				Model 3 Past 12-Week TRPs			
	β	SE	t	p	β	SE	t	p	β	SE	t	p
TRPs	-.003	.011	-0.28	.779	**.033***	**.013**	**2.54**	**.011**	**.034****	**.013**	**2.62**	**.009**
Mean neural response in memory encoding regions	.001	.037	0.03	.978	-.006	.035	-0.16	.877	-.003	.034	-0.10	.927
TRPs*mean neural response in memory encoding regions	.013	.009	1.44	.149	**.049*****	**.011**	**4.39**	**.000**	**.043*****	**.012**	**3.66**	**.000**
Age	.028	.015	1.81	.071	.027	.015	1.79	.073	.028	.015	1.83	.068

Sex	**-.035***	**.015**	**-2.41**	**.016**	**-.035***	**.015**	**-2.44**	**.015**	**-.035***	**.015**	**-2.43**	**.015**
Race (White=*Ref.*)												
Hispanic	**.033***	**.016**	**2.01**	**.045**	**.032***	**.016**	**1.98**	**.048**	**.032***	**.016**	**1.98**	**.048**
Black/African American	**.074*****	**.015**	**4.78**	**.000**	**.074*****	**.015**	**4.77**	**.000**	**.074*****	**.015**	**4.80**	**.000**
Other/multiple races	.020	.015	1.32	.187	.020	.015	1.31	.189	.020	.015	1.33	.184
Sensation seeking	**.059*****	**.015**	**3.96**	**.000**	**.058*****	**.015**	**3.93**	**.000**	**.058*****	**.015**	**3.90**	**.000**
Parent disapproval												
(Would/disapprove a lot=*Ref.)*												
Don't/wouldn't mind	-.013	.015	-0.84	.401	-.012	.015	-0.81	.417	-.012	.015	-0.79	.432
Would/disapprove a little	**-.034***	**.014**	**-2.32**	**.020**	**-.033***	**.014**	**-2.31**	**.021**	**-.033***	**.014**	**-2.31**	**.021**

Household cigarette use	**.045****	**.015**	**3.00**	**.003**	**.046****	**.015**	**3.03**	**.002**	**.046****	**.015**	**3.03**	**.002**
Parental education (HS=*Ref.*)												
Some college	-.030	.017	-1.75	.081	-.030	.017	-1.71	.088	-.030	.017	-1.73	.085
College degree	-.036	.019	-1.89	.059	-.036	.019	-1.87	.062	-.036	.019	-1.89	.059
Graduate degree	**-.039***	**.019**	**-2.07**	**.038**	**-.039***	**.019**	**-2.04**	**.042**	**-.039***	**.019**	**-2.05**	**.040**
TV watching	**.099*****	**.015**	**6.78**	**.000**	**.099*****	**.015**	**6.78**	**.000**	**.099*****	**.015**	**6.78**	**.000**
Interview week	-.029	.017	-1.72	.085	-.005	.018	-0.28	.784	-.003	.018	-0.18	.861

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).
β = standardized coefficient. SE = standard error. *Ref.* = reference category. HS = high school degree or some high school.

