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Neural correlates of persuasive message framing effects and their relationship to behavior

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Psychology

by

Irena S Vezich

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ABSTRACT OF THE DISSERTATION

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University of California, Los Angeles, 2015

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Designing health messages that successfully elicit message-consistent behavior continues to be a challenge, in large part because people are often poor predictors of their future actions. Past work that aimed to improve our predictive abilities has suggested that activation in a ventral subregion of medial prefrontal cortex (MPFC) during receipt of a persuasive message can reliably predict downstream behavior (Falk et al., 2010; Falk et al., 2011; Falk, Berkman, & Lieberman, 2012; Falk et al., 2015; Cooper, Tompson, O'Donnell, & Falk, in press), that gain-framed messages are more effective in promoting prevention behaviors than loss-framed messages (Detweiler, Bedel, Salovey, Pronin, & Rothman, 1999; Rothman et al., 1993; Christophersen & Gyulay, 1981; Robberson & Rogers, 1988; Treiber, 1986), and that persuasive

messages that contain action plans are more effective than those that do not (Gollwitzer, 1993; Gollwitzer & Brandstätter, 1997; Gollwitzer & Sheeran, 2006; Hagger & Luszczynska, 2014; Sniehotta, Scholz, & Schwarzer, 2006); however, the psychological mechanisms that support these effects are not fully understood. In the current experiment, we argue that persuasion may occur via *self-integration*—the incorporation of persuasive messages into one's self-concept and identity—by connecting these bodies of literature in our study design. Pulling from the topics of framing effects and action planning in health psychology, along with neuroscience work in persuasion and action understanding, we exposed participants to four types of messages about sunscreen use in the fMRI scanner while also tracking their sunscreen use behaviors and intentions: 1) Fact – facts about sunscreen (control), 2) How – how to wear sunscreen, 3) Why_{gain} – why one should wear sunscreen to garner a benefit, and 4) Why_{loss} – why one should wear sunscreen to avoid a loss. We replicated past findings on the relationship between MPFC activity during message exposure and future behavior controlling for intentions, along with past action understanding work on the role of rostral inferior parietal lobule (rIPL) and posterior inferior frontal gyrus (pIFG) in response to How>Why and conversely MPFC in response to Why>How; however, we also found preliminary support for our theory of persuasion as a self-integration process by focusing on different message types individually. We found greater MPFC activity during gain-framed messages relative to loss-framed messages, raising the possibility that gain frames tend to be more effective than loss frames for prevention behaviors because they lead individuals to consider the personal positive value of the behavior, which may support the integration of the behavior into one's self-concept. We also found stronger correlations between MPFC activity and future behavior for participants who were not preexisting sunscreen users than for those that were, potentially suggesting that non-users may have more room for self-

integration to facilitate behavioral choices (whereas users already consider sunscreen use part of their self-concept). Finally, the fact that activity in both MPFC and rIPL was related to message-consistent behavior suggests that both personal valuation and cognitive rehearsal may contribute to self-integration during message encoding and may support downstream behavioral choices. Both theoretical and practical implications of these findings are discussed along with future directions.

The dissertation of Irena S Vezich is approved.

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TABLE OF CONTENTS

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PUBLICATIONS AND PRESENTATIONS

Vezich, I.S., Gunter, B.C., & Lieberman, M.D. (2015). *The mere green effect: An fMRI study of pro-environmental advertisements*. Manuscript under review.

Vezich, I.S., Gunter, B.C., & Lieberman, M.D. (2015). *An fMRI investigation of women's responses to stereotyped female images*. Manuscript under review.

Delmas, M., **Vezich, I.S.**, & Goldstein, N.J. (2015). *Unpacking normative influences: The role of the reference group in residential energy use feedback*. Revise & resubmit at *Journal of Marketing Research*.

Vezich, I.S., Falk, E.B., & Lieberman, M.D. (2015). *Persuasive influence: A neuroscience perspective*. Invited book chapter.

Vezich, I.S., Gunter, B.C., & Lieberman, M.D. (2015, April). *The mere green effect: An fMRI study of pro-environmental advertisements*. Poster session presented at the Social and Affective Neuroscience Conference, Boston, MA.

Vezich, I.S., Gunter, B.C., & Lieberman, M.D. (2015, February). *Women's cognitive responses to female-targeted advertising*. Poster session presented at the Society for Personality and Social Psychology Conference, Long Beach, CA.

Goldstein, N.J., **Vezich, I.S.**, & Shapiro, J.R. (2014). Perceived perspective taking: When others walk in our shoes. *Journal of Personality and Social Psychology, 106*(6), 941-960.

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Gunter, B.C., **Vezich, I.S.**, & Lieberman, M.D. (2014, April). *Factors leading to attitude-behavior divergence in advertising among women*. Poster session presented at the Social and Affective Neuroscience Conference, Denver, CO.

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Welborn, B.L., Gunter, B.C., & **Vezich, I.S.** (2012, April). *Motivated reasoning and the false consensus effect: An fMRI study*. Poster session presented at the Social and Affective Neuroscience Society Annual Meeting, New York, NY.

Gunter, B.C., Welborn, B.L., **Vezich, I.S.**, Monti, M.M., & Lieberman, M.D. (2012, April). *Using the brain to predict real-world trends in mainstream film releases*. Poster session presented at the Social and Affective Neuroscience Society Annual Meeting, New York, NY.

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Introduction

Although interest in various topics in social psychology has waxed and waned over the years, "persuasion must surely be among the 'nearest and dearest' to the heart of our discipline" (Kruglanski, Thompson, & Spiegel, 1999; p. 293). Indeed, the study of persuasive influence has been a mainstay in the field since the early 20th century. Whether it was a matter of keeping kids off crime (Blumer & Hauser, 1933), convincing housewives to use cheaper cuts of meat (Lewin, 1943), or encouraging citizens to buy war bonds (Cartwright, 1947), legislators hoped to encourage everyday Americans to change their attitudes and habits for the good of the country, and they needed the most effective advertising to get the message across. With mass communication enjoying an exponential boom and recent burgeoning of social science research, academics were ideally positioned to embark on widespread systematic investigation of propaganda, both enhancing basic research and providing practical prescriptions to the media.

Research in the mid 20th century took an important first step in establishing the boundary conditions of persuasive influence, delving into the subtle nuances of effective message features, characteristics of persuasive spokespeople, and individual differences in propensity to be persuaded. However, this work yielded inconsistent results. People sometimes expressed overt attitude changes and consequently behaved in line with their expressed attitudes, but they often did not (Ajzen & Fishbein, 1977). Out of this inconsistency grew an interest in implicit attitudes, and with it, a whole host of new questions. Could someone's "true" attitudes be accessed, and if so, would it actually be possible to change them? Could they predict behavior better than explicit measures?

Several techniques to access implicit attitudes in the domain of persuasion have emerged; however, neuroimaging methodology has shown promise as a useful complement to behavioral measures for several reasons. First, imaging methods often circumvent participants' inability or unwillingness to report attitudes that are predictive of subsequent behaviors (Wicker, 1969; Nisbett & Wilson, 1977). Second, fMRI studies have demonstrated a power to significantly predict persuasion-related outcomes over and above self-report (Berns & Moore, 2012; Falk et al., 2010; Falk et al., 2011). In particular, activity in a ventral subregion of medial prefrontal cortex (MPFC; Falk et al., 2010; Falk et al., 2011; Falk, Berkman, & Lieberman, 2012; Falk et al., 2015; Cooper, Tompson, O'Donnell, & Falk, in press) has been reliably associated with downstream behavior controlling for self-reported intentions. Finally, and perhaps most unique, imaging methods allow the researcher to interrogate multiple psychological processes at once without interrupting the participant—in other words, we are able to assess aspects of participants' cognitive, affective, and social processes during the viewing of a persuasive message, rather than after the message is finished.

The goal of this dissertation is to extend past work regarding our ability to predict real-world behaviors (in this case, sunscreen use) using neural activity during initial processing of a persuasive message in three major ways. First, we draw on health psychology theory to directly compare gain- and loss-framed messages both to each other and to fact-based control messages (Salovey & Wegener, 2003; Detweiler, Bedel, Salovey, Pronin, & Rothman, 1999; Rothman et al., 1993; Christophersen & Gyulay, 1981; Robberson & Rogers, 1988; Treiber, 1986; Banks et al., 1995; Schneider et al., 2001a; Kalichman & Coley, 1995; Gallagher & Updegraff, 2012). Both gain and loss frames explain *why* an individual should perform a desired behavior; however, 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 may be critical precursors to message-consistent behavior (Gollwitzer & Sheeran, 2006; Gollwitzer, 1993;

Orbell, Hodgkins, & Sheeran, 1997; Gollwitzer & Brandstätter, 1997; Hagger & Luszczynska, 2014; Sniehotta, Scholz, & Schwarzer, 2006; Scholz, Schüz, Ziegelmann, Lippke, & Schwarzer, 2008; Jones, Abraham, Harris, Schulz, & Chrispin, 2001; van Osch et al., 2008; Craciun, Schüz, Lippke, & Schwarzer, 2011; Craciun, Schüz, Lippke, & Schwarzer, 2012a, b). A separate literature has examined brain regions associated with processing why someone is performing a behavior vs. how they are doing so; therefore, as a second extension, we examine neural correlates of messages that outline how to perform the desired behavior, both compared to Why (gain and loss) messages and Fact control messages (Spunt, Falk, & Lieberman, 2010; Spunt & Lieberman, 2012; Spunt, Satpute, & Lieberman, 2010; Spunt & Lieberman, 2011; Spunt & Adolphs, 2014; Desmurget et al., 2009; Desmurget & Sirigu, 2009; Lau, Rogers, Haggard, & Passingham, 2004; Van Overwalle & Baetens, 2009; Rizzolatti & Sinigaglia, 2010; Rizzolatti & Craighero, 2004; Keysers & Gazzola, 2010; Gazzola & Keysers, 2009). Finally, given the role of MPFC activity in cognition about the self, we directly compare effects among participants who already performed the behavior before the study (in this case, those who had used sunscreen in the week prior to the study), who may find the messages more self-relevant, and those who did not.

Review of the relationship between MFPC activity and persuasion

Following a long tradition in persuasion research of manipulating source expertise, Klucharev, Smidts, and Fernández (2008) performed one of the first persuasion neuroscience investigations. Replicating behavioral work, they found that source expertise and attractiveness in advertisements for various products are associated with greater purchase intentions. However, their major advance involved the underlying cognitive mechanisms responsible for an expertise-by-purchase intention interaction. Specifically, they found that perceived source expertise impacts activation in the caudate nucleus and MPFC in Brodmann area (BA) 10, which predicts positive attitudes toward the products. They interpreted these findings to suggest that the persuasive impact of expert sources may lie in their ability to modulate "perceived value, trust or risk-reward tradeoffs" (p. 364).

