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Modulating the neural bases of persuasion: why/how, gain/loss, and users/non-users

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Keywords

persuasion, message framing, action planning, fMRI, MPFC

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Modulating the neural bases of persuasion: why/how, gain/loss, and users/non-users

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Abstract

Designing persuasive content is challenging, in part because people can be poor predictors of their actions. Medial prefrontal cortex (MPFC) activation during message exposure reliably predicts downstream behavior, but past work has been largely atheoretical. We replicated past results on this relationship and tested two additional framing effects known to alter message receptivity. First, we examined gain- vs. loss-framed reasons for a health behavior (sunscreen use). Consistent with predictions from prospect theory, we observed greater MPFC activity to gain- vs. loss-framed messages, and this activity was associated with behavior. This relationship was stronger for those who were not previously sunscreen users. Second, building on theories of action planning, we compared neural activity during messages regarding how vs. why to enact the behavior. We observed rostral inferior parietal lobule and posterior inferior frontal gyrus activity during action planning ("how" messages), and this activity was associated with behavior; this is in contrast to the relationship between MPFC activity during the "why" (i.e., gain and loss) messages and behavior. These results reinforce that persuasion occurs in part via *self-value integration*—seeing value and incorporating persuasive messages into one's self-concept—and extend this work to demonstrate how message framing and action planning may influence this process.

Key words: persuasion; message framing; action planning; fMRI; MPFC

Introduction

The study of persuasion has remained a mainstay in psychology because it impacts such a wide range of activities and outcomes, yet constructing optimal messages continue to be a challenge. In recent research, neuroimaging methods have demonstrated the ability to predict persuasion-related outcomes over and above self-report (Falk et al., 2010, 2011); in particular, activity in a ventral subregion of medial prefrontal cortex has been reliably associated with downstream behavior, controlling for a wide range of self-reported responses to messaging (MPFC; Falk et al., 2010, 2011, 2012, 2015; Cooper *et al.*, 2015). However, this work has been largely atheoretical, mostly focusing on the link between MPFC activity during message encoding and subsequent behavior without attention to which kinds of messages might modulate this link (Falk *et al.*, 2015) or explicit connection to well-established theories of persuasion (Vezich *et al.*, 2016).

The aim of the current study is to extend past work regarding our ability to predict real-world behaviors (in this case, sunscreen use) from neural activity by making direct links to select theories relevant to persuasion. More specifically, we draw on two major theories highlighting important moderators of message effects. First, an extension of prospect theory in health psychology considered when gain- versus loss-framed messages may be differentially effective (Salovey and Wegener, 2003; Rothman *et al.*, 2006; O'Keefe and Wu, 2012; Gallagher and Updegraff, 2012). Other work outside the purview of health psychology has examined patterns in neural activation associated with gain- versus loss-framing (Tom *et al.*, 2007), but this work has not extended to predicting behaviors outside of the lab. Second, work on the role of action plans in promoting health behaviors suggests that both reasons *why* one should perform a behavior and guidance on *how* to perform it

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may be critical precursors to message-consistent behavior (Gollwitzer and Sheeran, 2006; Hagger and Luszczynska, 2014). Therefore, we examined the neural correlates of persuasive messages focused on why or how a behavior should be performed.

Finally, we explored whether these effects were moderated by the prior behavior of the participants. Specifically, a persuasive message could be thought of as trying to motivate someone to initiate a new behavior they have not performed in the past, or as trying to motivate someone who already performs a behavior to perform it more often or differently (Weinstein *et al.*, 1998; Miilunpalo *et al.*, 2000). In this study, we compared the neural responses to persuasive messages about sunscreen use in individuals who already used sunscreen prior to the study (i.e. *users*) and in those who did not (i.e. *non-users*).

Review of the relationship between MPFC activity during messages and behavior

Previous work has demonstrated that activation in an *a priori* MPFC region of interest (ROI) (a cluster overlapping Brodmann areas 10 and 11; Figure 1a) during viewing of sunscreen ads is correlated with increased sunscreen use (Falk *et al.*, 2010). A cross-validation approach revealed that MPFC activation predicted, on average, 23% more of the variance in behavior than did self-reported attitudes and intentions to wear sunscreen. In other studies, this same ROI in MPFC predicts smoking reduction (Falk *et al.*, 2011; Cooper *et al.*, 2015) and reductions in sedentary behavior (Falk *et al.*, 2015). Similar effects have also been observed in a somewhat more dorsal region of MPFC (Chua *et al.*, 2011; Wang *et al.*, 2013). Finally, activity in the MPFC ROI from a small sample of participants who were shown a set of advertisements can predict the behavior of larger media markets exposed to the same ads (Falk *et al.*, 2012, 2015).

Why does MPFC activity predict future and out-of-sample behavior in response to persuasive messages? One possibility is that MPFC is supporting the integration of persuasive messages with one's self-concept and identity, or *self-value integration*. Persuasion research has demonstrated that messages that already align with an individual's attitudes foster agreement with the message, suggesting that people assess whether a new message can be integrated with one's current beliefs and self-concept, and that this assessment determines the success of the persuasive message (Hovland *et al.*, 1957; Atkins *et al.*, 1967; Eagly and Telaak, 1972). In a similar vein, Social Cognitive Theory posits that individuals adopt message-consistent behaviors to the extent that personal value outweighs personal cost (Bandura, 1998, 2001, 2004). Taken together, we propose that MPFC activity during receipt of a persuasive message may reflect assessment of the extent to which the behavior is deemed valuable enough to incorporate into one's self-concept.

MPFC activity has been regularly associated with self-concept processes (Lieberman, 2010; Chua *et al.*, 2011) as well as the representation of personal beliefs and values (Harris *et al.*, 2008; Brosch *et al.*, 2011). The particular subregion we consider in this study is at the intersection between two other subregions associated with self- and value-related cognition, respectively, in past work (Cooper *et al.*, 2015). Although the idea is preliminary, there are some data to suggest that activity in this region may link to behavior in the context of persuasion attempts to the extent that successful self-value integration is occurring in response to the message. Likewise, manipulations that increase self-related processing in turn increase MPFC activity and message-consistent behavior (Falk *et al.*, 2015). Consistent with this idea, Chua *et al.* (2011) found that tailored smoking cessation messages—which they argue may be particularly self-relevant because they appeal to the individual's values and address obstacles to adopting the behavior—were associated with greater activity in a more dorsal region of MPFC overlapping with a region activated specifically by a self-task, and this increased activity was associated with future quitting. These findings could be consistent with our thinking around self-value integration because tailored messages are designed specifically to make the desired behavior appear in line with the individual's self-concept, and it is those messages that more effectively engage MPFC, leading to message-consistent behavior.

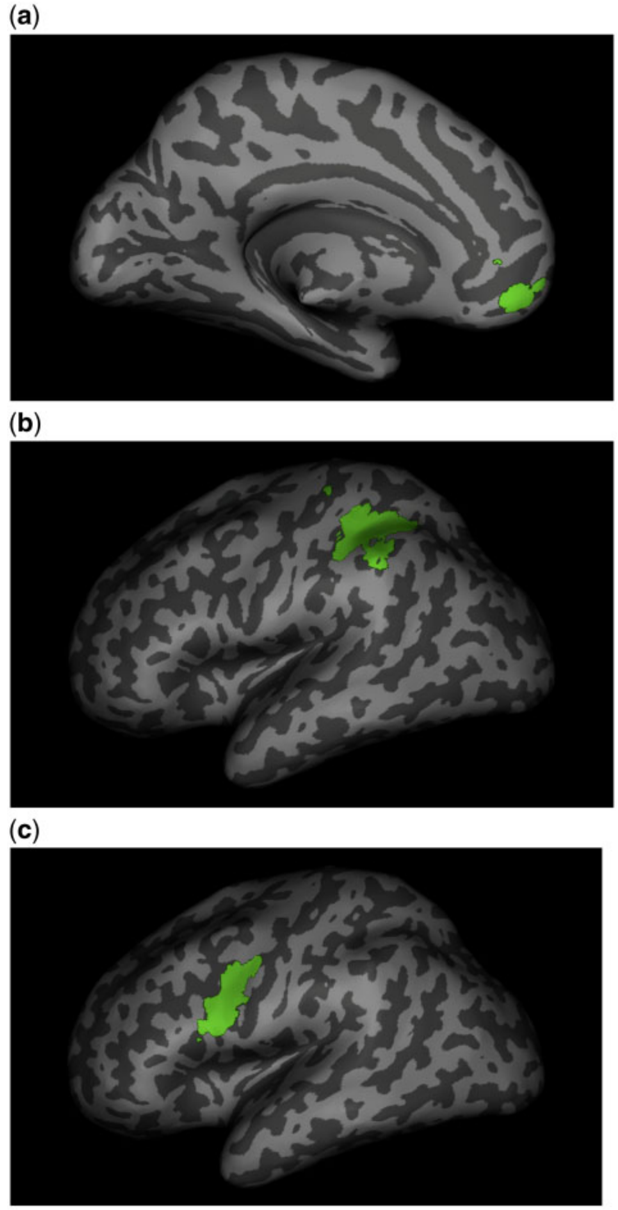

Fig. 1. (a) MPFC ROI constructed from the region most strongly associated with behavior change in Falk *et al.* (2010) and used in subsequent studies (Falk *et al.*, 2011, Falk*et al.*, 2012; Cooper *et al.*, 2015; Falk *et al.*, 2015) including this one, and (b) rIPL and (c) pIFG ROIs used in this study.