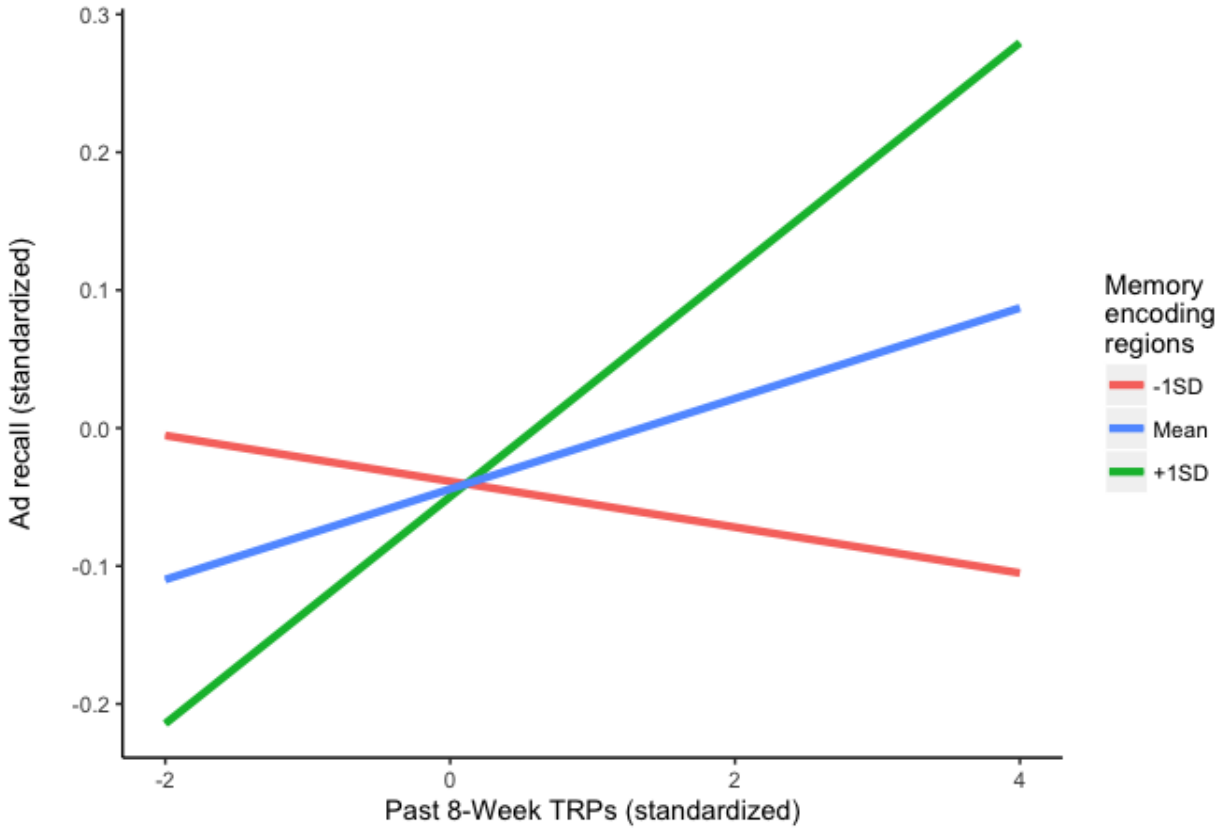


Figure 5.4 *Association between past 8-week TRPs and past 30-day ad recall at varying levels of ad-elicited neural response in memory encoding regions*

Note. SD = standard deviation. The blue line illustrates the relationship between TRPs and ad recall for ads that elicited mean levels of neural response in memory encoding regions. The red and green lines illustrate the relationship between TRPs and ad recall for ads that elicited neural response in memory encoding regions equal to one standard deviation below and above, respectively, the mean neural response. The negative slope of the line representing the TRP-recall relationship at one standard deviation below the mean (red line) was nonsignificant.

Moderation of the Relationship Between TRPs and Ad Recall is Not Explained by Global Increases in Brain Function

Finally, we estimated parallel models to examine the moderating effect of neural response in the supplementary motor cortex to address whether the results in social processing and memory encoding regions are explained by increased activation throughout the brain. Results demonstrated a non-significant effect for the interaction between neural response in the motor cortex and past 4-week (β = -.014, p = .118, 95% CI [-0.032, 0.004]), 8-week (β = -.011, p = .357, 95% CI [-0.035, 0.013]), and 12-week TRPs (β = -.013, p = .336, 95% CI [-0.040, 0.014]) on ad recall (see Table 5.6). In other words, the strength of the relationship between TRPs and ad recall was not contingent on differences in ad-induced neural response in this brain region. Results did not differ substantively when covariates were omitted from each model.

Table 5.6 *Results from mixed-effect multilevel regression models testing the moderating effect of mean neural response in the supplementary motor cortex on the association between past 4-, 8-, and 12-week TRPs and past 30-day ad recall, controlling for potential covariates*

	Model 1 Past 4-Week TRPs				Model 2 Past 8-Week TRPs				Model 3 Past 12-Week TRPs			
	β	SE	t	p	β	SE	t	p	β	SE	t	p
TRPs	-.010	.011	-0.94	.349	.014	.012	1.13	.258	.019	.013	1.48	.138
Mean neural response in the motor cortex	-.051	.028	-1.82	.095	-.047	.028	-1.68	.121	-.047	.029	-1.65	.127
TRPs*mean neural response in the motor cortex	-.014	.009	-1.56	.118	-.011	.012	-0.92	.357	-.013	.014	-0.96	.336