Shortly after these initial findings, an upsurge of work in this domain identified consistent neural correlates of persuasive influence, often manipulating factors traditionally used in behavioral persuasion research. For instance, Chua et al. (2009) contrasted high and low tailoring of smoking cessation ads and found that MPFC (BA9 & 10) and precuneus (BA7) activity is associated with self-reported personal relevance. Citing prior work indicating that self-relevant health messages tend to be particularly effective (Stretcher, Shiffman, & West, 2006; Dijkstra, 2005), they argued that these regions may in turn be predictive of persuasive outcomes because self-relevant thinking "promotes elaboration, organization of encoded information, and enhanced memory and helps people choose which motivational and behavioral representations would guide behavior" (p. 167).

Moving beyond using brain activity as an outcome, the next wave of research examined whether activity in certain regions could in fact show relationships with downstream behavior. Initial work in our lab demonstrated that activation in an *a priori* MPFC region of interest (ROI) (overlapping BA10/11) during viewing of sunscreen ads was correlated with change in sunscreen use (Falk et al., 2010; Figure 1). Particularly informative, a cross-validation approach revealed that MPFC activation predicted, on average, 23 percent more of the variance in behavior than did self-reported intentions to wear sunscreen. In effect, this study not only extended support for the notion of a tenuous or imperfect connection between self-reported intentions and behavior but further provided an alternative method that could predict downstream behavior from a thin slice of time during receipt of persuasive messages (Wicker, 1969).

Later work confirmed the utility of this “brain-as-predictor” method by examining a behavior that is much harder to enact (smoking cessation vs. sunscreen use) and by employing a more accurate gauge of behavior (carbon monoxide levels for smoking cessation vs. self-report for sunscreen use; Berkman & Falk, 2013). Constructing an ROI based on the cluster revealed to be the most highly associated with behavior change whole-brain in Falk et al. (2010; the same ROI used in the present study; Figure 2a), Falk et al. (2011) again found that MPFC activity during message receipt successfully predicts behavior change, this time tracked up to a month after initial exposure to anti-smoking ads. Moreover, adding this neural activity to an existing model predicting behavior change from self-reported intentions, self-efficacy, and ability to relate to the message doubled the variance explained, significantly increasing predictive ability, R^2 = .15 vs. .35. Also using the same ROI employed in the present study, Cooper et al. (in press) found that MPFC activity predicts self-reported smoking reduction, significantly increasing variance explained relative to intentions alone, R^2 = .10 vs. .28, and Falk et al. (2015) found that MPFC activity is related to decreases in sedentary behavior over the following month controlling for baseline sedentary behavior and demographics.

Chua and colleagues found additional support for downstream behavioral effects of initial neurocognitive processing with evidence indicating that activation in dorsomedial prefrontal cortex (DMPFC; BA9, 10) and precuneus (BA31, 7) is associated with tailored messages, and moreover that this activation during tailored messages predicts smoking cessation 4 months later (Chua et al., 2011). Similarly, Wang et al. (2013) manipulated argument strength (AS) and message sensation value (MSV) in smoking cessation advertisements and found that high AS and DMPFC activation are significantly associated with lower cotinine levels (i.e., less smoking) one month later.

Finally, work in our lab extended this predictive approach beyond behavior in the participants directly in the study to entire regions of the U.S. exposed to the ads that study participants saw (Falk, Berkman, & Lieberman, 2012). In this experiment, participants viewed ads for three different smoking cessation campaigns in the scanner and made predictions about which campaign would fare best. Calls to a smoking cessation hotline were then tracked in response to each campaign. While participants' (and experts') rank predictions about the relative effectiveness of each campaign were inaccurate, activity in the MPFC ROI successfully predicted which campaign was the most, intermediate, and least effective (Figure 3).

Why does MPFC activity predict future behavior in response to persuasive messages? At this point there is no definitive answer to this question, but one viable possibility is that MPFC is supporting the integration of persuasive messages with one's self-concept and identity, or *self-integration*. Persuasion research has demonstrated that messages that already at least somewhat 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 they behave in line with the message to the extent that the answer is yes (Hovland, Harvey, & Sherif, 1957; Atkins, Deaux, & Bieri, 1967; Eagly & Telaak, 1972). MPFC activity has been regularly associated with self-concept processes (Lieberman, 2010) as well as the representation of personal beliefs and values (Brosch, Coppin, Schwartz, & Sander, 2011; Harris, Sheth, & Cohen, 2008). This region may therefore activate in the context of persuasion attempts to the extent that successful self-integration is occurring in response to the message. There are many factors that could influence the extent to which a message is seen as consistent with one's self-concept; however, this dissertation will focus on three of them, reviewed in the next sections: 1) Whether the desired behavior is described as garnering a gain or avoiding a loss (message framing effects), 2) whether the message describes why one should enact the behavior or how they should do so, a part of action planning (why vs. how), and 3) whether one already performs the behavior or not.

Review of message framing effects

The health psychology literature distinguishes between gain- and loss-framed messages: "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 health'). 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 & Wegener, 2003). The literature around gain and loss frames grew out of the work on Prospect Theory, which explained how factually equivalent information can be interpreted as either a gain or loss, and how those distinct interpretations lead to differences in decision-making (Kahneman & Tversky, 1979, 1982; Tversky & Kahneman, 1981). This literature has found that individuals avoid risk when considering benefits and conversely are more risk-tolerant when considering losses (Kahneman & Tversky, 1979; Salovey & Wegener, 2003; Rothman, Salovey, Antone, Keogh, & Martin, 1993).

Prevention behaviors (i.e., taking action to prevent illness) may be perceived as less risky than detection behaviors (i.e., taking action to detect illness) because they are performed to maintain existing good health rather than to discover information about potential poor health (Gallagher & Updegraff, 2012). Therefore, Prospect Theory would predict that gain-framed messages are more effective at promoting prevention behaviors (Rothman & Salovey, 1997).

And indeed, after decades of inconsistent findings regarding which type of frame better promotes health behaviors overall, the current empirical evidence suggests that gain-framed messages are more effective for prevention behaviors such as sunscreen use, the use of infant car restraints, and regular exercise (Detweiler, Bedel, Salovey, Pronin, & Rothman, 1999; Rothman et al., 1993; Christophersen & Gyulay, 1981; Robberson & Rogers, 1988; Treiber, 1986); while loss-framed messages are more effective for detection behaviors such as mammography and HIV testing (Banks et al., 1995; Schneider et al., 2001; Kalichman & Coley, 1995). Likewise, a recent meta-analysis found that gain-framed messages promote prevention behaviors (r = .083, p = .002)—especially skin cancer prevention, smoking cessation, and physical activity—but in contrast to prior thinking did not find an effect of framing for detection behaviors (Gallagher & Updegraff, 2012). In terms of mechanism, the Health Belief Model and Prospect Theory would suggest that gain framing is effective to the extent that it focuses individuals on the perceived value of performing the desired behavior; however, these types of mediations have not been widely tested (Wilson, Purdon, & Wallston, 1988). Interestingly, though, the idea is consistent with theory that posits the MPFC as a computer of personal value (Hare, Malmaud, & Rangel, 2011; Knutson et al., 2007). That is, the effectiveness of gain messages may lie in their ability to enhance the personal value of performing a certain behavior, thereby supporting self-integration.

Focusing on gain and loss framing in the context of sunscreen use specifically, findings have been consistent across diverse settings. 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 (i.e., 15 or higher) and more information about skin cancer (Rothman et al., 1993). Although differences were small among men, they were substantial among women; 79

percent of women in the gain-frame condition mailed in the request for appropriate SPF, whereas only 45 percent in the loss-frame condition did (50 percent and 47 percent among men, respectively). Similarly, 71 percent of individuals at the beach who read gain-framed messages requested sunscreen samples, while 53 percent of those who read loss-framed messages did (Detweiler et al., 1999). Further, this difference remained significant after controlling for prior intentions to use sunscreen that day, and the advantage of gain framing was stronger for those who did not have intentions to wear sunscreen.

Studies that look at intentions to wear sunscreen rather than actual behavior appear not to show main effects of message framing, although there are some interesting interactions. Hoffner and Ye (2009) did not find that gain-framed messages are more effective than loss-framed messages overall in promoting intentions to wear sunscreen, but they reported that gain-framed messages are more effective to the extent that participants perceive themselves as similar to the exemplar in the message. Likewise, Hevey et al. (2010) did not find a main effect of message framing on sunscreen use intentions but did find an interaction with body consciousness such that gain-framed messages are more effective for those high in body consciousness (with women being significantly higher in body consciousness than men). Finally, Hwang, Cho, Sands, and Jeong (2012) found that gain-framed messages are more effective at promoting sunscreen use intentions when perceived effectiveness is high but not overall. However, it is important to remember that none of these studies looked at actual behavior.

Review of action planning and "why" vs. "how"

Both gain- and loss-framed messages in essence list reasons *why* an individual should perform an action; however, there is ample evidence to suggest that explaining *how* to perform that action also fosters message-consistent behavior. Specifically, the health literature on the related concepts of implementation intentions and action planning[1] demonstrates that these plans—which include how to perform the desired behavior—improve an individual's chances at enacting the behavior (Gollwitzer, 1993; Gollwitzer & Brandstätter, 1997; Gollwitzer & Sheeran, 2006; Hagger & Luszczynska, 2014; Sniehotta, Scholz, & Schwarzer, 2006). Furthermore, planning mediates between intentions and behavior (Sniehotta, Scholz, & Schwarzer, 2006; Scholz, Schüz, Ziegelmann, Lippke, & Schwarzer, 2008; Jones, Abraham, Harris, Schulz, & Chrispin, 2001; van Osch et al., 2008; Craciun, Schüz, Lippke, & Schwarzer, 2012a). Action planning, often discussed in the context of the Health Action Process Approach (HAPA; Schwarzer, 2008), therefore provides an important extension to the theory of reasoned action (Fishbein & Ajzen, 1975) and its follow-up, the theory of planned behavior (Ajzen, 1985, 1991). These two theories posit intentions as the most direct and proximal link to behaviors, but intentions can only explain 20 to 30 percent of the variance in behavior in meta-analyses (Hagger, Chatzisarantis, & Biddle, 2002; Webb & Sheeran, 2006; Sheeran & Orbell, 1999). As further evidence of the intention-behavior gap, past work has found that 47 percent of individuals with intentions to enact health behaviors don't ultimately do so (Sheeran, 2002).