Although past studies of messaging have used arguments that are likely to elicit varying degrees of these processes, this has not been systematically manipulated in a theory-driven way. In the current investigation, we used extensions of prospect theory to frame messages that should be processed with varying degrees of self-value based on our target behavior (sunscreen use). We also extended past work by considering additional brain regions (outside of MPFC) that might be associated with message-consistent behaviors for other reasons. Specifically, we manipulated another aspect of message framing (*how vs why* messages) and examined theoretically relevant brain systems implicated in action understanding. Finally, we explored the extent to which these findings were moderated by past behavior.

Gain *vs* loss message framing

One important factor that may influence a message's value to an individual is whether the outcomes are framed as gains or losses: 'Gain-framed messages usually present the benefits that are accrued through adopting the behavior (e.g. a diet high in fruits and vegetables but low in fat can keep you healthy). Loss-framed messages generally convey the costs of not adopting the requested behavior (e.g. a diet low in fruits and vegetables but high in fat can lead to cancer)' (Salovey and Wegener, 2003). Health psychology's interest in gain and loss frames grew out of the work on prospect theory, which explains how factually equivalent information can be interpreted as either a gain or loss, and how those distinct interpretations lead to differences in decision making and perceived value to oneself of different decisions (Kahneman and Tversky, 1979; Tversky and Kahneman, 1981; Kahneman and Tversky, 1982); individuals avoid risk when considering benefits and conversely are more risk-tolerant when considering losses (Kahneman and Tversky, 1979; Rothman *et al.*, 1993; Salovey & Wegener, 2003). We build on literature within health psychology which suggests that gain and loss frames result in different value of decisions to the self, depending on the nature of the behavior. Some studies suggest that gain-framed messages appear more effective in a particular subset of cases: fostering healthy *prevention* behaviors, such as the use of infant car restraints to prevent infant injuries and regular exercise to prevent health issues such as cardiovascular diseases (Christophersen and Gyulay, 1981; Treiber, 1986; Robberson and Rogers, 1988; Rothman *et al.*, 1993; Detweiler *et al.*, 1999; Rothman *et al.*, 2006). In cases where gain framed messages are effective, what is the pathway leading to these effects? If gain-frame messages highlight the value of performing a behavior, prompting more self-value integration, then gain-framed messages would more strongly engage the MPFC than loss-framed messages, and that this differential engagement would be associated with subsequent message-consistent behaviors.

One prevention behavior that has supported the use of gain-framed messages is sunscreen use. For example, one study prompted undergraduates to read either gain- or loss-framed pamphlets about skin cancer and sunscreen use, and subsequently tracked how many participants in each condition mailed in postcards to request sunscreen samples with appropriate SPF and more information about skin cancer (Rothman *et al.*, 1993). Among women in the study who requested sunscreen samples, 79% of participants in the gain-frame condition mailed in the request for appropriate SPF, whereas only 45% in the loss-frame condition did so. In other work, 71% of beachgoers who read gain-framed messages requested sunscreen samples, while only 53% of those who read loss-framed messages did (Detweiler *et al.*, 1999). Moreover, the advantage of gain framing was stronger for those who did not have prior intentions to wear sunscreen.

Although gain-framed messages are not always more effective in promoting prevention behaviors, these messages may be effective in some contexts such as in certain domains or among particular subgroups, as meta-analytic results show a stronger effect for women than men in the context of skin cancer prevention (Gallagher and Updegraff, 2012; O'Keefe and Wu, 2012). As such, we chose to examine sunscreen use among women as a prevention behavior for which gain-framed messages may be effective and investigate mechanisms through which this framing may exert its effect on behavior. Persuasion research rooted in prospect theory suggests that gain framing is effective to the extent that it successfully focuses individuals on the perceived value of performing the desired behavior; however, these types of mediations have not been widely tested (Wilson *et al.*, 1988). This mechanism—positive message valuation—is consistent with our proposal that MPFC may compute the personal value of a message with respect to the self (Knutson *et al.*, 2007; Hare *et al.*, 2011), thereby enhancing self-value integration and subsequent behavioral follow-through. Indeed, past empirical work has linked MPFC activity with promotion-focused cognition (Johnson *et al.*, 2006), along with positive cognition about the self (Fossati *et al.*, 2004; Frewen *et al.*, 2013; Lemogne *et al.*, 2011), which gain-framed messages may more effectively promote than loss-framed messages. It is also consistent with the work demonstrating that tailored messages, which focus on the individual's personal values, better engage the MPFC and promote message-consistent behavior than more general messages (Chua *et al.*, 2011). Therefore, we examine MPFC activity as one mechanism through which gain-framed messages may exert an influence when they are effective.

Why *vs* how messages

Both gain- and loss-framed messages characterize the reasons *why* an individual should perform an action; however, there is ample evidence to suggest that explaining *how* to perform an action also fosters message-consistent behavior. Specifically, the related concepts of implementation intentions and action planning[1] suggest that these plans—which include how to perform the desired behavior—improve an individual's chances at enacting the behavior (Gollwitzer, 1993; Gollwitzer and Brandstätter, 1997; Gollwitzer and Sheeran, 2006; Sniehotta *et al.*, 2006; Schwarzer, 2008; Hagger and Luszczynska, 2014). Proponents of action plans suggest that they are effective because they increase attention and memory relevant to enacting one's intentions, while simultaneously increasing the speed of action initiation (Gollwitzer, 1993; Gollwitzer and Brandstätter, 1997; Orbell *et al.*, 1997). That is, because individuals have exerted the cognitive effort to consider exactly when, where, and how they will perform the desired behavior, it is more salient and easily retrievable in memory, eliminating barriers to performing the behavior and allowing successful enactment to occur more quickly and automatically (Hagger and Luszczynska, 2014). Therefore, these researchers argue that action plans do not affect motivation per se, but do affect the feasibility of behaviors via cognitive rehearsal of those behaviors (i.e. imagining oneself enacting the behavior) (Sheeran and Orbell, 1999). Creating action plans increases a range of healthy behaviors such as exercise, diet, smoking, breast self-examination, physical rehabilitation, adherence to a vitamin regimen, cancer screening, vaccination, use of contraceptives, dental health and, importantly for the current study, sunscreen use (Craciun *et al.*, 2011; Hagger and Luszczynska, 2014).

Because persuasive messages that focus on action planning instruct individuals on how to perform the desired behavior, it is relevant to consider the neural systems that might support action planning processes in response to these messages. The literature on *how* and *why* action understanding—in which participants distinguish between *why* another individual is performing a behavior (e.g. studying to do well on a test) and *how* the individual is doing it (e.g. studying by quizzing oneself with flashcards)—is informative in this regard. Across a range of

1 For a full discussion of the subtle distinction between implementation intentions and action planning, see Hagger and Luszczynska (2014).

studies, two regions that are consistently activated when thinking about *how* someone is performing an action are rostral inferior parietal lobule (rIPL) and posterior inferior frontal gyrus (pIFG). Conversely, MPFC tends to activate during *why* relative to *how* messages (Spunt *et al.*, 2010; Spunt and Lieberman,2011, 2012; Spunt and Adolphs, 2014).

An embodied cognition perspective provides one account of these findings—arguing that action understanding relies on these regions precisely because these regions support action *execution* (Pulvermüller, 2005; Gallese, 2007; Mahon and Caramazza, 2008; Bastiaansen *et al.*, 2009; Niedenthal *et al.*, 2010). Much of the foundation for this idea comes from work on the mirror neuron system, which shows that these regions activate both in observing and enacting behaviors (Van Overwalle and Baetens, 2009; Rizzolatti and Sinigaglia, 2010). Indeed, one's own action intentions are associated with activity in these regions as well (Lau *et al.*, 2004; Desmurget and Sirigu, 2009; Desmurget *et al.*, 2009). In the context of *how* persuasive messages, it is possible that these regions may activate to support cognitive rehearsal of the desired behavior. That is, while prior work has focused on the role of a message's self-relevance in persuasion, we argue that messages that engage cognition about lower level motor actions may also be particularly effective—though for entirely different reasons.

Amplifying an existing behavior *vs* starting a new one

Several models of health behavior suggest a psychological distinction between initial enactment of a new behavior (e.g. wearing sunscreen when one does not normally do so) and subsequent maintenance or amplification of that behavior (e.g. applying sunscreen everyday rather than occasionally) (Weinstein *et al.*, 1998; Miilunpalo *et al.*, 2000; Fogg, 2009). In the first case, individuals may not see themselves as sunscreen users; the persuasion process for them may involve coming to integrate sunscreen use into their identity (i.e. self-value integration). In the second case, persuasion may be less about self-value integration because the behavior is already consistent with one's identity. Therefore, stronger ties between MPFC activity and behavior in response to messaging among individuals who are not current sunscreen users relative to those who are would be consistent with this account. Some tangential support for this argument comes from the aforementioned behavioral study on sunscreen use in which gain-framed messages were more persuasive among those who did not intend to wear sunscreen compared to those who did (Detweiler *et al.*, 1999). A competing argument is the MPFC activity-behavior link may be driven by those who already identify highly with the behavior (e.g. users), because they will be able to identify more readily with persuasive arguments. Therefore, as an initial investigation of these competing hypotheses, we examine the relationship between MPFC activity and behavior in sunscreen-users vs. non-sunscreen-users.