Age	.028	.015	1.80	.071	.028	.015	1.82	.068	.028	.015	1.84	.066
Sex	**-.035***	**.015**	**-2.42**	**.016**	**-.035***	**.015**	**-2.41**	**.016**	**-.035***	**.015**	**-2.42**	**.016**
Race (White=*Ref.*)												
Hispanic	**.033***	**.016**	**2.00**	**.046**	**.032***	**.016**	**1.97**	**.049**	**.032***	**.016**	**1.98**	**.048**
Black/African American	**.074*****	**.015**	**4.77**	**.000**	**.074*****	**.015**	**4.77**	**.000**	**.074*****	**.015**	**4.77**	**.000**
Other/multiple races	.020	.015	1.33	.185	.020	.015	1.32	.188	.020	.015	1.33	.185
Sensation seeking	**.059*****	**.015**	**3.97**	**.000**	**.059*****	**.015**	**3.95**	**.000**	**.059*****	**.015**	**3.94**	**.000**
Parent disapproval												
(Would/disapprove a lot=*Ref.)*												
Don't/wouldn't mind	-.012	.015	-0.83	.406	-.012	.015	-0.81	.416	-.012	.015	-0.80	.422

Would/disapprove a little	**-.034***	**.014**	**-2.34**	**.019**	**-.034***	**.014**	**-2.34**	**.020**	**-.034***	**.014**	**-2.33**	**.020**
Household cigarette use	**.045****	**.015**	**2.97**	**.003**	**.045****	**.015**	**3.00**	**.003**	**.045****	**.015**	**3.01**	**.003**
Parental education (HS=*Ref.*)												
Some college	-.030	.017	-1.75	.081	-.030	.017	-1.75	.080	-.031	.017	-1.75	.080
College degree	-.036	.019	-1.90	.058	-.036	.019	-1.91	.057	-.036	.019	-1.91	.057
Graduate degree	**-.040***	**.019**	**-2.09**	**.037**	**-.040***	**.019**	**-2.08**	**.037**	**-.040***	**.019**	**-2.08**	**.037**
TV watching	**.099*****	**.015**	**6.79**	**.000**	**.098*****	**.015**	**6.76**	**.000**	**.099*****	**.015**	**6.77**	**.000**
Interview week	**-.035***	**.017**	**-2.08**	**.038**	-.021	.018	-1.15	.251	-.019	.018	-1.06	.336

Note. Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).
β = standardized coefficient. SE = standard error. *Ref.* = reference category. HS = high school degree or some high school.

Discussion

This study examined neurocognitive factors that increase the efficacy of ad exposure in producing large-scale recall. Specifically, we examined whether message-evoked brain responses in a small group of adolescents, within regions associated with social processing and memory encoding in response to The Real Cost campaign ads, moderate the population-level relationship between Target Rating Points (TRPs)—opportunities for ad exposure—and ad recall in a large-scale, nationally representative dataset. Consistent with past message effects research (Cowling et al., 2010; Kranzler et al., 2017; Niederdeppe, 2005; Richardson, McNeill, et al., 2014; Brian G. Southwell et al., 2002), results demonstrated positive and significant relationships between past 8- and 12-week TRPs and ad recall. Next, we turned our attention to what factors might moderate the relationship between exposure and ad recall beyond the main effect of exposure alone. We thus measured how ads engaged brain regions implicated in social processing and memory encoding in a separate sample of adolescents. We find that ads that prompted stronger brain responses showed tighter correspondence between opportunities for exposure (TRPs) and actual recall in a nationally-representative sample of adolescents.

Results established significant, positive effects of the interaction between mean neural response in social processing regions and TRPs on ad recall. These results suggest that ads that prompt stronger activity in regions involved in social processing are better encoded during exposure, leading to enhanced recall given the availability of messages in the media environment. Findings may reflect adolescents' enhanced sensitivity to social

cues and considerations (Crone & Dahl, 2012), which play a prominent role in their thoughts, beliefs, and actions (Liu et al., 2017; Rimal & Real, 2005; Steinberg & Monahan, 2007). Adolescence is characterized by social changes as individuals transition from childhood to adulthood and learn how to navigate the social world (for reviews, see Blakemore, 2008; Crone & Dahl, 2012). In light of the significant influence of social considerations during this developmental stage, our findings further highlight the importance of social processing during adolescence and are consistent with theories of message effects that emphasize the importance of social factors in influencing message effects (Cialdini & Trost, 1998; Fishbein & Ajzen, 2011; Glanz et al., 2008; Rimal & Real, 2005). Results also extend previous research conducted with this fMRI data, which demonstrated that neural response in social processing regions associates with perceptions of ad effectiveness (Kranzler et al., in revision).