Instead, proponents of action plans suggest that they are effective because they increase attention and memory relevant to enacting one's intentions, along with increasing the speed of action initiation (Gollwitzer, 1993; Orbell et al., 1997; Gollwitzer & Brandstätter, 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 happen more quickly and automatically (Hagger & Luszczynska, 2014). Therefore, these researchers

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

argue that action plans do not affect motivation per se—in contrast to the theory of planned behavior and other traditional models of behavior change—but do affect the feasibility via cognitive rehearsal of the behavior (i.e., being able to imagine oneself enacting the behavior), which we argue may facilitate self-integration and ultimately substantially affect the likelihood of behavior enactment (Sheeran & Orbell, 1999). Creating action plans has been shown to increase a range of healthy behaviors such as exercise (Arbour & Ginis, 2009; Barg et al., 2012; Conner, Sandberg, & Norman, 2010; Gellert, Zeigelman, Lippke, & Schwarzer, 2012; Luszczynska, 2006; Milne, Orbell, & Sheeran, 2002; Prestwich et al., 2012; Prestwich, Lawton, & Conner, 2003), diet (Adriaanse, de Ridder, & de Wit, 2009; Adriaanse et al., 2010; Armitage, 2007; Chapman, Armitage, & Norman, 2009; Prestwich, Ayres, & Lawton, 2008; Sullivan & Rothman, 2008), smoking (Armitage, 2008; Armitage & Arden, 2008), drinking (Armitage, 2009; Hagger et al., 2012), breast self-examination (Orbell, Hodgkins, & Sheeran, 1997; Prestwich et al., 2005), physical rehab (Scholz, Sniehotta, Schüz, & Oeberst, 2007), adherence to a vitamin regimen (Sheeran & Orbell, 1999), cancer screening (Browne & Chan, 2012; Rutter, Steadman, & Quine, 2006; Sheeran & Orbell, 2000), vaccination (Milkman, Beshears, Choi, Laibson, & Madrian, 2011; Payaprom, Bennett, Alabaster, & Tantipong, 2011), use of contraceptives (de Vet et al., 2011; Martin, Sheeran, Slade, Wright, & Dibble, 2009; Teng & Mak, 2011), dental health (Orbell & Verplanken, 2010; Schüz, Wiedemann, Mallach, & Scholz, 2009), and, importantly, sunscreen use (Craciun, Schüz, Lippke, & Schwarzer, 2011; Craciun, Schüz, Lippke, & Schwarzer, 2012a, b; Jones et al., 2001, van Osch et al., 2008). Meta-analyses investigating the impact of implementation intentions on behavior over a variety of domains demonstrate that they have a moderate-to-large effect (d = .65; Gollwitzer & Sheeran, 2006).

Because persuasive messages that focus on action planning instruct individuals 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. Though it doesn't examine responses to persuasive messages specifically, the literature on How and Why action understanding—in which participants distinguish between why an 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 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) (Spunt, Falk, & Lieberman, 2010; Spunt & Lieberman, 2012; Spunt, Satpute, & Lieberman, 2010; Spunt & Lieberman, 2011; Spunt & Adolphs, 2014). Couched in an embodied cognition framework, some researchers argue that action understanding relies on these regions because they support actual action execution (Pulvermüller, 2005; Mahon & Caramazza, 2008; Bastiaansen et al., 2009; Gallese, 2007; 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 actions (Van Overwalle & Baetens, 2009; Rizzolatti & Sinigaglia, 2010; Rizzolatti & Craighero, 2004; Keysers & Gazzola, 2010; Gazzola & Keysers, 2009). And indeed, one's own action intentions are associated with activity in these regions as well (Desmurget et al., 2009; Desmurget & Sirigu, 2009; Lau, Rogers, Haggard, & Passingham, 2004). In the context of How persuasive messages that focus on *one's own behavior*, it is possible that both action understanding regions and MPFC—although often considered separate or even competitive systems (Fox et al., 2005; Spengler, Cramon, & Brass, 2009; Van Overwalle & Baetens, 2009; but see also Zaki & Ochsner, 2011; Lombardo et al., 2010)—might work together to support persuasive processing of these messages by enabling cognitive rehearsal of the desired behavior (Spunt & Lieberman, 2012; Meyer, Spunt, Berkman, Taylor, & Lieberman, 2012). That is, the process of self-integration that ultimately brings about message-consistent behavior may rely both on personal value computation in the MPFC and cognition about oneself enacting the behavior in action understanding regions.

Persuading individuals to amplify an existing behavior vs. start a new one

Existing models of behavior change typically frame this process as a linear series of stages that one must pass through, from initial thoughts about the behavior to the first enactment of the behavior to subsequent repeated enactments. For example, the Transtheoretical Model posits that individuals go through precontemplation, contemplation, planning, action, and maintenance (Miilunpalo, Nupponen, Laitakari, Marttila, & Paronen, 2000; Weinstein, Sutton, & Rothman, 1998). Although Social Cognitive Theory doesn't label the stages as explicitly, it also argues that an individual does not initially enact a new behavior until certain conditions are met—namely, that the gains must outweigh the costs—and that subsequent enactment of the behavior depends on further conditions (Bandura, 2001; Bandura, 2004; Bandura, 1998). Fogg's (2009) Behavior Grid goes a step further and separates repeated enactment of a behavior after initial adoption into several categories, including basic maintenance, behavior increase, behavior decrease, and behavior cease (Figure 4). The important commonality across these models is that they suggest a psychological distinction between initial enactment of a new behavior (e.g., wearing sunscreen when one doesn't normally do so) and subsequent maintenance or amplification of that behavior (e.g., reapplying sunscreen multiple times in one day when one normally only applies it once). In the first case, an individual may not see themself as a sunscreen user and must overcome that barrier to integrate sunscreen use into their identity. In the second case, the individual may already identify as a sunscreen user and have less room for self-integration to support message-consistent behavior. Although it has not yet been studied, therefore, we have reason to believe that the neural mechanisms supporting the decision to enact a new behavior may be distinct from those supporting the decision to amplify an existing behavior. For instance, because MPFC activity is associated with self-related processing, a persuasive message related to a behavior someone already performs (i.e., a relatively self-relevant behavior) may differentially activate MPFC relative to a message about a behavior someone doesn't already perform (i.e., a relatively less self-relevant behavior). As an initial investigation of this idea, we look at brain activity in pre-existing users vs. non-users of sunscreen separately in the current study.

Hypotheses

We have two initial hypotheses replicating past work. First, we predict that activity in the MPFC ROI shown in Figure 2a during all other messages relative to control messages and during Why messages relative to control messages will be associated with sunscreen use controlling for intentions. This hypothesis is in line with the original finding in Falk et al. (2010). Second, we predict 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—in line with past work on the distinction between Why and How processes (Spunt, Falk, & Lieberman, 2010; Spunt & Lieberman, 2012; Spunt, Satpute, & Lieberman, 2010; Spunt & Lieberman, 2011; Spunt & Adolphs, 2014).

We then have three other focal hypotheses that extend prior findings. Along with MPFC, we believe that activity in action understanding regions (i.e., rIPL, pIFG) during all other messages relative to control messages, Why messages relative to control messages, and How messages relative to control messages, will be associated with sunscreen use controlling for intentions. This finding would support the idea that what are often viewed as antagonistic systems can sometimes work together, perhaps in this case to support self-integration processes that foster message-consistent behavior.

We also predict that activity in our regions of interest will be greater during Why_{gain} messages relative to Why_{loss} messages, consistent with the idea that gain messages are more effective than loss messages for prevention behaviors like sunscreen use. That is, gain messages should facilitate cognition about the personal value of the behavior and cognitive rehearsal of the behavior more than loss messages. This hypothesis is also in line with neuroeconomic theories about MPFC activity as a signal of personal value (Hare, Malmaud, & Rangel, 2011; Knutson et al., 2007) and would support our overarching theory that these messages may be effective because they foster self-integration via consideration of personal value and cognitive rehearsal.

Finally, we predict that the relationship between brain activity in our regions of interest and behavior will be stronger among participants who did not use sunscreen before the study ("non-users") than among those who already did ("users"), as non-users may have more room for self-integration to guide behavior.

Methods

Participants

32 right-handed women were recruited from flyers posted around the UCLA campus (M_{age} = 20.50*;* SD_{age} = 2.54). We focused specifically on women based on past evidence that they are more concerned than men about tanning and skin cancer, along with the fact that our gain messages focused on skin beauty, which is more self-relevant for women than for men

(Rothman et al., 1993). Pretesting of our messages also revealed that women found them clearer and more persuasive than did men. Potential participants were screened and excluded if they were claustrophobic, pregnant or 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 31 participants in those models. For main effects analyses, univariate outliers were identified and excluded using Grubbs' test. For correlational analyses, we searched for multivariate outliers using Mahalanobis' Distance, but none were found.

Procedure

On the day of the session, prior to scanning, participants completed a questionnaire that assessed 1) behavior during the past week for a variety of health behaviors including the regular use of sunscreen, and 2) intentions of performing the same health behaviors over 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" for the following behaviors, in randomized order: used sunscreen, exercised, flossed, ate vegetables, got at least 7 hours of sleep, skipped class, and got at least 8 hours of sleep (Figure 5). 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} = .998, r_{intent} = 1) and the measure of days was used in Falk et al. (2010), we used days in all subsequent analyses.

While undergoing fMRI, participants viewed 40 text-based ads promoting sunscreen use. An audio recording of each ad was also played to control for reading speed. The ads were written to be roughly equal in length (M = 52.88 words, SD = 3.95 words, range = 45-60 words); there were no significant differences in length among the 4 conditions (all ps > .30). The arguments in the ads fell into 4 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). Our pretesting data indicated that participants considered both Why ad types to be more persuasive than the Fact or How ad types. In addition, pretesting data indicated that participants found all the ads clear and could distinguish among the 4 ad types. The 40 ads were divided into 2 runs, roughly 8 minutes each; each participant saw a repeated sequence of the four ad types (e.g., How, Why_{gain}, Fact, Why_{loss}, How, Why_{gain}, Fact, Why_{loss}, etc.), but the order of the four types was counterbalanced across participants. Subjects passively viewed and listened to each ad, akin to naturalistic experiences of ad exposure in everyday life (M = 19.21 sec, SD = 1.55 sec, range = 16.59-22.10 sec), and ads were separated by a jittered fixation centered around 4 seconds (range = 2-6 sec).