Hypotheses

Persuasion is a multi-faceted phenomenon, in which message content, person-specific variables, and contextual factors combine to produce behavioral outcomes. We focus on three theoretically relevant determinants of persuasion to extend prior theory and data relevant to the brain systems that support persuasion: (1) *gain vs loss* framing, (2) *how vs why* messages and (3) *users vs non-users*.

Gain vs loss. We argue that gain framing, which highlights the value of the behavior to the self, may exert positive effects on behavior by engaging the MPFC in consideration of personal value. We therefore predict that, in the context of sunscreen use, MPFC activity will be greater during gain-framed messages relative to loss-framed messages. We also expect that MPFC activity will be more strongly related to downstream behavior during gain-framed messages relative to loss-framed messages, in line with the idea that gain-framed messages may better highlight the personal value of the message, thereby supporting MPFC activity that has been linked with behavior. These findings would suggest a theoretically plausible mechanism underlying the consistent link between MPFC activity during persuasive public health messages and downstream message-consistent behavior (Falk et al., 2010, 2011, 2012; Cooper *et al.*, 2015; Falk *et al.*, 2015). Specifically, such findings would support the idea that the MPFC may function to assess the personal value of a message during encoding, which may guide behavior to the extent that value is deemed to be high. This hypothesis is also in line with neuroeconomic theories about MPFC activity as a signal of value (Knutson *et al.*, 2007; Hare *et al.*, 2011) and is consistent with the idea that these messages may be effective because they foster self-value integration (i.e. they explicitly highlight the benefit of the behavior to oneself).

How vs why. Second, in line with past literatures on action planning and how *vs* why processing modes, we hypothesize that activity in rIPL and pIFG will be greater during How messages relative to Why messages and How messages relative to control messages—and conversely that activity in MPFC will be greater in Why messages relative to How messages and Why messages relative to control messages. We also predict that activity in rIPL and pIFG (i.e. action understanding regions) during How messages will be associated with downstream behavior. This finding would provide biological support for an emerging account of the psychological processes underlying the effectiveness of action planning—namely, that it engages cognitive rehearsal processes supported by rIPL and pIFG, and is distinct from other forms of persuasion.

Users vs non-users. One question not addressed in previous work is whether the relationship between MPFC activity and behavior observed in prior studies is driven by those who already identify with the behavior, and hence experience all behavior-related content as more self-relevant. We suggest that the converse relationship may actually be true: the relationship between MPFC activity and behavior may be stronger among participants who did not use sunscreen before the study (non-users) than among those who already did (users). In other words, individuals who did not previously see the relationship as consistent with their self-image should engage in the activity to the extent that they begin to consider the personal value during message encoding, whereas individuals who currently enact the behavior may have already undergone self-value integration and thus may show weaker effects. Examining users and non-users separately allows us to test these two competing accounts.

Methods

Participants

Thirty-seven right-handed women were recruited from flyers posted around the campus ($M_{age} = 20.43$; $SD_{age} = 2.44$). We focused specifically on women because they are more concerned than men with tanning and skin cancer (Rothman *et al.*, 1993)—two of the central issues concerning sunscreen use. In addition, our gain messages focused on skin beauty, which is perceived as more self-relevant for women than for men (Rothman *et al.*, 1993). Pre-testing of our messages also revealed that women found the messages clearer and more persuasive than did men. Potential participants were screened and excluded if they were claustrophobic, pregnant or

Table 1. Examples of the four ad types

Ad type	Example
Fact (control)	'In the United States, sunscreen products are regulated as over-the-counter (OTC) drugs by the U.S. Food and Drug Administration (FDA). The FDA has several safety and effectiveness regulations in place that govern the manufacture and marketing of all sunscreen products, including safety data on its ingredients'.
How	'Apply liberally and evenly to all exposed skin. The average adult in a bathing suit should use approximately one ounce of sunscreen per application. Not using enough will reduce the product's SPF and the protection you get. Be sure to cover often-missed spots: lips, ears, around eyes, neck, scalp if hair is thinning, hands and feet'.
Why_{gain}	'Daily application of broad spectrum sunscreen with SPF 15 or higher has been clinically demonstrated to keep skin looking younger, more elastic and healthier. Maintaining good habits about using sunscreen is crucial for having beautiful skin for years to come, that not only looks better but is more likely to remain healthy'.
Why_{loss}	'Studies have found that inconsistent use of sunscreen is associated with a number of skin issues. These include, but are not limited to, wrinkling, sagging, splotchy, leathery, uneven skin. To avoid these issues, you should apply broad-spectrum sunscreen with SPF 15 or higher to any and all skin that will be exposed to the sun'.

breastfeeding, had any metal in their bodies, or were currently taking psychoactive medication. In analyses using the MPFC ROI, one participant could not be included due to dropout in that region, leaving a total of 36 participants in those models. Of the 37 total participants, 19 were existing users of sunscreen, and 18 were not existing users of sunscreen.

Procedure

Immediately prior to scanning, participants completed a questionnaire that assessed (1) how often they had engaged in various behaviors—including the regular use of sunscreen—over the course of the previous week, and (2) intentions of performing these same behaviors during the next week. Specifically, participants responded to the following items: (1) 'Out of the past 7 days, how many days did you do each of the following? Please enter a number from 0 to 7 in each box. You can estimate a number if you're unsure'; and (2) 'Out of the next 7 days, how many days do you intend to do each of the following? Please enter a number from 0 to 7 in each box. You can estimate a number if you're unsure'. Participants answered these two questions for each of the following behaviors, presented in randomized order: used sunscreen, exercised, flossed, ate vegetables, got at least 7 h of sleep, skipped class and got at least 8 h of sleep. We also asked how many *times* they performed and intended to perform these behaviors, but because the correlation between their responses for *days* and *times* was quite high ($r_{beh} = 0.998$, $r_{intent} = 1.00$), we used the *days* measure in all subsequent analyses (as in previous research; Falk *et al.*, 2010).

While undergoing fMRI, participants viewed 40 text-based ads promoting sunscreen use. An audio recording of each ad was also played to standardize reading speed across participants. The ads fell into four categories: 10 control ads simply listed facts about sunscreen (Fact), 10 ads discussed how to use sunscreen (How), 10 ads discussed why sunscreen use is beneficial (Why_{gain}) and 10 ads discussed why not using sunscreen is harmful (Why_{loss}; see Table 1 for examples of each ad type). The ads were of equal length across all conditions ($M = 52.88$ words, $SD = 3.95$ words, range = 45–60 words; all $Ps > 0.30$). Pre-testing indicated that participants considered both Why ad types (Loss and Gain) to be more persuasive than Fact or How ad types [$Why_{gain} > \text{Fact}$, $t(80) = 11.22$, $P < 0.001$; $Why_{loss} > \text{Fact}$, $t(80) = 12.86$, $P < 0.001$; $Why_{gain} > \text{How}$, $t(80) = 7.91$, $P < 0.001$; $Why_{loss} > \text{How}$, $t(80) = 9.71$, $P < 0.001$]. Why_{loss} ads were rated as marginally more persuasive than Why_{gain} ads, $t(80) = 1.81$, $P = 0.074$[2]. The pre-test sample found all the ads clear (ratings of clarity on a four point scale: $M = 3.59$, $SD = 0.16$), and could distinguish among the four ad types (i.e. each of the 40 statements except for 2 was correctly classified by more than half the sample; on average, a statement was correctly classified by 74.56% of the sample). The 40 ads were divided into two runs, roughly 8 min each; a random order of the four ad types was generated for each participant, and this order was repeated five times per run (e.g. How, Why_{gain}, Fact, Why_{loss}, How, Why_{gain}, Fact, Why_{loss}, etc.). Subjects passively viewed and listened to each ad, akin to naturalistic experiences of ad exposure in everyday life ($M = 19.21$ s, $SD = 1.55$ s, range = 16.59–22.10 s), and ads were separated by a jittered fixation centered around 4 s (range = 2–6 s).

After the scanning session, participants completed a questionnaire assessing intentions to enact the same health behaviors assessed prior to scanning, along with other attitudes and individual differences not included in the current analyses (see supplementary materials for exact items). Eight days after scanning, we contacted participants by email to complete a follow-up questionnaire, which was identical to the pre-scan questionnaire (i.e. assessing behaviors over the prior week and intentions for the next week). All participants completed the follow-up questionnaire.