Study results also established significant, positive effects of the interaction between mean neural response in memory encoding regions and TRPs on ad recall. The Neurosynth reverse inference brain map is primarily focused on the medial temporal lobe, including the hippocampus. These results suggest that ads that evoke enhanced neural response in memory encoding regions are more strongly encoded during exposure, such that they are better recalled given the opportunity for exposure. Ads that inspire enhanced memory encoding in our small sample in Philadelphia are more readily retrieved by larger groups as well, given that individuals have the opportunity to be exposed to those ads in the first place. Moreover, our novel analytical approach offers

evidence that ad-evoked neural responses in a small sample of individuals, in combination with media market variables, can explain population-level recall.

Finally, we conducted a discriminant validity check to examine whether the observed moderation effects in social processing and memory encoding regions reflected more global increases in brain activity to effective ads. Results from our set of control analyses indicated that, as hypothesized, mean neural response in the motor cortex, a brain region implicated in the control and execution of voluntary movement, but not expected to be relevant to ad effectiveness, does not moderate the relationship between TRPs and ad recall. These findings offer evidence consistent with a claim that the observed moderation effects are not merely the result of general brain activity during ad exposure.

Regression results from multilevel models (Tables 5.4 and 5.5) demonstrate that the standardized regression coefficients for the interaction terms (TRPs * mean neural response) robustly predict recall, above and beyond the main effects of TRPs. This is the case for all TRP time intervals and for neural response in both social processing and memory encoding regions, demonstrating that neural measures of message engagement, in combination with opportunities for exposure, provide additional information about message effects, beyond what is predicted by message exposure alone.

It is worth noting that the main effect of past 4-week TRPs on ad recall was not statistically significant, nor was the interaction between past 4-week TRPs and neural response in memory encoding regions on ad recall. Though all TRP variables had skewed distributions, past 4-week TRPs also contained a disproportionately large number of

cases with zero values, which may have influenced our results. Additionally, self-reports of past 30-day ad recall may reflect recalled exposure over a longer period of time. This explanation is a distinct possibility given that past 8- and 12-week TRPs were significant predictors of ad recall, in both main effect and moderation models (see Tables 5.4 and 5.5).

There are several strengths of this study. To our knowledge, this is the first study to examine the moderating role of neural response on the association between opportunities for exposure and ad recall. Results are unlikely to reflect reverse causal direction as they reflect analyses conducted with 3 separate datasets; it is unlikely that adolescents' recall of campaign ads influenced the extent to which those ads were aired on TV, or that ad recall from one sample of adolescents influenced neural response to those same ads in another sample. Additionally, moderation results are generally consistent across models with different aggregations of TRPs (4-, 8-, and 12-week periods) and when controlling for potential covariates, suggesting that study findings are robust.

Although recruitment in the fMRI study was limited to 14- to 17-year-old nonsmokers to align participants with the target audience for The Real Cost campaign, results from the fMRI study may not represent the target audience in other ways. That is, the observed moderation effects may not generalize to all members of the campaign's target audience. Similarly, the ads assessed in this study are a subset of all ads from The Real Cost campaign and may not represent all ads, both within and beyond this campaign. Previous research demonstrates that cognitive tasks that inspire social

processing and memory encoding elicit brain response in the regions examined in the current study. As with all neuroimaging studies, our psychological interpretations of activity within the brain regions of interest is subject to the constraints of reverse inference (i.e., making inferences about the engagement of specific cognitions based on the activation of specific brain regions) (Poldrack, 2006). However, our a priori theoretical focus on these regions, and use of Neurosynth reverse inference probabilistic maps strengthens our interpretation that neural response in these regions reflects the hypothesized cognitive processes. Regardless of the specific processes evoked during exposure to these ads, our findings shed light on the neural correlates of ads that are better recalled given the availability of exposure.