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. 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 x 256; 176 sagittal slices; FOV = 27.0 cm; 1.20 mm thick; voxel size = 1.1 mm x 1.1 mm x 1.2 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 x 104, 72 slices, FOV = 20.8 cm, 2 mm thick; voxel size = 2.0 x 2.0 x 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 subject level, comparing activity while viewing each focal message type (e.g., Why_{gain}, Why_{loss}, How) to activity while viewing the Fact control messages, along with comparing activity during all three focal message types combined ("All") to activity during Fact messages. We also compared activity while viewing Why_{gain} messages to Why_{loss} messages, and each of those to How messages. Finally, we compared activity while viewing all 20 Why messages (i.e., gain and loss combined) to 1) activity while viewing the Fact messages, and 2) 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 (ROI) that we chose to investigate *a priori*. First, in line with results from prior work on neural predictors of persuasive influence, we chose to look at the medial prefrontal cortex (MPFC). Specifically, we chose a cluster in the ventral portion of MPFC (see Figure 2a) that has been used in several past studies to predict behavior over and above self-reported intentions (Falk et al., 2011; Falk, Berkman, & Lieberman, 2012; Falk et al., 2015; Cooper, Tompson, O'Donnell, & Falk, in press). This ROI was constructed using Marsbar (Brett, Anton, Valabregue, & Poline, 2002) based on the cluster revealed to be the most highly associated with behavior change whole-brain in Falk et al. (2010). Second, given our interest in action planning and How messages, we were interested in 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 2b & c).

Results

Behavioral

Days of sunscreen use significantly increased from the week prior to the session (M = 1.66, SD = 2.54) to the week following the session (M = 2.78, SD = 2.90), $t(31) = 3.19$, $p = .003$ (Figure 6). Intentions of daily sunscreen use also significantly increased from before the session (M = 1.72, SD = 2.90) to after the session (M = 4.78, SD = 2.61), $t(31) = 6.03$, $p < .001$ (Figure 7). These trends held both for participants who were pre-existing users of sunscreen ("users") and for those who were not ("non-users"). Users wore marginally more sunscreen in the week following the session (M = 4.64, SD = 2.65) than in the week prior to the session (M = 3.79, SD = 2.56), $t(13) = 1.88$, $p = .082$. Non-users wore significantly more sunscreen in the week following the session (M = 1.33, SD = 2.22) than in the week prior to the session (M = 0, SD = 0), $t(17) = 2.55$, $p = .021$ (Figure 8). The increase in behavior was not significantly different for users vs. non-users $t(30) = .66$, $p = .51$. Users intended to wear more sunscreen after the scan (M

= 5.79, *SD* = 1.93) than before the scan (*M* = 3.93, *SD* = 3.27), *t*(13) = 2.77, *p* = .016. Non-users intended to wear more sunscreen after the scan (*M* = 4.00, *SD* = 2.85) than before the scan (*M* = 0, *SD* = 0), *t*(17) = 5.96, *p* < .001 (Figure 9). The increase in intentions was marginally greater for non-users vs. users, *t*(30) = 2.01, *p* = .053.

Post-scan intentions were significantly correlated with sunscreen use, *r*(30) = .61, *p* = <.001 (Figure 10). This trend was stronger for users relative to non-users. Intentions were significantly correlated with sunscreen use among users, *r*(12) = .89, *p* < .001, and marginally correlated among non-users, *r*(16) = .35, *p* = .075 (Figure 11). The difference in correlations between users and non-users was significant, *Z* = 2.62, *p* = .0088; that is, users were significantly better at predicting their own behavior than non-users.

fMRI main effects

We first looked at activation differences in our ROIs during Why_{gain} messages relative to Why_{loss} messages. As predicted, Why_{gain} messages produced significantly greater MPFC activity (*M* = .25, *SD* = .67), *t*(30) = 2.10, *p* = .045, than Why_{loss}, but surprisingly not more pIFG activity (*M* = .0078, *SD* = .28), *t*(31) = .15, *p* = .88, or rIPL activity (*M* = -.041, *SD* = .34), *t*(31) = -.68, *p* = .50 (Figure 12).

We next examined whether ROI activity during Why_{gain} messages relative to Why_{loss} messages differed as a function of whether the participant was a user or non-user of sunscreen prior to the study. In line with the idea that the messages may be more relevant for users than for non-users, MPFC activity was marginally greater during Why_{gain} messages relative to Why_{loss} messages for users, *t*(12) = 2.012, *p* =.067, but not for non-users, *t*(17) = 1.11, *p* = .28; however, the difference between users and non-users was not significant, *t*(29) = .62, *p* = .54. rIPL activity was marginally lower during Why_{gain} messages relative to Why_{loss} message for users, *t*(13) = -

1.87, p = .084, but not for non-users, $t(16)$ = 1.39, p = .18, and the difference between users and non-users was significant, $t(30)$ = 2.17, p = .038. pIFG activity was not significantly greater during Why_{gain} messages relative to Why_{loss} messages for users, $t(13)$ = -.52, p = .62, or for non-users, $t(16)$ = .39, p =.70, and the difference between users and non-users was not significant, $t(29)$ = .21, p = .83 (Figure 13).

Next, we were interested in investigating activation differences in our ROIs during Why messages (both gain and loss) vs. How messages. As predicted, there was significantly greater MPFC activity in the Why>How contrast (M = .53, SD = .97), $t(30)$ = 3.043, p = .0048, and significantly less rIPL activity (M = -.58, SD = .63), $t(31)$ = -5.21, p < .001 and pIFG activity (M = -.73, SD = .59), $t(31)$ = -7.01, p < .001 (Figure 14).

As above, each of these effects was next broken down by user vs. non-user. MPFC activity was significantly greater during Why relative to How messages for non-users, $t(17)$ = 3.87, p = .0012, but not for users, $t(12)$ = 1.28, p =.23. However, the difference between users and non-users was not significant, $t(29)$ = .27, p = .79. rIPL activity was significantly lower during Why relative to How messages for non-users, $t(17)$ = -2.85, p = .011, and for users, $t(13)$ = -5.00, p < .001, and this effect was significantly stronger for users than non-users, $t(30)$ = 2.37, p = .024. pIFG activity was significantly lower during Why relative to How messages for non-users, $t(17)$ = -4.42, p < .001, and for users, $t(13)$ = -6.15, p < .001, and and this effect was significantly stronger for users than non-users, $t(30)$ = 2.37, p = .024 (Figure 15).

We also looked at How messages relative to control messages and Why messages relative to control messages. As predicted, there was significantly greater activity in rIPL, (M = .16, SD = .37), $t(31)$ = 2.45, p = .020, and marginally greater activity in pIFG, (M = .10, SD = .34), $t(31)$ = 1.71, p = .097, but not MPFC, (M = .14, SD = 1.26), $t(30)$ = 1.26, p = .22, during How relative to control (Figure 16). There was significantly greater MPFC activity, (M = .81, SD = 1.07), $t(30)$ = 4.19, $p < .001$, significantly less rIPL activity, (M = -.26, SD = .57), $t(31)$ = -2.57, p = .015, and significantly less pIFG activity, (M = -.52, SD = .55), $t(31)$ = -5.36, $p < .001$, during Why relative to control (Figure 17).

Comparing users vs. non-users, rIPL activity was significantly greater during How vs. control messages for users, $t(13)$ = 2.81, p = .015, but not for non-users, $t(17)$ = .93, p = .36; however, the difference between users and non-users was not significant, $t(30)$ = 1.34, p = .19. Similarly, pIFG activity was significantly greater during How vs. control messages for users, $t(13)$ = 2.39, p = .032, but not for non-users, $t(17)$ = .43, p = .67, and the difference between users and non-users was not significant, $t(30)$ = 1.25, p = .22. There were no significant effects in MPFC activity for users, $t(12)$ = 1.15, p = .27, or non-users, $t(17)$ = .55, p = .59, and the difference was not significant, $t(29)$ = .82, p = .42 (Figure 18). MPFC activity was significantly greater during Why vs. control messages for users, $t(12)$ = 3.26, p = .0069, and for non-users, $t(17)$ = 2.70, p = .015, and the difference between users and non-users was not significant, $t(29)$ = .69, p = .50. rIPL activity was significantly lower during Why vs. control for users, $t(13)$ = -2.65, p = .020, but not for non-users, $t(17)$ = -1.30, p = .21, and the difference was not significant, $t(30)$ = .71, p = .48. pIFG activity was significantly lower during Why vs. control for users, $t(13)$ = -4.57, $p < .001$, and for non-users, $t(17)$ = -3.24, p = .0048, and the difference was not significant, $t(30)$ = .82, p = .42 (Figure 19).

For sake of completeness, we looked at activation differences in our ROIs during All messages (Why_{gain}, Why_{loss}, and How combined) vs. Fact control messages. There was significantly greater MPFC activity during All messages than Fact messages, (M = .95, SD = 1.32), $t(30)$ = 4.053 p = .0018. There was not significantly greater rIPL activity (M = -.095, SD =

.84), $t(31) = -.64$, $p = .53$, and surprisingly there was significantly less pIFG activity ($M = -.42$, $SD = .80$), $t(31) = -2.96$, $p = .0058$ (Figure 20).

We then broke this trend down into users vs. non-users. MPFC activity was significantly greater during All relative to Fact messages for users, $t(12) = 2.71$, $p = .019$, and for non-users, $t(17) = 2.13$, $p = .049$, and the difference between users and non-users was not significant, $t(29) = .80$, $p = .43$. rIPL activity was not significantly greater during All messages relative to Fact messages for users, $t(13)$, = -.41, $p = .69$, or for non-users, $t(17) = -.49$, $p = .63$, and the difference between users and non-users was not significant, $t(30) = .11$, $p = .92$. pIFG activity was significantly lower during All messages relative to Fact messages for users, $t(13)$, = -2.34, $p = .036$, and marginally lower for non-users, $t(17) = -1.95$, $p = .068$, and the difference between users and non-users was not significant, $t(30) = .038$, $p = .97$ (Figure 21).

Brain-behavior correlations

Consistent with Falk et al. (2010), we were first interested to see whether MPFC activity would be correlated with sunscreen use over and above the variance in behavior explained by intentions. This effect was confirmed using partial correlation; MPFC activity during All relative to Fact control messages was marginally correlated with sunscreen use controlling for the effect of intentions, $r(28) = .29$, $p = .058$ (Figure 22). Correlations between brain activity and behavior were often similar without controlling for intentions (see Table 2 for full comparisons). In line with the idea that there may be more room for self-integration to support message-consistent behavior among non-users than among users, this relationship was marginally significant for non-users, $r(15) = .37$, $p = .065$, but not for users, $r(10) = .069$, $p = .41$ (Figure 23). However, the difference in correlations between non-users and users was not significant, $Z = .78$, $p = .44$.