Data acquisition and analysis

Imaging data were acquired using a Siemens Prisma 3 Tesla head-only MRI scanner. Head motion was minimized using foam padding and surgical tape; goggles were also fixed in place using surgical tape connecting to the head coil and scanner bed. A T1-weighted magnetization-prepared rapid-acquisition gradient echo (MPRAGE) structural scan (TR = 2300 ms; TE = 2.95 ms; matrix size = 256×256; 176 sagittal slices; FOV = 27.0 cm; 1.20 mm thick; voxel size = $1.1\,\text{mm} \times 1.1\,\text{mm} \times 1.2\,\text{mm}$) was acquired. Two functional runs were recorded (echo-planar T2*-weighted gradient-echo, TR = 720 ms, TE = 37 ms, flip angle = 52°, matrix size = 104×104, 72 slices, FOV = 20.8 cm, 2 mm thick; voxel size = $2.0 \times 2.0 \times 2.0$ mm).

The fMRI data were analyzed using SPM12 (Wellcome Department of Imaging Neuroscience, London). Images were realigned to correct for motion, co-registered to the MPRAGE, normalized into Montreal Neurological Institute (MNI) space, and smoothed with a 6 mm Gaussian kernel full-width half-maximum. The task was modeled for participants at the single

2 Although it is intriguing that the pretest participants rated Why_{loss} ads as marginally more persuasive than Why_{gain} ads, we believe this trend was likely due to their inability to correctly predict which messages may be most effective in promoting desired behaviors, a consistent finding in the literature (Wicker, 1969; Nisbett and Wilson, 1977; Nolan et al., 2008).

subject level, comparing activity while viewing each focal message type (i.e. Why_{gain}, Why_{loss}, How) to activity while viewing the control messages (Fact). We also compared activity while viewing Why_{gain} messages to Why_{loss} messages. Finally, we compared activity while viewing all 20 Why messages (i.e. gain and loss combined) to activity while viewing the How messages. A random effects model was constructed, averaging over these single subject results at the group level using GLM Flex.

Regions of interest

We had three regions of interest (ROIs) that we chose to investigate *a priori*. First, following results from prior work on neural predictors of persuasive influence, we examined the medial prefrontal cortex (MPFC). Specifically, we chose a cluster in the ventral portion of MPFC (Figure 1a) that has been used in several past studies to predict behavior over and above self-reported intentions (Falk *et al.*, 2011, 2012; Cooper *et al.*, 2015; Falk *et al.*, 2015). This ROI was constructed using Marsbar (Brett *et al.*, 2002) based on the cluster revealed to be the most highly associated with behavior change in Falk *et al.* (2010). Second, given our interest in action planning and How messages, we examined regions that have been associated with action understanding in past work, namely, rostral inferior parietal lobule (rIPL) and posterior inferior frontal gyrus (pIFG). We used ROIs based on the conjunction of Why/How contrasts reported in studies 1 and 3 of Spunt and Adolphs (2014; see Figure 1b and c). We extracted parameter estimates of activity in each of these ROIs for each participant from Marsbar and conducted primary analyses in R version 3.2.2 (R Core Team, 2015). To test for differences in activity across our four conditions, we used a repeated-measure ANOVA and followed up with *t*-tests to examine pairwise comparisons (corrected for multiple comparisons using the Holm method). To examine relationships between brain activity and behavior, we correlated ROI activity during relevant contrasts with reported sunscreen use in the week following the scan session, controlling for the effect of intentions.

Supplementary whole-brain analyses

Whole-brain analyses were conducted to explore activation patterns in key contrasts of interest. To generate cluster-size thresholds at $P < 0.05$ combined with a voxel-wise threshold of $P < 0.005$, a Monte Carlo simulation with 10 000 iterations was run using 3dClustSim in AFNI (Cox, 1996; Version AFNI_2011_12_21_1014).

Results

Behavior

Days of sunscreen use significantly increased from the week prior to the session ($M = 2.08$, $SD = 2.70$) to the week following the session [$M = 3.16$, $SD = 2.94$), $t(36) = 3.50$, $P < 0.001$]. Intentions of daily sunscreen use also significantly increased from before the session ($M = 2.19$, $SD = 3.01$) to after the session [$M = 4.97$, $SD = 2.50$), $t(36) = 6.09$, $P < 0.001$]. These results held both for participants who were current users of sunscreen (users) and for those who were not (non-users). That is, both users and non-users wore significantly more sunscreen during the week following the session than during the week prior to the session [users: $M_{\text{pre-scanning}} = 4.05$, $SD_{\text{pre-scanning}} = 2.48$, $M_{\text{post-scanning}} = 4.89$, $SD_{\text{post-scanning}} = 2.47$, $t(18) = 2.45$, $P = 0.012$; non-users: ($M_{\text{pre-scanning}} = 0$, $SD_{\text{pre-scanning}} = 0$, $M_{\text{post-scanning}} = 1.33$, $SD_{\text{post-scanning}} = 2.22$, $t(17) = 2.54$, $P = 0.010$; Figure 2]. The increase in sunscreen use was not significantly different for users *vs* non-users $t(35) = 0.79$, $p = 0.22$. Users and non-users alike also reported greater *intentions* to wear more sunscreen after the scan than before the scan [users: $M_{\text{pre-scanning}} = 4.26$, $SD_{\text{pre-scanning}} = 2.96$, $M_{\text{post-scanning}} = 5.89$, $SD_{\text{post-scanning}} = 1.73$, $t(18) = 3.21$, $P = 0.002$; non-users: $M_{\text{pre-scanning}} = 0$, $SD_{\text{pre-scanning}} = 0$, $M_{\text{post-scanning}} = 4.00$, $SD_{\text{post-scanning}} = 2.85$, $t(17) = 5.96$, $P < 0.001$]. The increase in intentions was marginally greater for non-users *vs* users, $t(35) = 1.66$, $P = 0.10$ (Table 2).

Gain *vs* loss framing ROI analyses

A one-way within-subjects ANOVA revealed significant differences in MPFC activity across conditions, $F(3,104) = 9.25$,

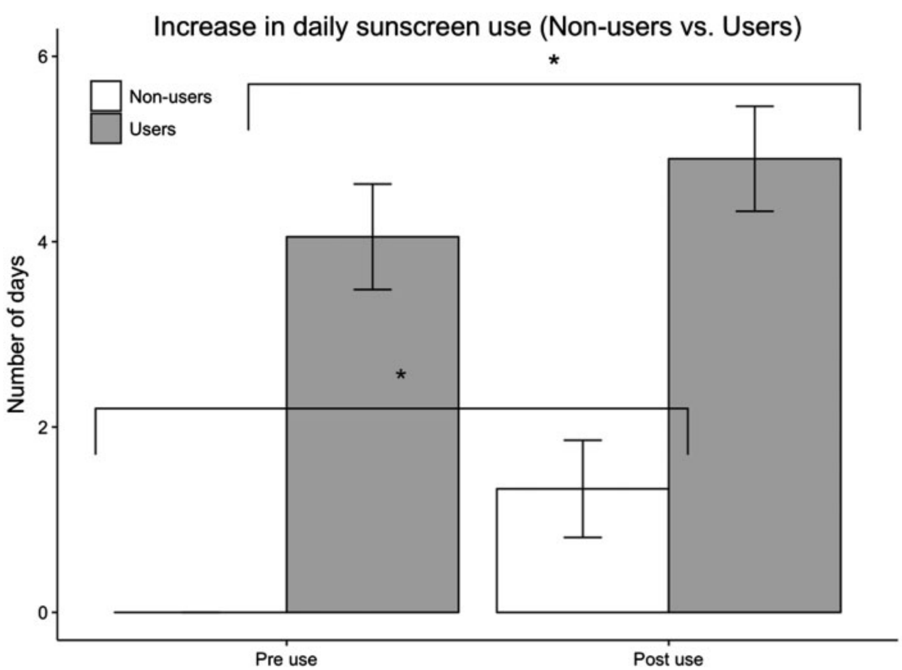

Fig. 2. Sunscreen use increases pre-session to post-session for users and non-users. Note: † $P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 2. Behavioral results

	Overall mean	Overall SD	Users mean	Users SD	Non-users mean	Non-users SD
Use pre	2.08	2.70	4.05	2.48	0	0
Use post	3.16	2.94	4.89	2.47	1.33	2.22
Intentions pre	2.19	3.01	4.26	2.96	0	0
Intentions post	4.97	2.50	5.89	1.73	4.00	2.85

Table 3. Mean parameter estimates of MPFC activity

	Why_{gain}> Fact	Why_{loss}> Fact	Why_{gain}> Why_{loss}
All	0.53^{***}	0.27^{*}	0.25^{*}
Non-users	$0.44^{\dagger}$	0.25	0.31
Users	0.61^{***}	0.29	$0.19^{\dagger}$
Non-users *vs* users sig. different?	No	No	No

Note:
$^{\dagger}P < 0.1$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

$P < 0.001$. We then examined several contrasts involving gain and loss framing, correcting *P*-values for multiple comparisons using the Holm method. There was greater MPFC activity during Why_{gain} relative to Fact control messages in the whole sample [$M = 0.53$, $SD = 0.64$; $t(34) = 4.85$, $P < 0.001$]. There was also greater MPFC activity during Why_{loss} relative to Fact control messages in the whole sample [$M = 0.27$, $SD = 0.57$; $t(35) = 2.82$, $P = 0.016$]. The difference between Why_{gain} and Why_{loss} was significant; that is, there was greater MPFC activity during Why_{gain} relative to Why_{loss} messages in the whole sample [$M = 0.25$, $SD = 0.63$; $t(34) = 2.31$, $P = 0.041$]. The Why_{gain} > Fact finding held for the two subgroups (users and non-users) (Table 3 and Figure 3).