Implications and Future Directions

Our results offer important implications that may inform formative health campaign work. This stage of campaign development typically involves pretesting potential messages prior to dissemination to assess their reception and gauge their potential effectiveness in members of the target audience. Prior to dissemination of The Real Cost campaign, developers conducted message pretesting experiments to examine the potential effectiveness of campaign messages, using an established measure of perceived ad effectiveness, which has been shown to predict actual effectiveness (Bigsby, Cappella, & Seitz, 2013; Dillard, Shen, et al., 2007; Dillard, Weber, et al., 2007), as the central criterion (Duke et al., 2015; Zhao et al., 2016). Findings from the current study suggest that neuroimaging methods, which may be used to measure objective responses to ads at the moment of reception, can complement self-report measures and be

incorporated into campaign development to predict which messages will be more readily encoded and thus recalled, supporting the dissemination of messages that are ultimately more effective.

Previous research demonstrates that messages that contain certain objectively-measured characteristics are better recalled, a phenomenon that is attributed to the fact that these message features facilitate processing of message content. Findings from the current study warrant additional research to examine the relationships between objectively-measured characteristics of messages (e.g., message sensation value, or the extent to which a message's audiovisual features and content elicit sensory, affective, and arousal responses [Palmgreen, Donohew, Lorch, Hoyle, & Stephenson, 2001]) and message-induced neural response in social processing and memory encoding regions to better understand what message features inspire this type of neural processing.

Conclusions

Though health campaigns hold great promise for influencing health-relevant behaviors at scale, the success of a health campaign is contingent on its ability to achieve not only adequate exposure in its target audience, but also sufficient message engagement and processing. Results from the current study demonstrate that opportunities for message exposure and message-elicited neural activation in brain regions associated with social processing and message encoding interact in their effects on message recall; the effect of opportunities for exposure on message recall are larger for messages that elicit greater neural response. These findings suggest that capturing ad-specific brain responses in small groups of people may facilitate the selection of campaign messages that are

better attended to and encoded at large scales. Finally, these findings provide new understanding of the cognitive mechanisms that account for enhanced message processing, which may aid the development of messages that are ultimately more effective.

CHAPTER 6. CONCLUSION

The success of a mass media campaign hinges on its ability to elicit effects through the dissemination of campaign messages to a target audience, with exposure to messages having been shown to influence message-consistent beliefs and, ultimately, behaviors (Hornik, 2002; Wakefield, Loken, & Hornik, 2010). However, this distillation of the process—from implementation to effects—overlooks the important sub-processes that happen along the path from message dissemination to belief and behavior change. In particular, the cognitive processes that occur at the moment of message reception may have profound implications for the ultimate success of those messages. This dissertation examined the interrelationships between elements of the exposure-effects continuum, with an aim of elucidating the cognitive processes that link message dissemination with behavior-relevant belief endorsement. Specifically, the goals of this dissertation were to better establish evidence for anti-smoking campaign effects, and to understand the ad-induced, cognitive processes that account for effective anti-smoking campaign messages, with a focus on advertisements from "The Real Cost" youth-targeted anti-smoking campaign.

Despite findings from previous research suggesting The Real Cost campaign has reduced smoking initiation (Farrelly et al., 2017), prior work has not examined the theorized pathway of campaign effects—through targeted beliefs associated with behavior. In Study 1, we examined this pathway of effects by assessing the relationship between recall of campaign ads and ad-specific anti-smoking beliefs. We used data from

a nationally-representative survey of nonsmoking youths (age 13-17) who reported exposure to four ads from the campaign and a fake ad, smoking-relevant beliefs (both those targeted and not targeted by campaign ads), and non-smoking intentions. Results from a series of regression models demonstrated that recall of four campaign ads (but not the fake ad) significantly predicted endorsement of the ad-targeted belief, and two-sided sign tests indicated stronger ad recall associations with the targeted belief relative to the non-targeted belief. Additionally, logistic regression analyses indicated that respondents who endorsed campaign-targeted beliefs were more likely to have no intention to smoke. This study is the first to demonstrate a relationship between recall of ads from The Real Cost campaign and the theorized pathway of effects, and analyses provide a methodological template for showing campaign effects despite limitations of available data.