Consistent with the notion that both MPFC *and* action understanding region activity may foster message-consistent behavior, we also found that rIPL activity during All relative to Fact messages was significantly correlated with sunscreen use controlling for intentions, $r(29) = .32$, $p = .042$ (Figure 24). However, we saw similar patterns for users, $r(11) = .32$, $p = .14$, and non-users, $r(15) = .26$, $p = .14$; the difference between users and non-users was not significant, $Z = .17$, $p = .87$ (Figure 25).

Similarly, MPFC activity during Why relative to Fact control messages was significantly correlated with sunscreen use controlling for the effect of intentions, $r(28) = .32$, $p = .041$ (Figure 26). This relationship was marginal for non-users, $r(15) = .36$, $p = .069$, but not for users, $r(10) = .22$, $p = .24$ (Figure 27). However, the difference in correlations between non-users and users was not significant, $Z = .38$, $p = .70$.

In addition, rIPL activity during Why relative to Fact control messages was marginally correlated with sunscreen use controlling for intentions, $r(29) = .28$, $p = .063$ (Figure 28). This relationship was marginal for users, $r(11) = .38$, $p = .092$, but not for non-users, $r(15) = .28$, $p = .13$, and the difference in correlations was not significant, $Z = .28$, $p = .78$ (Figure 29).

Next, in line with the theory that action planning processes might be important in guiding message-consistent behavior, we wanted to investigate action understanding region activity in How messages specifically. Activity in rIPL during How relative to Fact control messages was marginally correlated with behavior controlling for intentions, $r(29) = .28$, $p = .068$ (Figure 30). The correlation between rIPL activity during How relative to Fact control messages and behavior controlling for intentions was similar for non-users, $r(15) = .17$, $p = .24$, and for users, $r(11) = .12$, $p = .34$ (Figure 31). The difference between the two partial correlations was not significant, $Z = .13$, $p = .90$.

Finally, we wanted to see if the relationship between brain activity during Why relative to How messages and sunscreen use would differ by region. Consistent with this idea, we found a marginal *positive* correlation between MPFC activity during Why_{gain} vs. How messages and sunscreen use controlling for intentions, $r(28) = .27$, $p = .072$ (Figure 32), and a marginal *negative* correlation between rIPL activity during Why_{gain} vs. How messages and sunscreen use controlling for intentions, $r(29) = .25$, $p = .091$ (Figure 33). The relationship between MPFC activity and behavior controlling for intentions was marginal for non-users, $r(15) = .33$, $p = .093$, but not for users, $r(10) = .29$, $p = .17$, and the difference was not significant, $Z = .11$, $p = .91$ (Figure 34). The relationship between rIPL activity and behavior controlling for intentions was not significant for users, $r(11) = .12$, $p = .34$, or for non-users, $r(15) = -.22$, $p = .19$, and the difference was not significant, $Z = .87$, $p = .38$, (Figure 35).

Discussion

Given that there are often gaps between intentions and future actions, it is important to consider which factors aside from intentions may be associated with future behavior. In order to test this idea, we exposed female participants to four types of messages about sunscreen use in the fMRI scanner: 1) Fact – facts about sunscreen (control), 2) How – how to wear sunscreen, 3) Why_{gain} – the benefits of wearing sunscreen, and 4) Why_{loss} – the costs avoided by wearing sunscreen. In addition, we tracked their sunscreen use during the week after the study session. Finally, we gathered intentions to wear sunscreen.

MPFC activity and rIPL activity during receipt of persuasive messages (All and Why) were related to sunscreen use over the next week, *controlling* for intentions to wear sunscreen, in line with past work in this domain (Falk et al., 2010; Falk et al., 2011; Falk, Berkman, & Lieberman, 2012; Falk et al., 2015; Cooper et al., in press). Consistent with past work on Why vs. How processing, we also observed greater MPFC activity during Why messages relative to How messages, and rIPL and pIFG activity in the reverse contrast, along with rIPL and pIFG activity during How messages relative to control and MPFC activity during Why messages relative to control (Spunt, Falk, & Lieberman, 2010; Spunt & Lieberman, 2012; Spunt, Satpute, & Lieberman, 2010; Spunt & Lieberman, 2011; Spunt & Adolphs, 2014).

In addition, we observed greater activity in MPFC during receipt of Why_{gain} messages relative to Why_{loss} messages, which may be consistent with past work on message framing demonstrating that gain messages are more effective than loss messages for prevention behaviors such as sunscreen use (Detweiler, Bedel, Salovey, Pronin, & Rothman, 1999; Rothman et al., 1993; Gallagher & Updegraff, 2012).

We also found a positive correlation between rIPL activity during How messages and behavior controlling for intentions, suggesting that messages promoting action planning may also facilitate message-consistent behavior via self-integration.

Correlations between MPFC activity and behavior trended toward being stronger among participants who did not use sunscreen in the week prior to the study than among those who did, potentially suggesting that there was more room for self-integration to facilitate downstream behavior in non-users.

The observation of activation in both these lateral (rPL, pIFG) and medial (MPFC) regions in the same models also lends support to the idea that these often antagonistic systems can sometimes co-activate when an action plan is self-relevant, although this idea is mostly speculative at present (Zaki & Ochsner, 2011; Lombardo et al., 2010; Spunt & Lieberman, 2011).

While remaining consistent with past findings, this work also extends theory around the neural mechanisms supporting persuasion. It provides an additional explanation for why gain-framed messages may be more effective than loss-framed messages in the context of prevention behaviors; past theorizing couched in Prospect Theory suggested that gain frames lead individuals to avoid risk by performing a prevention behavior, but this explanation bypasses actual cognition about the message. Our finding that gain-framed messages engaged MPFC more than loss-framed messages raises the possibility that these messages may work by fostering consideration of the personal value of the behavior to oneself. In contrast, individuals may not want to consider the self-relevance nor mentally rehearse the scenarios outlined in the loss messages (e.g., getting skin cancer) given the uncomfortable nature of their content and thus may avoid such processing of the loss-framed messages entirely.

This explanation would also align with our proposal regarding why MPFC activity during a persuasive message has been so consistently related to future behavior: The MPFC may be indexing personal value of the behavior, contributing to integration of the behavior into one's self-concept. Support for this idea also comes from our finding that MPFC activity was often related to behavior for non-users but not users; non-users may have started to adopt the use of sunscreen to the extent that self-integration occurred during message processing, whereas there may have been less room for self-integration to facilitate message-consistent behavior in users because sunscreen use was already part of their self-concept. Such an explanation would dovetail nicely both with neuroeconomic theories about the MPFC, which view it as a computer of personal value (Hare, Malmaud, & Rangel, 2011; Knutson et al., 2007), 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, 2001; Bandura, 2004; Bandura, 1998). Our findings that both MPFC and rIPL activity were related to future sunscreen use also suggest that cognitive rehearsal may contribute to self-integration during message encoding and may support downstream behavioral choices. These ideas are of course preliminary, but they spur several avenues for future research.

First, while we are encouraged by some interesting trends in users vs. non-users, it would be useful to increase the power in these analyses (the current sample consisted of only 13 or 14 users and 17 or 18 non-users). We are in the process of collecting more data from users exclusively to balance out the number of participants in each cell and address the power issue. Second, interpretation of these results may be limited by the fact that all participants were women; while this decision was intentional based on evidence that women are more concerned with sun safety and skin protection (Rothman et al., 1993), a more robust test of our ideas would focus on behaviors that are relevant to both men and women. To address this concern, we are currently planning to continue this study with messages about sleep hygiene, recruiting both male and female participants. This follow-up work would circumvent another limitation as well—namely, that sunscreen use was self-reported and thus may be subject to social desirability biases (Schwarz, 2007)—by measuring time asleep via a wearable fitness tracker.

Given the robust interaction between message framing and prevention vs. detection health behaviors seen in past work, it may be informative for future research to look at the neural correlates of persuasive message-consistent behaviors in response to different message frames in the context of detection behaviors. In this case, one might predict greater MPFC and action understanding region activity in response to loss- relative to gain-framed messages, for instance. The present discussion of framing effects raises another important point that might be disentangled in future work—we are not able to truly isolate whether gain- or loss-framed messages are more effective in fostering message-consistent behavior and what neural systems might support these processes in the present study because participants saw both message types by design. Although more costly in sample size, it would be informative to make message frame a between-subject factor in future work to better understand the brain-behavior connections associated with different frames.

Despite these limitations, the present work is significant both in adding to a growing body of work that links MPFC activity to persuasive processes and builds on traditional models of attitudes and behaviors (Schwarzer, 2008; Craciun, Schüz, Lippke, & Schwarzer, 2011; Fishbein & Ajzen, 1975; Ajzen, 1985, 1991), and also in extending that body of work by connecting to related literatures on message framing and action planning. By focusing not only on neural predictors of message-consistent behavior in general but by considering 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 and hopefully use such models to craft more effective health campaigns as well.

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."

Table 2
Correlations between brain activity and behavior

	MPFC All>Fact	rIPL All>Fact	MPFC Why>Fact	rIPL Why>Fact	rIPL How>Fact	MPFC Gain>How	rIPL Gain>How
Behavior	.26†	.0093	.32*	-.043	.086	.18	-.33*
Behavior controlling for intentions	.29†	.32*	.32*	.28†	.27†	.27†	-.25†
Behavior users only	.17	.059	.26	.099	-.017	.082	.040
Behavior non-users only	.27	-.044	.32†	-.0030	-.10	.36†	-.18
Behavior controlling for intentions users only	.069	.32	.22	.38†	.12	.29	-.12
Behavior controlling for intentions non-users only	.37†	.26	.36†	.28	.17	.33†	-.22

Figure 1. Relationship between MPFC activity and behavior change in Falk et al. (2010).