Next, we tested whether MPFC activity during Why messages was associated with behavior and, critically, whether this pattern was different for Why_{gain} *vs* Why_{loss} messages. In order to determine whether the neural data offered any 'added value' over self-report, we controlled for participants' intentions in our primary analyses. As predicted, we found that MPFC activity during Why_{gain} relative to control (Fact) messages was correlated with subsequent sunscreen use controlling for the effect of intentions, $r(34) = 0.34$, $P = 0.021$ (Figure 4a). In contrast, MPFC activity during Why_{loss} relative to Fact control messages was not significantly correlated with sunscreen use controlling for the effect of intentions, $r(34) = 0.045$, $P = 0.40$. Additionally, MPFC activity during Why_{gain} relative to Why_{loss} messages was significantly correlated with sunscreen use controlling for the effect of intentions, $r(34) = 0.30$, $P = 0.036$ (Figure 4b). Zero-order correlations showed similar, but weaker patterns for Why_{gain} relative to Fact but not Why_{gain} relative to Why_{loss} (see supplementary materials). These findings are consistent with our hypothesis that when gain-framed messages are effective in promoting prevention health behaviors, this behavioral adoption may be subserved, in part, by self-valuation processes in MPFC.

Also as predicted, the relationship between MPFC activity and subsequent sunscreen use differed for sunscreen users and non-users. MPFC activity during Why_{gain} relative to Fact control messages was significantly correlated with sunscreen use controlling for the effect of intentions for non-users, $r(16) = 0.46$, $P = 0.027$, but not for users, $r(16) = -0.070$, $P = 0.39$. The difference in correlations between non-users and users was marginally significant, $Z = 1.55$, $P = 0.061$ (Figure 5a). Similarly, MPFC activity during Why_{gain} relative to Why_{loss} messages was significantly correlated with sunscreen use controlling for the effect of intentions for non-users, $r(16) = 0.51$, $P = 0.015$, but not for users, $r(16) = -0.23$, $P = 0.18$, and

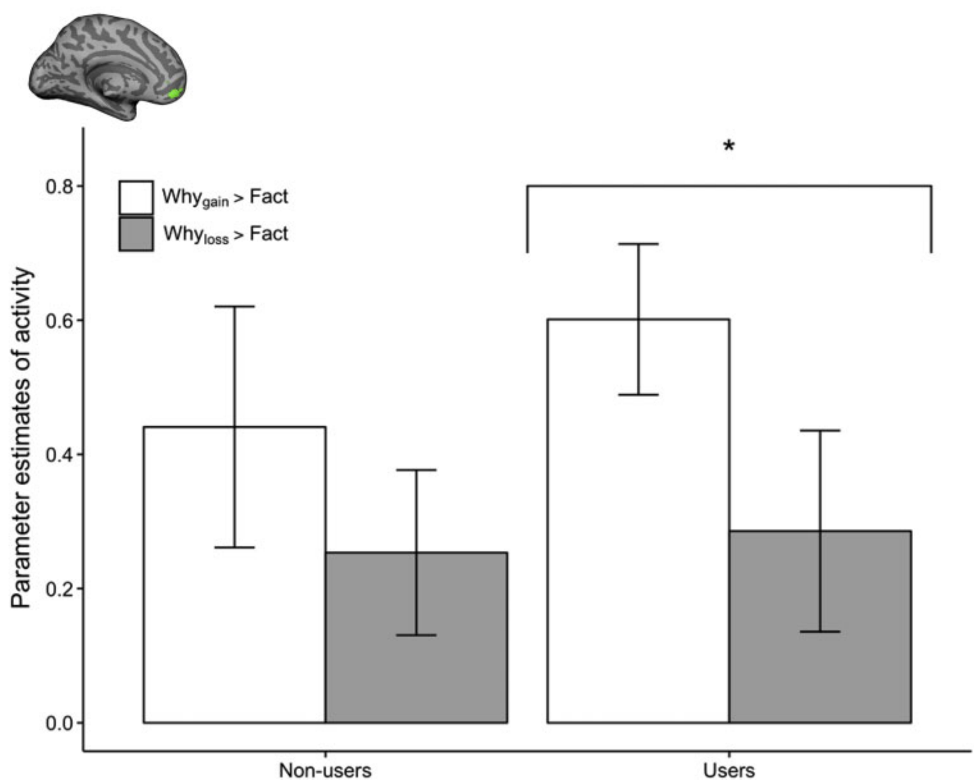

Fig. 3. MPFC activity during Why_{gain} and Why_{loss} messages relative to Fact control messages for non-users *vs* users. Note: $\dagger P < 0.1$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

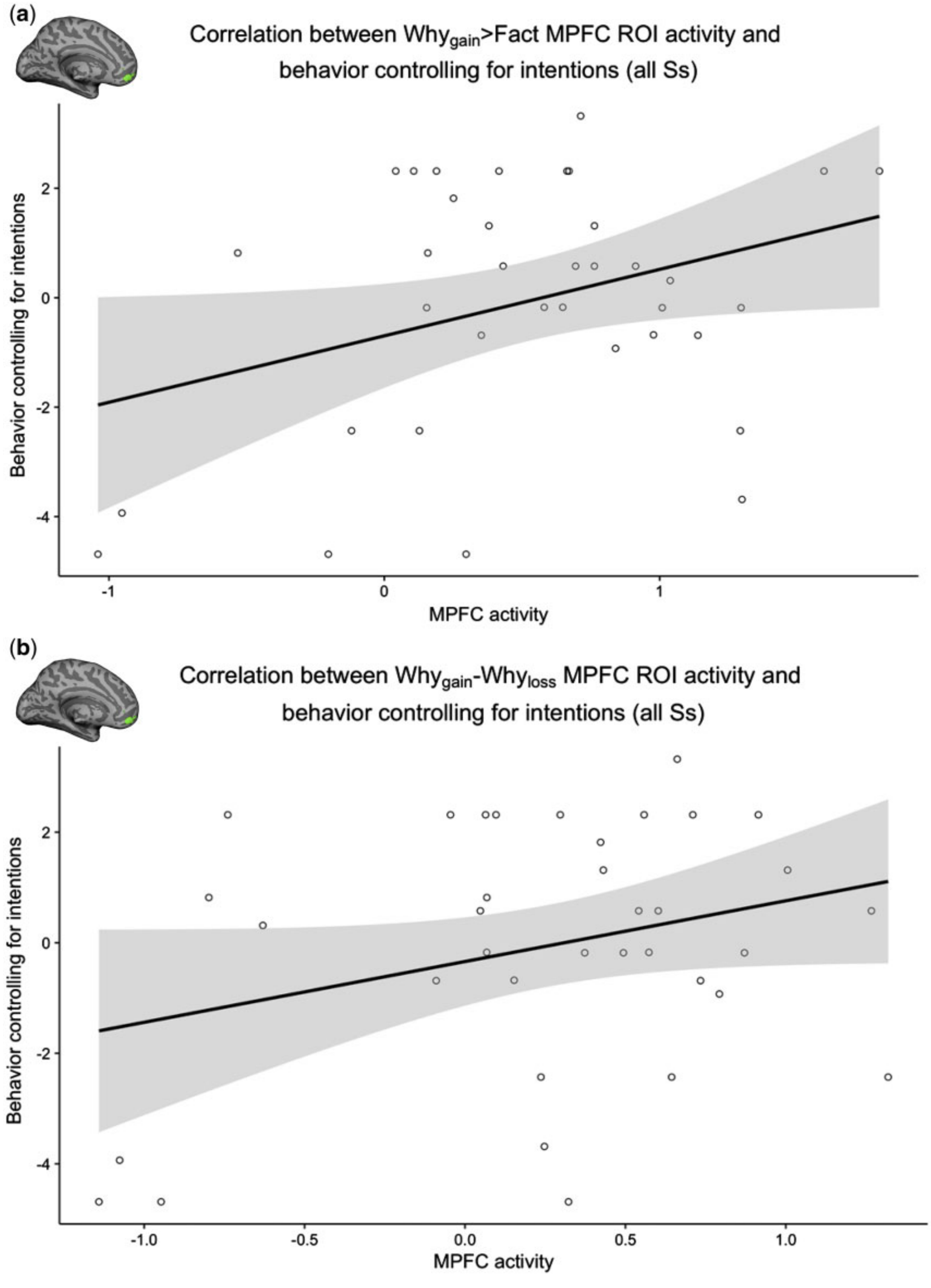

Fig. 4. Correlation between activity in MPFC during (a) Why$_{gain}$ relative to Fact messages and behavior controlling for intentions, $r(34) = 0.34$, $P = 0.021$, and (b) Why$_{gain}$ relative to Why$_{loss}$ messages and behavior controlling for intentions, $r(34) = 0.30$, $P = 0.036$.

the difference in correlations between non-users and users was significant, $Z = 2.17$, $P = 0.015$ (Figure 5b). Zero-order correlations revealed similar patterns, but were weaker (see supple mentary materials). These findings are consistent with the idea of MPFC activity playing a role in self-value integration among non-users as they consider adopting new, healthy behaviors, rather than the brain–behavior correlation reflecting existing self-relevance among users. This contrasts with the competing account described in the introduction: that the relationship between MPFC activity and behavior observed in previous studies (Falk et al., 2010, 2011, 2012; Cooper *et al.*, 2015; Falk *et al.*, 2015) is driven by individuals who are already 'on board' with the health goal being promoted (i.e. people who already use sunscreen and who self-identify as sunscreen users).