A limitation to Study 1 is that results rely on self-reported recall as a measure of exposure and are thus open to concerns about reverse causation. Exogenous measures of exposure, assessed independently of outcomes, support stronger causal inferences. In Study 2, we examined the relationship between Target Rating Points (TRPs), an exogenous measure of exposure opportunities, for specific ads available over four-week periods and anti-smoking beliefs in a national sample of adolescent nonsmokers and experimenters (n = 4,780). Results demonstrated positive relationships between TRPs for ads targeting two of four belief categories tested (Control and Chemical) and targeted-belief endorsement. Furthermore, two-sided sign tests indicated that TRP/targeted-belief associations for Control- and Chemical-targeted ads were more positive than TRP/non-

targeted belief associations for all comparisons. Findings support a claim of campaign effects while reducing concerns about reverse causal direction and the influence of unmeasured confounders.

Studies 1 and 2 provided evidence consistent with a claim of large-scale campaign effects through targeted beliefs, demonstrating that opportunities for exposure and recalled exposure to campaign ads are associated with endorsement of ad-targeted beliefs. However, findings raise questions about the micro-level cognitive processes, occurring during the moment of message reception, that associate with campaign effects. Studies 3 and 4 investigate these ad-induced, psychological processes, and assess whether they relate to small- and large-scale campaign effects.

In Study 3, we examined the relationships between ad-elicited neural response and ratings of perceived ad effectiveness and intentions to share ads on social media. Forty adolescent nonsmokers (aged 14-17) from the greater Philadelphia area completed a functional magnetic resonance imaging (fMRI) scan, during which their brain response was measured while they viewed 12 ads from The Real Cost campaign. We linked neural responses in meta-analytically defined brain regions during ad reception with participants' subsequent ratings of perceived ad effectiveness and intentions to share ads on social media. Results from multilevel regression analyses demonstrated that perceived ad effectiveness was positively associated with ad-elicited neural activity in the social processing network and marginally associated with neural activity in the self-relevance network, whereas it was not associated with neural activity in the subjective valuation network. Conversely, sharing intention was not associated with neural activity in any of

the hypothesized networks. In contrast with previous neuroimaging studies with adult subjects, findings highlight the potential role of social cognition in adolescent processing of persuasive messages.

Together, Studies 1-3 linked campaign dissemination and the cognitive processes that occur at the moment of reception with measures of campaign efficacy. To extend this work, Study 4 examined whether neural response to ads in a small group of adolescents enhances the prediction of population-level recalled exposure to campaign ads, given opportunities for exposure. Drawing on theories of message processing and prior empirical findings, we hypothesized that message-elicited responses in brain regions associated with social processing and memory encoding moderate the relationship between opportunities for campaign exposure and message recall. We merged 3 datasets pertinent to the "The Real Cost" youth-targeted anti-smoking campaign: past 30-day ad recall from a rolling, nationally-representative survey of adolescents (n=5,110), ad-specific Target Rating Points (TRPs), which measure campaign reach and frequency, during 4-, 8-, and 12-week periods, and ad-elicited neural response in brain regions implicated in social processing and memory encoding from the sample of adolescents who participated in Study 3 (n=40). Multilevel regression models showed that brain response in both social processing and memory encoding regions significantly moderates the relationship between past 8- and 12-week TRPs and ad recall. Results indicate that the interaction between TRPs and brain response more strongly predicts recall than TRPs alone. In sum, findings demonstrate that measuring brain responses to health messages

can improve our understanding of how and when exposure produces recall, and that is likely to mediate large-scale campaign effects.

Strengths and Limitations

There are several strengths associated with this set of studies. In Studies 1 and 2, the strongest support comes from the specificity of our findings—that exposure, whether recalled (Study 1) or available (Study 2), associates more strongly with targeted beliefs than non-targeted beliefs. In Study 1, a lack of association between recall of a fake ad and campaign-targeted beliefs also reduces concerns that recall-targeted belief associations are driven by reverse causation or third variable influence. Furthermore, in Study 2, the use of a time-varying exogenous measure of exposure (TRPs) reduces concerns about reverse causation inherent in studies that rely on self-reported campaign awareness or recall (Slater, 2004). Moreover, the use of exogenous exposure can eliminate biases affiliated with self-reported exposure, including variation in ability to recall campaign exposure and social desirability bias (Liu & Hornik, 2016), thereby offering a measure less vulnerable to individual idiosyncrasies.