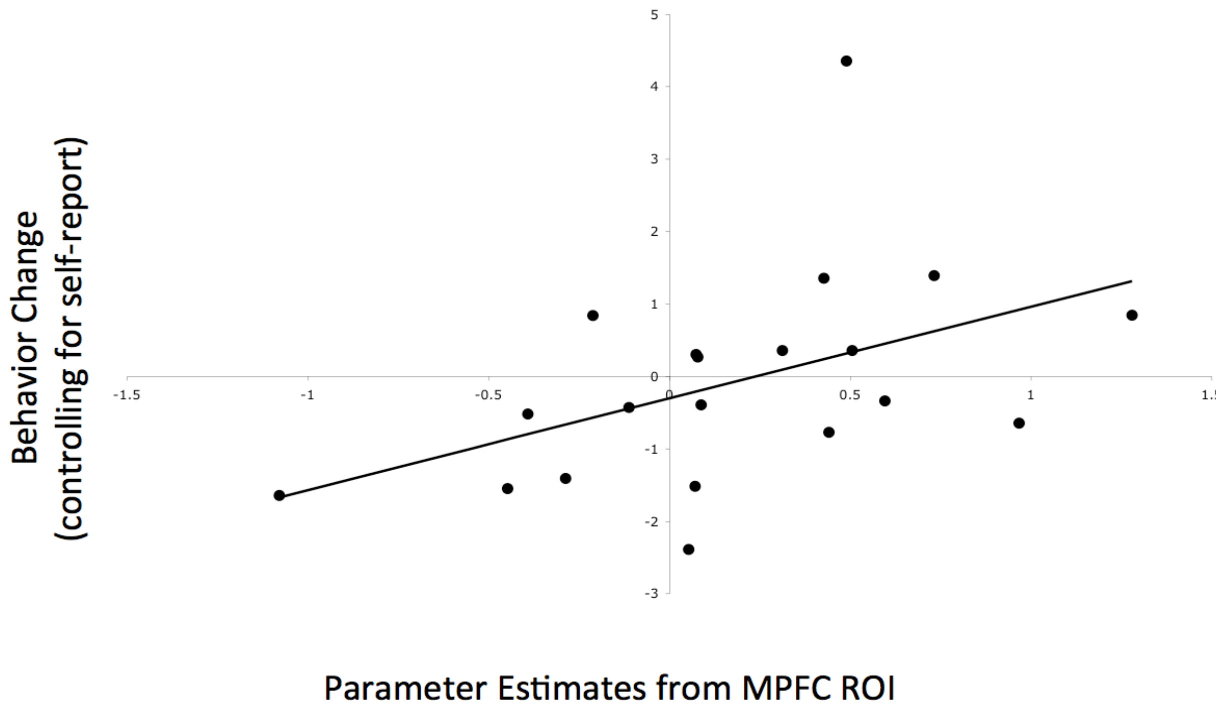


Figure 2. a) MPFC ROI constructed from the region most strongly associated with behavior change in Falk et al. (2010) and used in subsequent studies (Falk et al., 2011, Falk, Berkman, & Lieberman, 2012; Falk et al., 2015; Cooper, Tompson, O'Donnell, & Falk, in press) including this one, and b) rIPL and c) pIFG ROIs used in this study.

a)

b)

c)

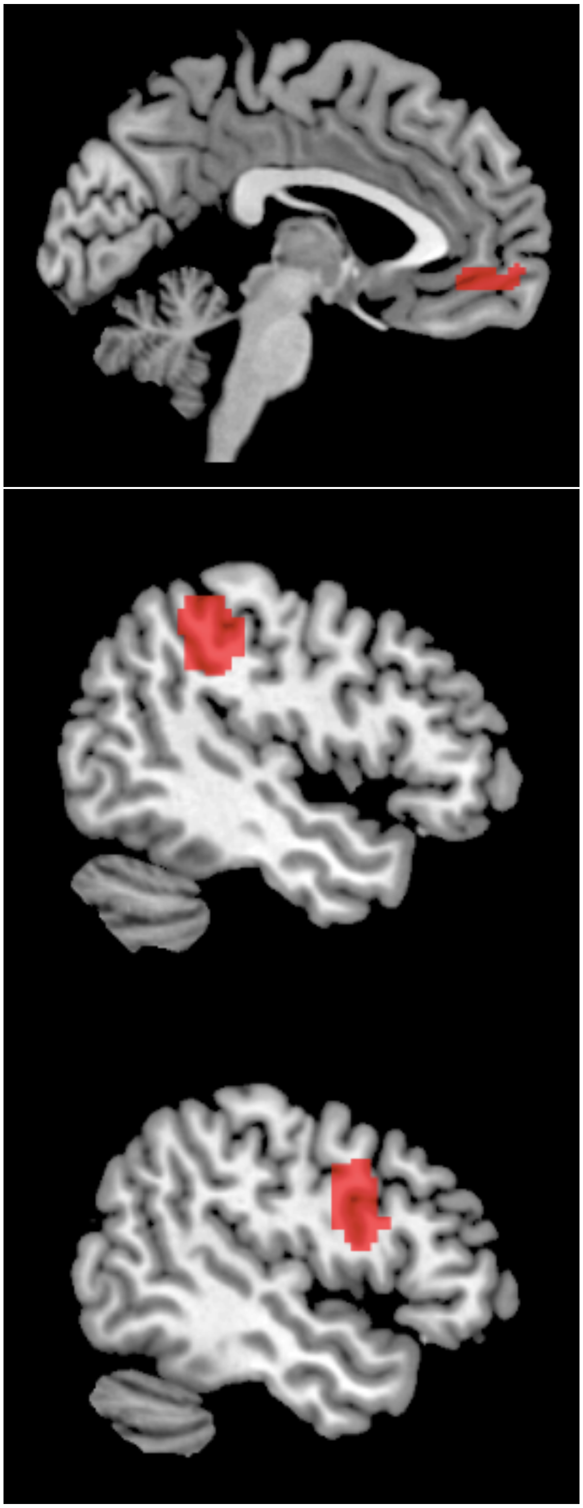


Figure 3. MPFC activity predicts population-level advertising outcomes better than self-report predictions in Falk, Berkman, & Lieberman (2012).

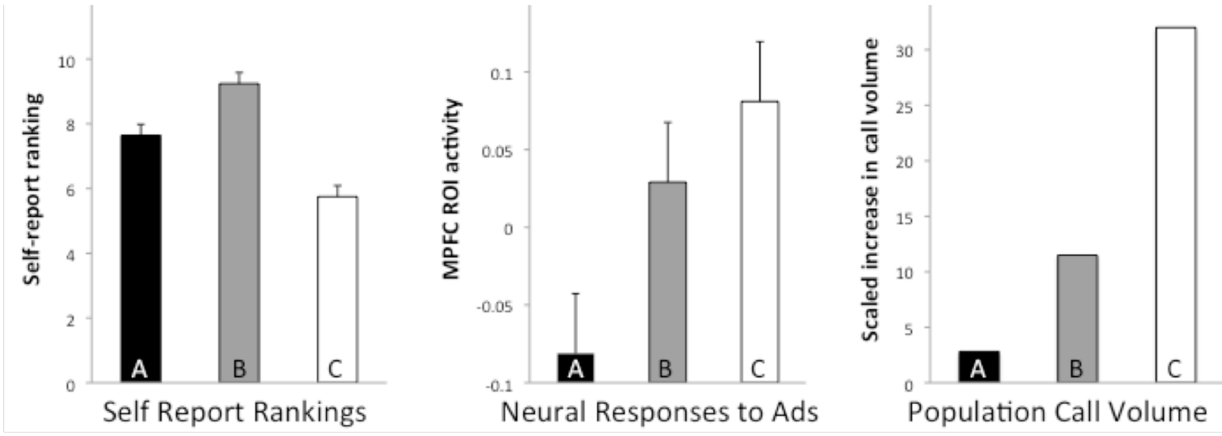


Figure 4. Fogg's (2009) Behavior Grid distinguishes between performing new vs. existing behaviors.

On What Schedule? / What Type of Behavior Change?	A perform new behavior (unfamiliar behavior)	B perform existing behavior (familiar behavior)	C increase behavior (frequency, intensity, or duration)	D decrease behavior (frequency, intensity, or duration)	E stop behavior (cease ongoing behavior)
1 one time behavior	*Take a new type of survey online*	*Purchase book at Amazon*	*Buy additional books online today*	*Spend less time on mySpace today*	*Don't eat desert tonight*
2 one time behavior that leads to ongoing obligation/cost	*Adopt a dog*	*Agree to host a party*	*Agree to pay more on mortgage*	*Pay less on a credit card one time*	*Refuse to continue chemotherapy*
3 behavior for a period of time (X has a duration)	*Play a new video game for one hour*	*Exercise for 30 minutes*	*Floss longer for two weeks.*	*Spend less money on books this month*	*Don't complain about anything today*
4 behavior on a predictable schedule (X gets repeated, periodicity)	*Attend online class each week for a month*	*Gamble online each morning at 10am*	*Exercise with higher heartrate each morning*	*Eat smaller portions for dinner.*	*Don't smoke after dinner each evening*
5 behavior is on cue (X is cued irregularly; it's a change in habitual response)	*Report any spam to AOL*	*Drink water at each fountain you see.*	*Write a longer thank you note after a dinner party*	*Control your frustration when driving in gridlock*	*Don't buy anything at checkout stand*
6 behavior is at will (can perform x at any moment)	*Read website privacy policy*	Check computer for viruses	*Check for computer viruses more often*	*Drink less coffee*	*Stop interrupting during conversations*
7 behavior is always performed (X means change in habit, in way of being)	*Use Google for online searching*	*Maintain good posture*	*Think thoughts of appreciation*	*Reduce energy consumption in home*	*Stop cursing*

Figure 5. Pre-scan and follow-up questionnaire.

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.

Used sunscreen	
Got at least 7 hours of sleep	
Got at least 8 hours of sleep	
Flossed	
Skipped class	
Ate vegetables	
Exercised	

Over the past 7 days, how many **times** did you do each of the following? Please enter a number in each box. You can estimate a number if you're unsure.

Ate vegetables	
Got at least 7 hours of sleep	
Flossed	
Got at least 8 hours of sleep	
Used sunscreen	
Skipped class	
Exercised	