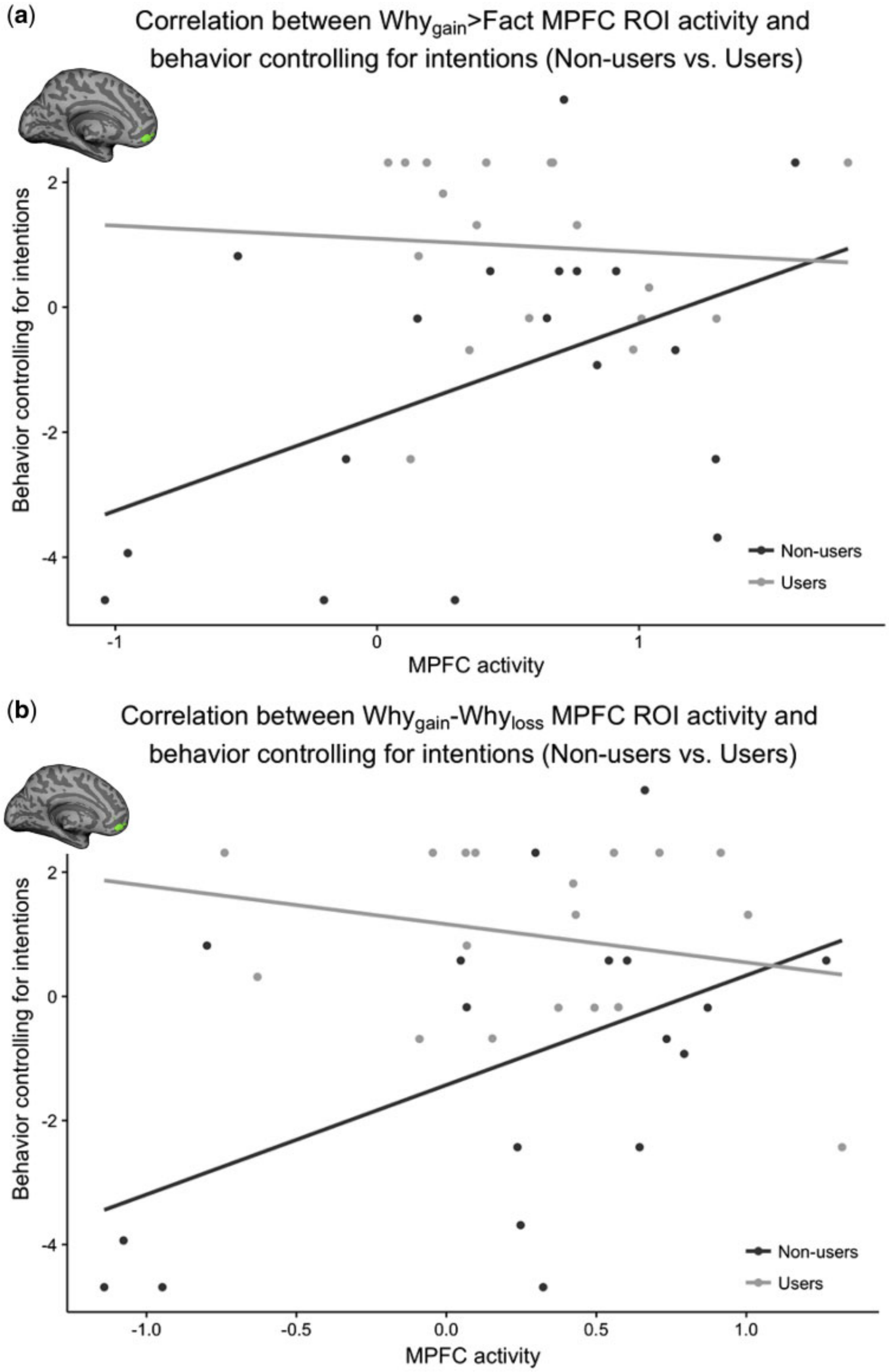

Fig. 5. Correlation between activity in MPFC during (a) Why$_{gain}$ relative to Fact messages and behavior controlling for intentions in users, $r(16) = -0.070$, $P = 0.39$, *vs* non-users, $r(16) = 0.46$, $P = 0.027$; $Z_{diff} = 1.55$, $P = 0.061$, and (b) Why$_{gain}$ relative to Why$_{loss}$ messages and behavior controlling for intentions in users, $r(16) = -0.23$, $P = 0.18$, *vs* non-users, $r(16) = 0.51$, $P = 0.015$; $Z_{diff} = 2.17$, $P = 0.015$.

Action planning and 'why' *vs* 'how' ROI analyses

Next, we investigated activity in action understanding regions during action plan messages (How) relative to control messages (Fact). As predicted, there was greater activity during How relative to Fact control messages in rIPL [$M = 0.22$, $SD = 0.40$; $t(36) = 3.38$, $P < 0.001$] and pIFG [$M = 0.16$, $SD = 0.37$; $t(36) = 2.71$, $P = 0.005$] across the whole sample. Users showed greater activation in rIPL [$M = 0.35$, $SD = 0.37$; $t(18) = 4.093$, $P < 0.001$] and pIFG [$M = 0.28$, $SD = 0.33$; $t(18) = 3.72$, $P < 0.001$] to How relative to Fact messages overall than non-users in rIPL ($M = 0.085$, $SD = 0.39$; $t(17) = 0.93$, $P = 0.18$) and pIFG [$M = 0.038$, $SD = 0.37$, $t(17) = 0.43$, $P = 0.34$]. The difference between non-users and users was significant both for rIPL, $t(36) = 2.13$, $P = 0.020$, and for pIFG, $t(36) = 2.12$, $P = 0.020$ (Figure 6). The fact that users, compared with non-users, showed more activity in these action understanding regions during How messages might reflect the fact that that users can more easily imagine the act of applying sunscreen because they have more experience from which to draw. Indeed, prior work has shown that greater experience with a set of actions is associated with increased activity in action understanding regions during domain-relevant tasks; for example, experienced musicians show greater activity in these regions while listening to music or enacting musical motor actions relative to novices (Haslinger *et al.*, 2005; Bangert *et al.*, 2006).

These results align with previous research highlighting the critical contributions of rIPL and pIFG to understanding how human actions are performed (Spunt *et al.*, 2010; Spunt and Lieberman, 2011, 2012; Spunt and Adolphs, 2014). These studies consistently reveal a double-dissociation, with rIPL and pIFG being preferentially recruited for understanding the physical properties of actions (How > Why), and MPFC being preferentially recruited for understanding the mental states that underlie these actions (Why > How). In a conceptual replication of these findings, we observed greater rIPL [$M = 0.61$, $SD = 0.61$; $t(36) = 6.05$, $P < 0.001$] and pIFG [$M = 0.75$, $SD = 0.60$; $t(36) = 7.68$, $P < 0.001$] activity to How relative to Why messages, and greater MPFC activity during Why messages relative to How messages [$M = 0.43$, $SD = 0.96$; $t(35) = 2.70$, $P = 0.005$] (Figure 7). Supplementary whole-brain analyses confirmed these effects as well (Table 4 and Figure 8). No interaction emerged between message type (Why *vs* How) and user type (user *vs* non-user, see supplementary materials for subgroup analyses and relevant whole-brain analyses).

An additional question—untested in previous investigations of 'why' *vs* 'how' action understanding—is whether the action planning processes thought to be instantiated in 'how' regions (rIPL and pIFG) might be important in promoting message-consistent behavior. Existing behavioral theories propose that cognitive rehearsal of the desired action in the present helps to make that behavior more 'automatic' in the future (Gollwitzer and Brandstätter, 1997; Sheeran and Orbell, 1999). Consistent with this suggestion, we found that sunscreen use in the week following scanning was associated with activity in physical-action-oriented 'how' regions while participants considered how to increase sunscreen use. Specifically, we found that activity in both rIPL and pIFG for How relative to control (Fact) messages was significantly correlated with behavior controlling for intentions [rIPL: $r(35) = 0.35$, $P = 0.016$; pIFG: $r(35) = 0.28$, $P = 0.047$; Figure 9]. These correlations were not significantly different for users and non-users Ps > 0.30 (see supplementary ma terials for full details).

Discussion

Given the high prevalence of melanoma in the U.S. (5.4 million cases in 3.3 million people; Rogers *et al.*, 2015) and its associated costs ($4.8 billion annually; Guy *et al.*, 2015), a better understanding of the mechanisms underlying effective health messaging could provide significant benefit to the public. A number of studies have demonstrated that greater MPFC activity during the encoding of health-persuasive messages is associated with greater message-consistent behavior in the future (Falk *et al.*, 2010; Chua *et al.*, 2011; Falk *et al.*, 2011, 2012; Cooper *et al.*, 2015; Falk *et al.*, 2015). The present work replicates this finding, but extends beyond previous demonstrations by examining three key psychological variables that help to illuminate the meaning behind these brain–behavior correlations.