In Study 3, we examined neural response to ads at the moment of exposure as a measure of the cognitive processes engaged during exposure to effective and shareworthy ads. This study was strengthened by the use of meta-analytically defined brain regions. Additionally, we employed mixed-effect multilevel regression models to take advantage of repeated measures within subjects while accounting for non-independence of data points both within subjects and across ads. Study 4 is the first to examine the moderating role of ad-specific neural responses collected in a small group on the association between

opportunities for exposure and population-level ad recall. Results are unlikely to reflect reverse causal direction as they reflect analyses conducted with 3 separate datasets; it is unlikely that adolescents' recall of campaign ads influenced the extent to which those ads were aired on TV, or that ad recall from one sample of adolescents influenced neural response to those same ads in another sample. Additionally, moderation results are generally consistent across models with different aggregations of TRPs (4-, 8-, and 12-week periods) and when controlling for potential covariates, suggesting that study findings are robust. Furthermore, our discriminant validity check indicated that mean neural response in the motor cortex, a brain region implicated in the control and execution of voluntary movement, but not expected to be relevant to ad effectiveness, does not moderate the relationship between TRPs and ad recall. These findings offer evidence consistent with a claim that the observed moderation effects are not merely the result of general brain activity during ad exposure.

There are also several limitations associated with this set of studies. Across all studies, measures that relied on self-report (ad recall, belief endorsement, intention to smoke, perceived ad effectiveness, and sharing intention) may have been influenced by response bias. In particular, self-reported recall may not reflect actual ad exposure, or may exclude influential first exposures as recall items assess past 30-day exposure. Across those studies that used survey data (Studies 1, 2 and 4), non-response bias may limit inferences about national populations made from study results. Similarly, in Study 3, findings from neural response data in a relatively small sample of adolescents may not generalize beyond the study sample.

In Study 1, analyses were conducted with cross-sectional data, which limits our ability to draw causal inferences. We attempted to address non-response bias by weighting the survey to known characteristics of the population. In Study 2, TRPs represent opportunities for exposure available in the media environment during a specified period of time, and thus may not index actual exposure to advertisements. However, given previous work demonstrating relationships between exposure opportunities and self-reported recall, both for previous campaigns (Cowling et al., 2010; Niederdeppe, 2005; Richardson, McNeill, et al., 2014; Southwell et al., 2002) and for The Real Cost campaign (Kranzler et al., 2017), there is empirical support for a claim that TRPs represent actual ad exposure. TRPs index reach and frequency of campaign exposure on a national scale; thus, results may over- or underestimate effects for individual respondents based on the TRPs available in their specific media market. Finally, analyses controlled for potential covariates but did not employ survey weights. Survey weights for this dataset were developed at the quarterly level, rather than the weekly level, to adjust for some of the same covariates. Due to this time interval mismatch, we expected that survey weights would inflate standard errors without providing much additional effective adjustment.

Analyses from Study 3 resulted in several non-significant associations between ad-induced neural response and our outcomes of interest (perceived ad effectiveness and intention to share ads on social media). The null sharing intention findings may stem from greater variability in adolescents, relative to adults, in the brain systems examined in this study. It is possible that different rates of maturation across study participants led

to greater variation in neural activation in corresponding regions of the brain, which could make it more difficult to detect the expected relationships between brain response in self-relevance, social, and value processing systems and sharing intention. Additionally, the small number of ads in our stimuli (12) and variability across ads may have limited our power to detect true effects. Our measure of sharing intention was based on a single item that lacked specificity about intention to share on a specific social media platform; these factors may have added noise to our findings, potentially impeding our ability to detect true effects.

Although recruitment in the fMRI study was limited to 14- to 17-year-old nonsmokers to align participants with the target audience for The Real Cost campaign, results from the fMRI study may not represent the target audience in other ways. That is, the observed moderation effects in Study 4 may not generalize to all members of the campaign's target audience. Similarly, the ads assessed in this study are a subset of all ads from The Real Cost campaign and may not represent all ads, both within and beyond this campaign. Previous research demonstrates that cognitive tasks that inspire social processing and memory encoding elicit brain response in the regions examined in the Study 4. As with all neuroimaging studies, our psychological interpretations of activity within the brain regions of interest is subject to the constraints of reverse inference (i.e., making inferences about the engagement of specific cognitions based on the activation of specific brain regions) (Poldrack, 2006). However, our a priori theoretical focus on these regions, and use of Neurosynth reverse inference probabilistic maps strengthens our findings and supports the interpretation that neural response in these regions may reflect

the hypothesized cognitive processes. Regardless of the specific processes evoked during exposure to these ads, our findings shed light on the neural correlates of ads that are better recalled given the availability of exposure.