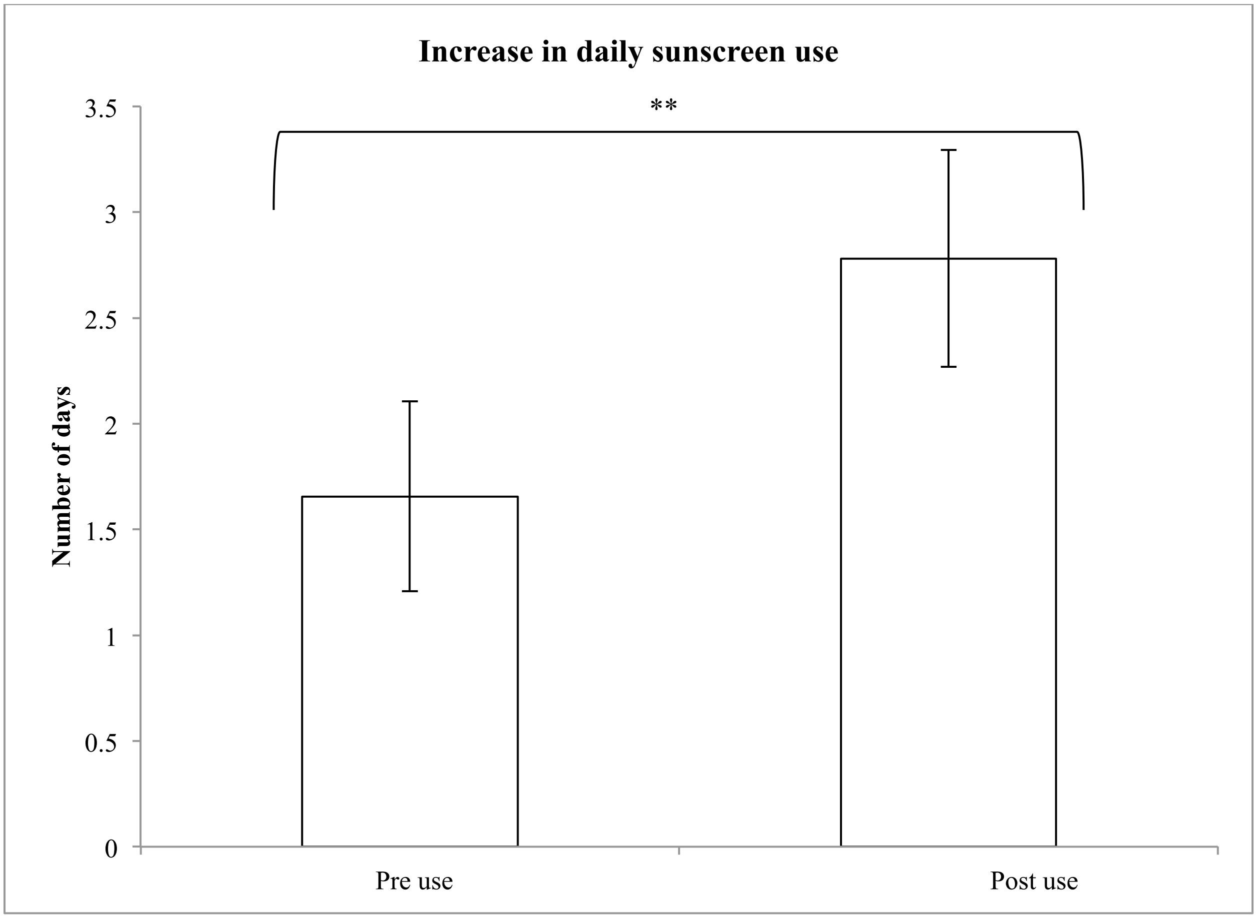
Out of the next 7 days, how many **days** do you intend to do each of the following? Please enter a number from 0 to 7 in each box. You can estimate a number if you're unsure.

Eat vegetables	
Use sunscreen	
Skip class	
Get at least 7 hours of sleep	
Get at least 8 hours of sleep	
Exercise	
Floss	

Over the next 7 days, how many **times** do you intend to do each of the following? Please enter a number in each box. You can estimate a number if you're unsure.

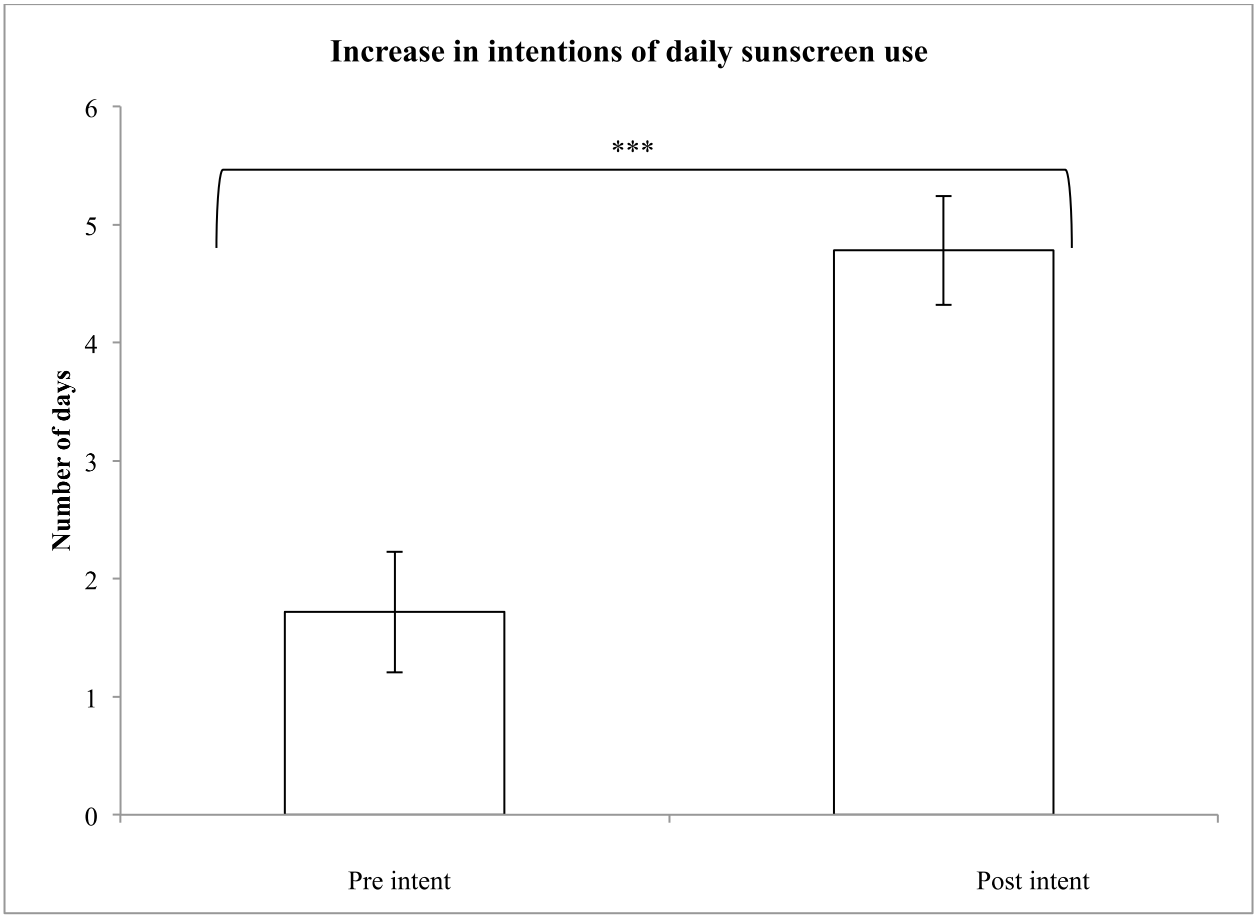
Floss	
Skip class	
Exercise	
Use sunscreen	
Get at least 7 hours of sleep	
Get at least 8 hours of sleep	
Eat vegetables	

Figure 6. Sunscreen use significantly increases pre session to post session.



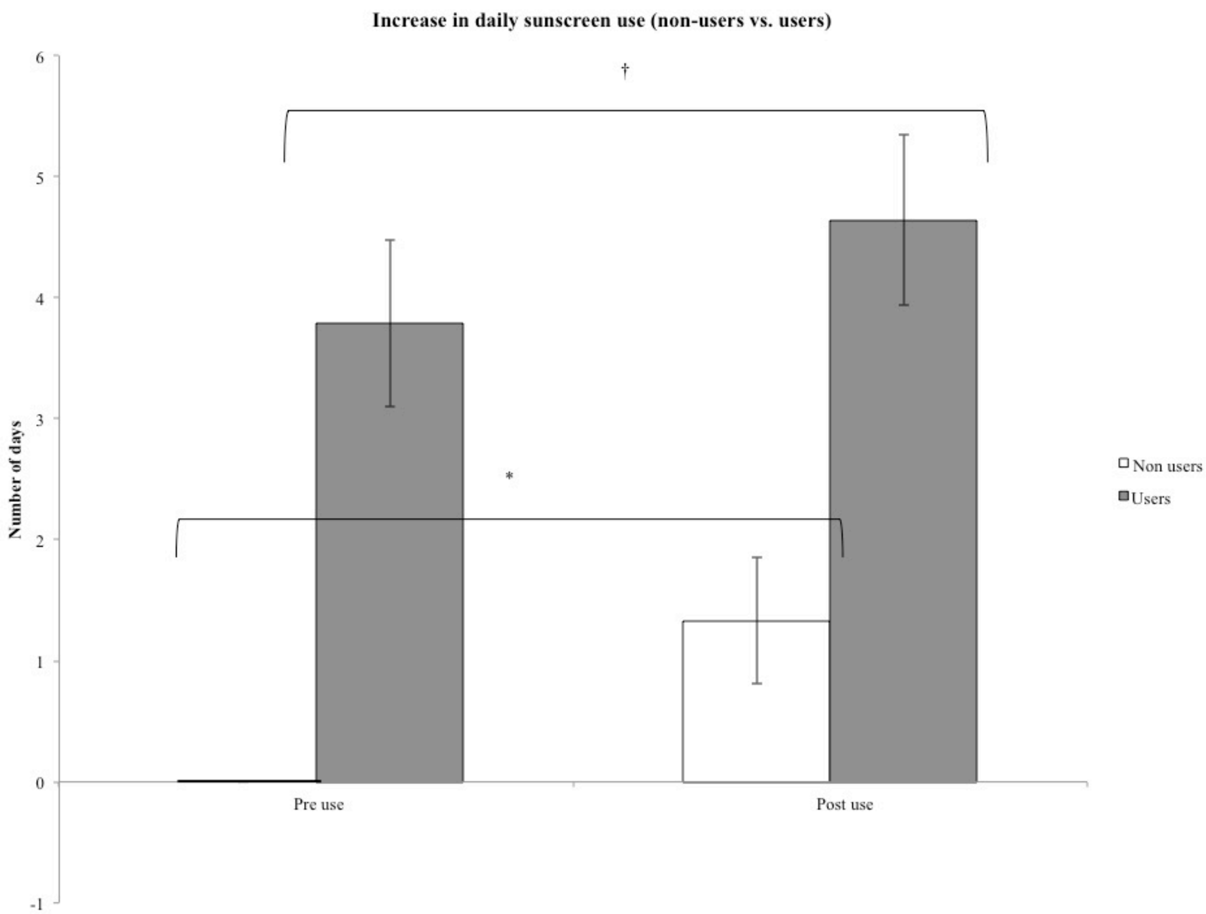
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 7. Intentions to wear sunscreen significantly increase pre session to post session.