First, building on theories in health psychology regarding gain- and loss-framed messages, we suggest a mechanism

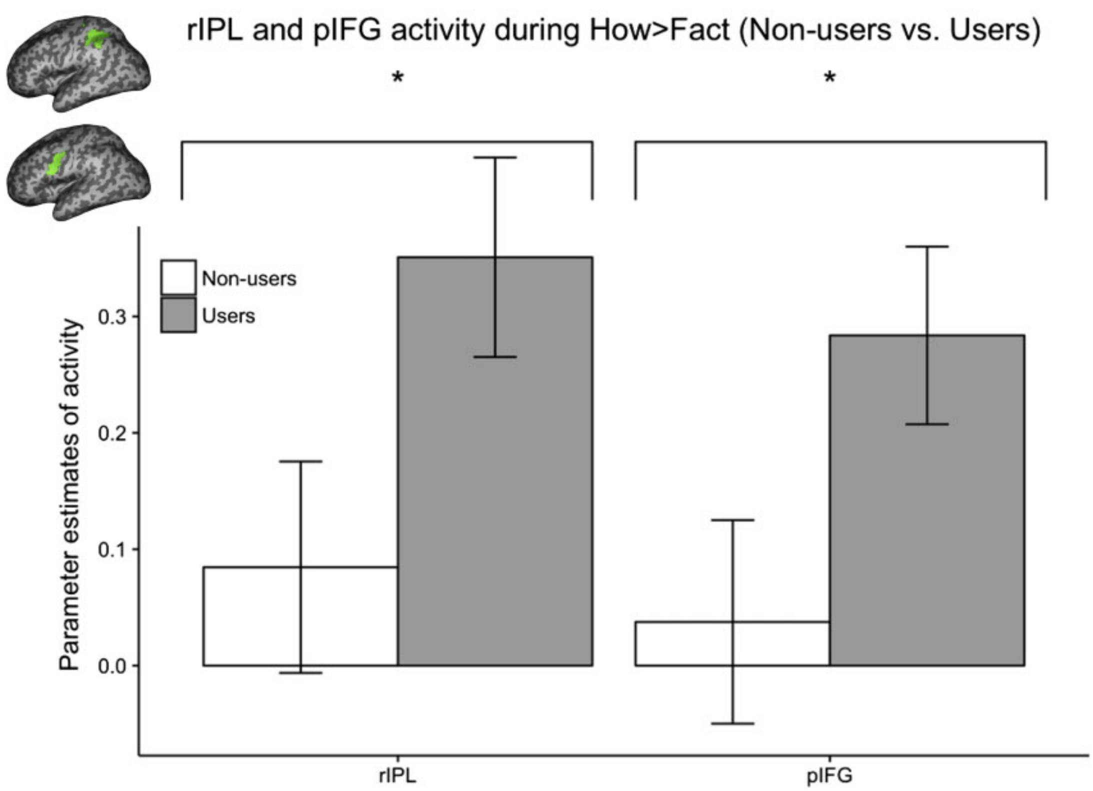

Fig. 6. Activity in rIPL and pIFG during How relative to Fact control messages for users *vs* non-users. Note: † $P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

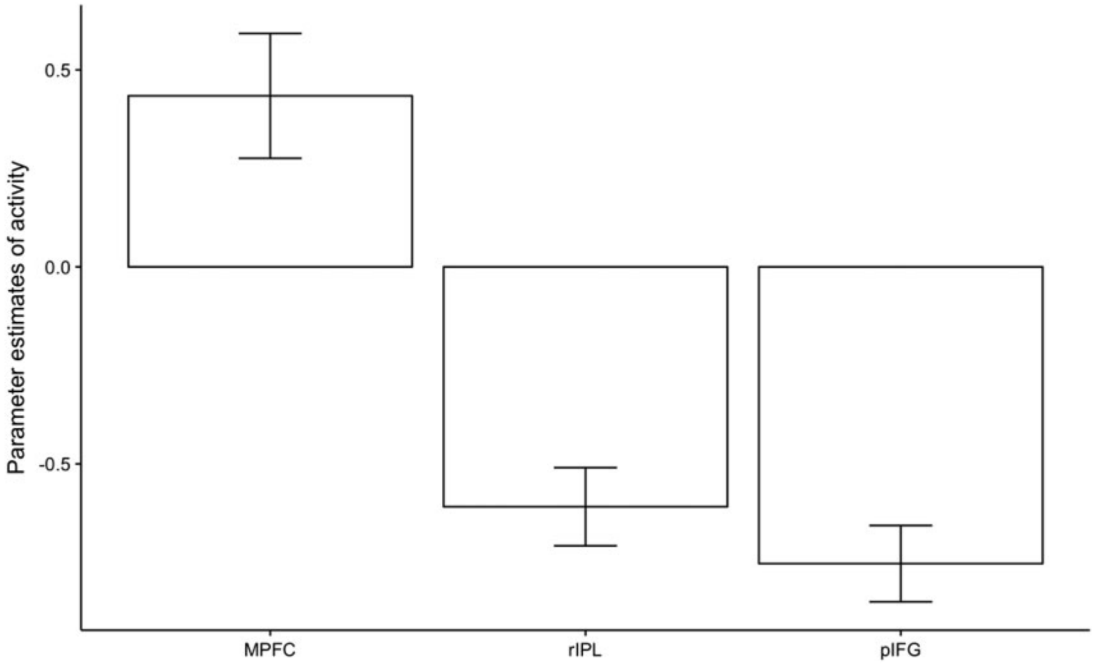

Fig. 7. Activity in MPFC, rIPL, and pIFG during Why relative to How messages.

whereby gain-framed messages may exert positive effects by engaging cognition around the personal value of the desired behavior, which we believe may be supported by MPFC activity during message encoding. We predicted and found that MPFC activity during Why_{gain} relative to both Why_{loss} and control (Fact) messages was associated with sunscreen use over the next week controlling for the effect of intentions. This observation aligns well with past work in this domain (Falk et al., 2010, 2011, 2012; Cooper et al., 2015; Falk et al., 2015) and is consistent with the theoretical suggestion that MPFC activity during encoding of persuasive prevention-focused messages may be indexing the personal value of the message-consistent behavior. We suggest that this personal positive value is made more explicit in our gain-framed stimuli relative to our loss-framed messages, and that calculating the personal value of ideas like 'becoming a sunscreen-user' may facilitate self-value integration processes. In parallel, the

Table 4. Activity during Why > How messages, $P < 0.005$, $k = 78^3$

Region	x	y	z	t	voxels
Why>How					
MPFC	2	46	18	7.202	6477
VLPFC	−32	14	−22	5.330	284
VLPFC	32	18	−12	5.977	705
Precuneus	−2	−20	34	8.711	4254
Supramarginal gyrus	66	−44	40	3.821	350
How>Why					
pIFG	−46	32	12	8.083	2553
pIFG	52	38	16	5.409	657
rIPL	−54	−28	46	8.675	3370
rIPL	36	−38	32	4.874	356
Middle temporal gyrus	56	−48	−12	8.196	2842
Middle temporal gyrus	−48	−52	−8	9.663	4767
Middle temporal gyrus	−52	6	−16	6.925	382
Parahippocampal gyrus	−14	−8	−16	6.032	187
VLPFC	−36	36	−14	5.537	138
PCC	8	−66	10	4.179	181
Thalamus	−8	−14	10	5.828	126
Superior temporal gyrus	54	−24	4	4.896	184
Caudate	−12	6	12	6.556	229
Caudate	16	6	4	3.955	83
Superior parietal lobule	36	−70	36	5.457	962
Cingulate gyrus	−2	6	28	5.157	139
DLPFC	−26	8	56	8.224	1253
DLPFC	30	16	52	4.515	176

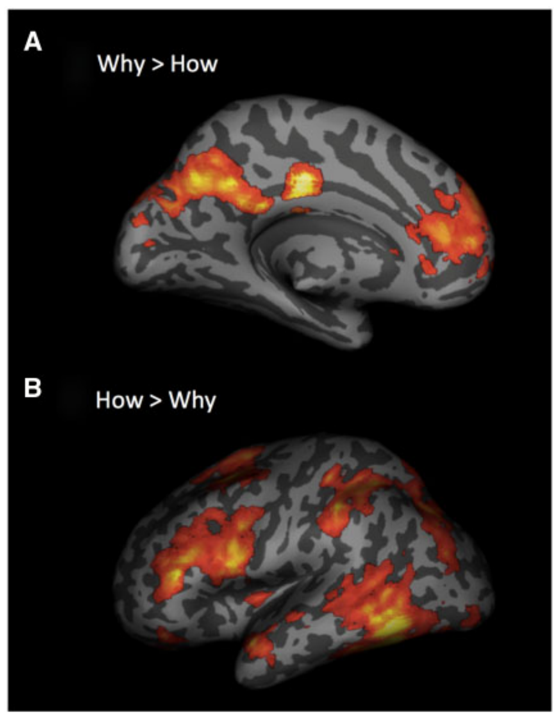

Fig. 8. Whole-brain activity in (a) MPFC during Why relative to How messages and in (b) rIPL, and pIFG during How relative to Why messages, $P < 0.005$, $k = 78$.