Future Directions

From the studies that comprise this dissertation, we can conclude the following: 1) opportunities for exposure and recalled exposure to campaign ads associate with endorsement of ad-targeted beliefs, suggesting the campaign has been effective through the theorized pathway of effects 2) ads that are perceived as more effective elicit greater response in brain regions implicated in social processing, and 3) ad-induced neural response in social processing and memory encoding regions affects the relationship between opportunities for ad exposure and recalled exposure. These conclusions have important implications for the future design and implementation of mass media campaigns.

From a campaign evaluation perspective, it is important to examine the theorized pathway through which campaign ads are expected to influence outcomes. The selection of beliefs that were targeted by The Real Cost campaign was driven by formative research to identify beliefs that hold particular promise for preventing youth from initiating smoking (Brennan et al., 2017). Had we failed to establish relationships between ad exposure and ad-targeted beliefs, this finding could indicate that the target audience was not sufficiently exposed to campaign ads to influence their targeted beliefs, suggesting that the relationship between campaign exposure and smoking behavior could instead be attributed to a confounding variable. In light of evidence that exposure to the

campaign is associated with reduced risk for smoking initiation (Farrelly et al., 2017), failure to establish exposure-targeted belief relationships could also suggest that the campaign was effective through alternative pathways, warranting additional research to examine these pathways. To bolster claims of effects from the evaluative studies conducted as part of this dissertation, future work in this area should examine whether targeted beliefs mediate the relationship between exposure and effects using appropriate methods.

From a campaign development perspective, findings suggest that neural measures of ad processing may be a useful tool for forecasting which ads will be more effective in a target audience. Despite the high cost of conducting neuroimaging research, investing funds in fMRI studies to examine the neural correlates of effective messages may provide campaign developers with the information they need to maximize campaign funds. Future research should assess whether other physiological measures of ad engagement (e.g., eye tracking) associate with ratings of ad effectiveness and population-level campaign outcomes, as these measures may be less expensive to collect and more easily procured relative to fMRI data. Furthermore, findings warrant additional research to examine the relationships between objectively-measured characteristics of messages (e.g., message sensation value) and ad-induced neural response. This line of work may extend our understanding of the features of messages that inspire certain types of neural processing associated with outcomes, thereby improving the design and implementation of effective health campaign messages.

APPENDIX. SCREENSHOTS OF ADS FROM “THE REAL COST” CAMPAIGN

Ad Name: Alison

Ad Name: Any Reason

Ad Name: Band

Ad Name: Bully

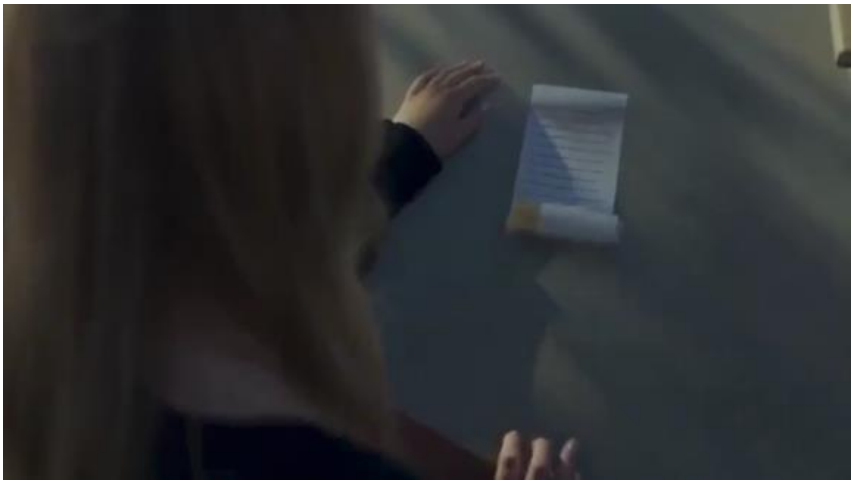
Ad Name: Dance

Ad Name: Found It

Ad Name: #ReasonsNotToSmoke

Ad Name: Science Class

Ad Name: Stay in Control



Ad Name: The 7,000

Ad Name: Your Skin

Ad Name: Your Teeth

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