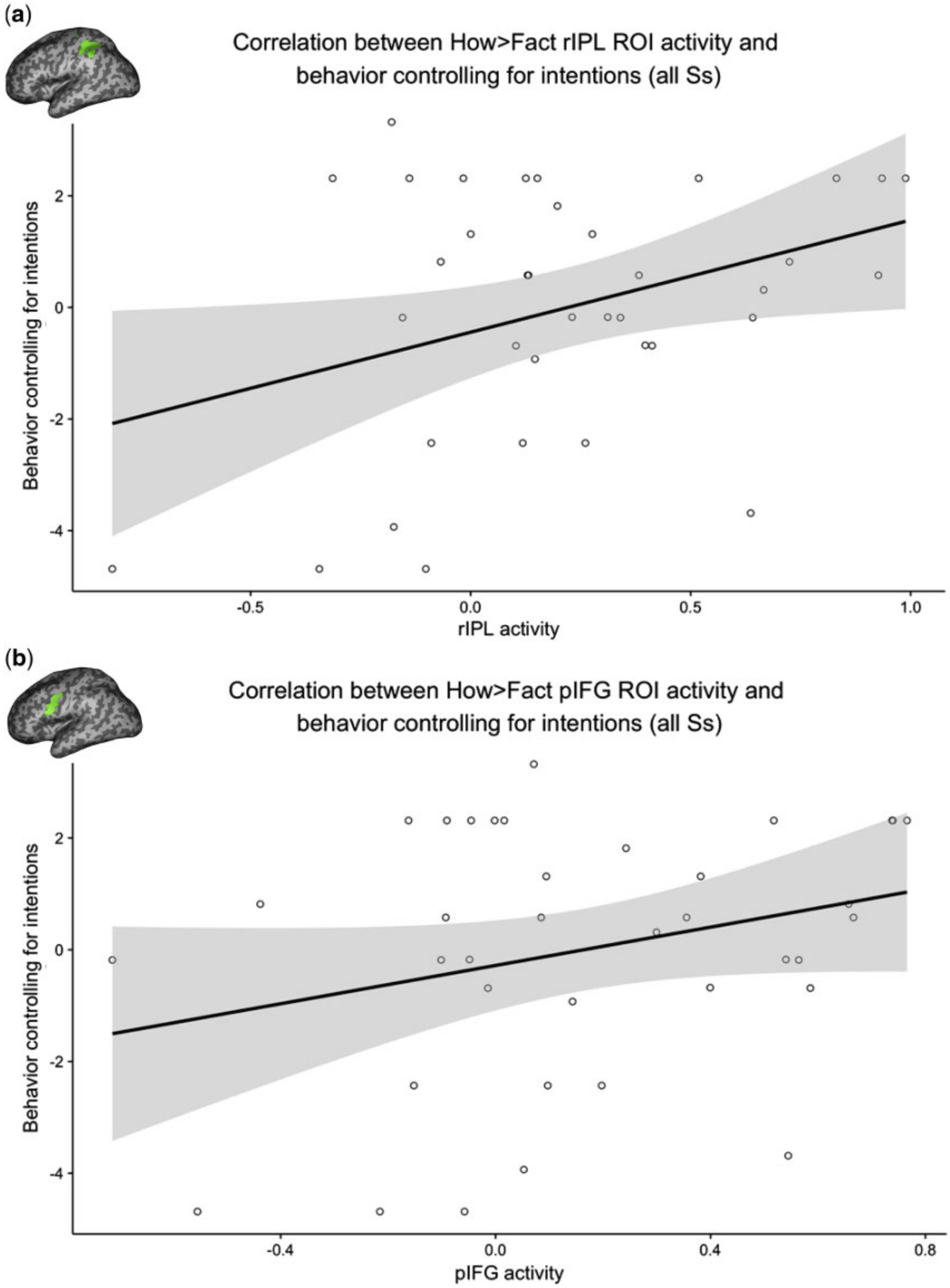

Fig. 9. Correlation between (a) activity in rIPL, $r(35) = 0.35$, $P = 0.016$, and (b) pIFG, $r(35) = 0.28$, $P = 0.047$, during How relative to Fact messages and behavior controlling for intentions.

effectiveness of tailored messages in engaging the MPFC and promoting message-consistent behavior may also be due to the fact that these messages highlight personal value in particular to the individual (Chua *et al.*, 2011).

Second, this study connects behavioral research on the effectiveness of action plan messaging to neuroscience research on the contributions of specific brain regions (i.e. rIPL, pIFG) to action understanding. As predicted, we observed that these regions were more responsive during How messages than during either Why messages or control (Fact) messages—while the opposite pattern was observed in MPFC. In addition, we observed that rIPL and pIFG activity during How relative to Fact control messages was associated with future behavior. These findings are consistent with the proposal that rIPL and pIFG may support cognitive rehearsal during encoding of action plan messages. That is, action plan messaging may be effective, in part, because it specifically engages regions involved in observing and enacting behaviors (Lau *et al.*, 2004; Desmurget and Sirigu, 2009; Desmurget *et al.*, 2009; Van Overwalle and Baetens, 2009; Rizzolatti and Sinigaglia, 2010). These findings also expand the neural model of persuasion beyond the MPFC region that has been examined repeatedly in previous studies, suggesting that lower-level motor planning may also play an important role. One might wonder why we observed differences between users and non-users in the correlation between MPFC activity and behavior but not rIPL or pIFG activity and behavior. To the best of our knowledge, this is the first study to consider regions involved in action planning processes as precursors to message-consistent behavior, and it is possible that differences may emerge in future research. However, the current results are not entirely unsurprising because although users engage these regions more when considering sunscreen use in general, the relationship between engagement of these regions and downstream behavior should not be modulated by user status. That is, among both users and non-users, those who engage in action planning to a greater extent should enact the behavior more.

Finally, we tested competing theories regarding whether self-related processes in MPFC would be more strongly associated with behavior for users (i.e. those whose self-concept might already be in line with the messaging, and hence might find the messages more self-relevant from the start), or for non-users (i.e. those who have greater opportunity for self-value integration to support a brain–behavior link). We found results more consistent with the latter, such that MPFC activity (but not rIPL or pIFG activity) was associated with behavior only in non-users. This finding addresses the question of whether previously observed relationships between MPFC activity and downstream behavior were merely driven by individuals who were already highly identified with the behavior in question. Our data suggest that this is not the case; rather, the relationship between MPFC activity and behavior may reflect the persuasive impact of coming to identify with that behavior, which we refer to as self-value integration. In other words, because there is more room for the messages to drive behavior among non-users who have less competing influence from other drivers such as past behavior, the link between MPFC activity during message encoding and downstream behavior (but not simply MPFC activity—we did not find a main effect of user status on activity in the MPFC ROI) may be particularly strong among this group. Once this process has already taken place, the relationship between MPFC activity and behavior weakens, as seen in our sample of 'users'. Notably, this finding concerning MPFC activity and behavior stands in sharp contrast to the relationship between *intentions* and behavior, which was markedly stronger for users ($r = 0.90$) than non-users ($r = 0.35$; see supplementary materials). One seemingly plausible interpretation of this is that, because users have more prior behavior on which to base their intentions, they are more accurate at predicting their future behavior.

The proposal that MPFC could play a critical role in determining the value of prevention behavior messages dovetails nicely both with neuroeconomic theories about the MPFC, which highlight this region's role in computing value (Knutson *et al.*, 2007; Hare *et al.*, 2011), and with Social Cognitive Theory, which posits that overcoming the obstacle of adopting a new behavior only happens to the extent that personal value outweighs personal cost (Bandura, 1998, 2001, 2004). These ideas are of course preliminary, and more research is required to delineate the specific contributions of MPFC to reward processing and social-cognitive processing (Harris *et al.*, 2007; Ersner-Hershfield *et al.*, 2009). At present, the research presented here provides an initial theoretical account for the consistent link observed between MPFC activity and persuasive outcomes in past work.

In sum, the present work is significant in adding to a growing body of literature that links MPFC activity to persuasive processes—connecting neuroscience and persuasion research through traditional models of attitudes and behaviors (Fishbein and Ajzen, 1975; Ajzen, 1985, 1991; Schwarzer, 2008; Craciun *et al.*, 2011). It also extends the purview of this body of work by connecting it to related literatures on message framing and action planning. By focusing not only on neural predictors of message-consistent behavior in general, but also on interactions between activity in these regions and different message features (e.g. framing, inclusion of action plan language), we may build a more comprehensive theoretical model of persuasive influence. In particular, we find preliminary evidence consistent with MPFC's role in self-value integration rather than merely reflecting prior pre-disposition to the behavior in question, and we broaden the model of brain–behavior relationships to include additional key systems involved in action plans. Such advancements not only benefit persuasion science, but also have the potential to improve messaging strategy in public health and beyond.

Supplementary data

Supplementary data are available at *SCAN* online.

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Conflict of interest. None declared.

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