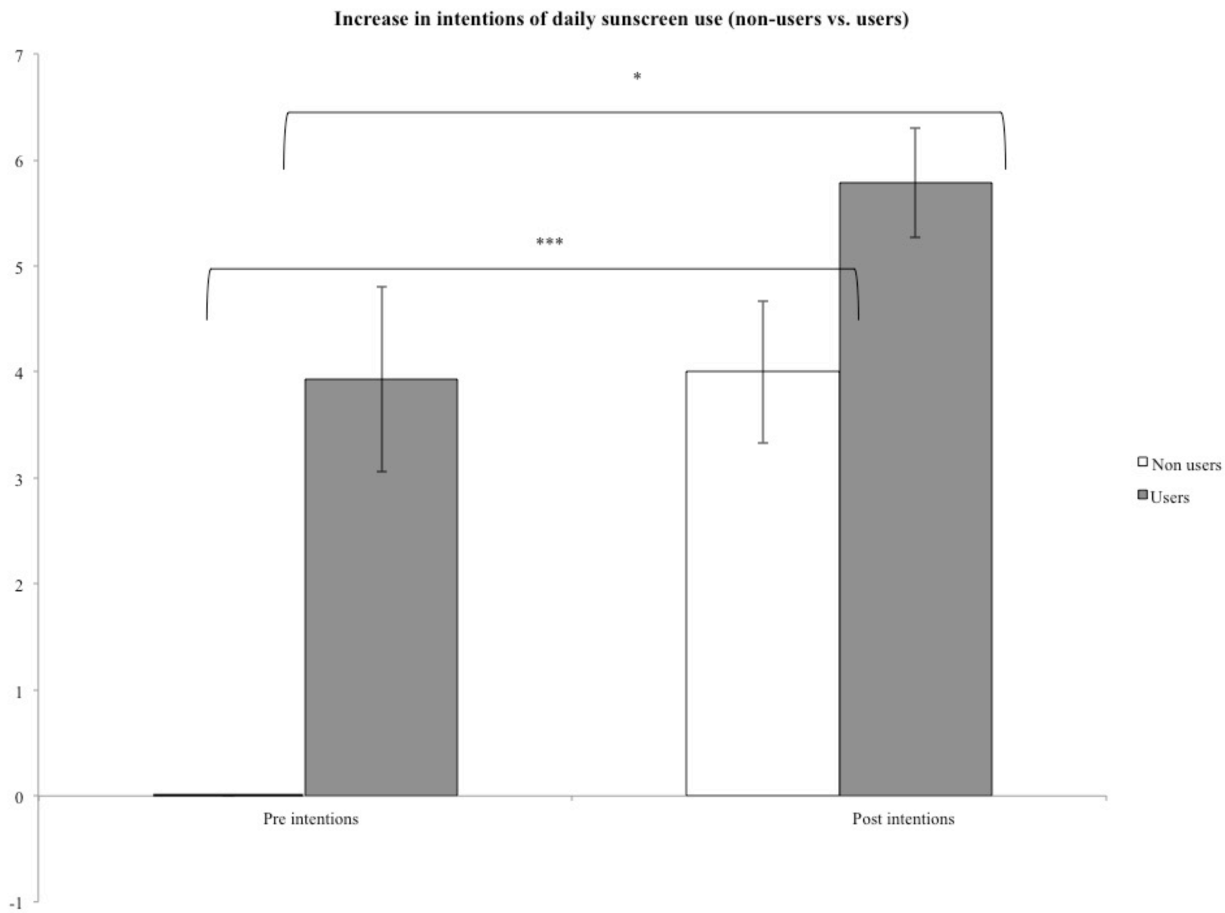
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 8. Sunscreen use increases pre session to post session for users and non-users.



Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 9. Intentions to wear sunscreen significantly increase pre session to post session for users and non-users.



Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 10. Correlation between intentions and behavior, $r(30) = .61$, $p < .001$.

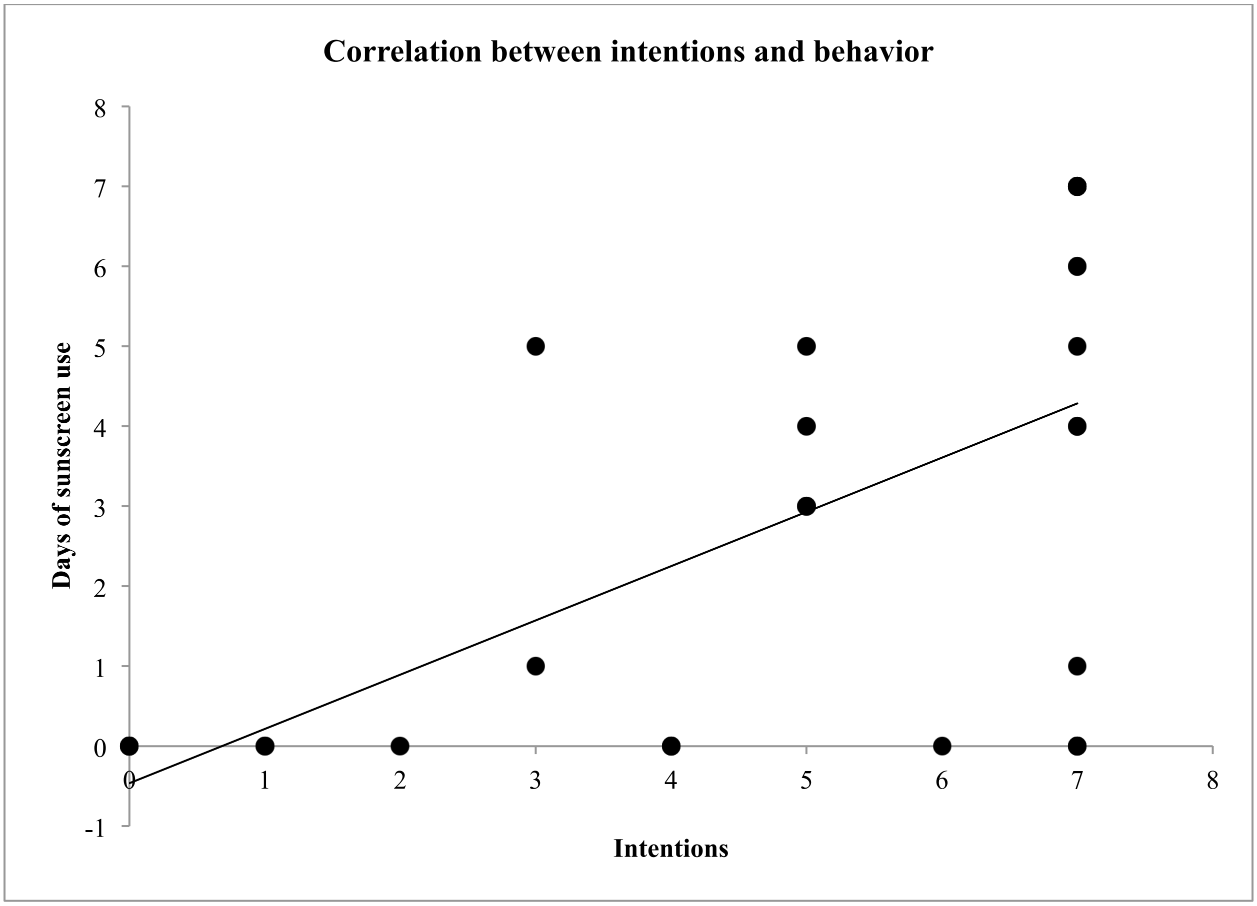


Figure 11. Correlation between intentions and behavior for users, $r(12) = .89$, $p = <.001$, vs. non-users, $r(16) = .35$, $p = .075$.

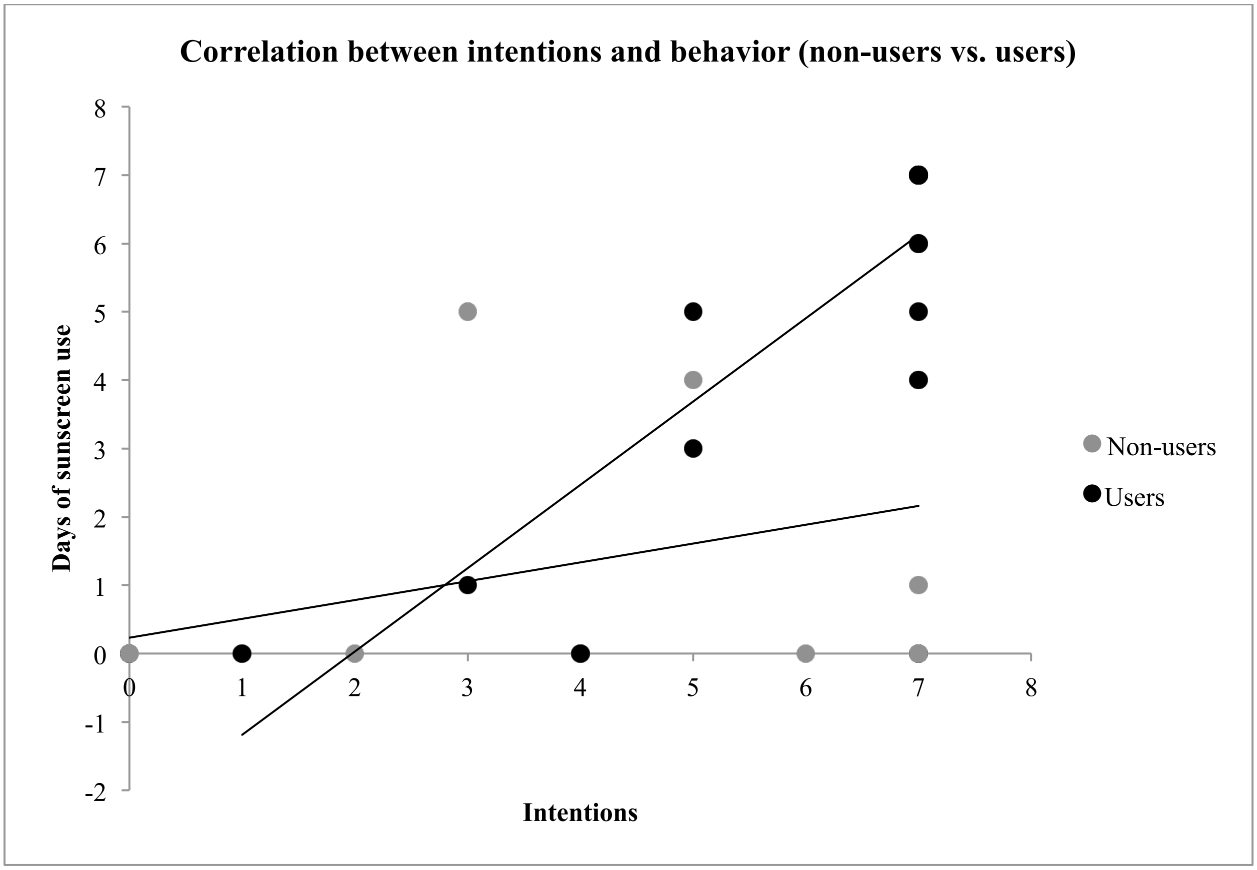
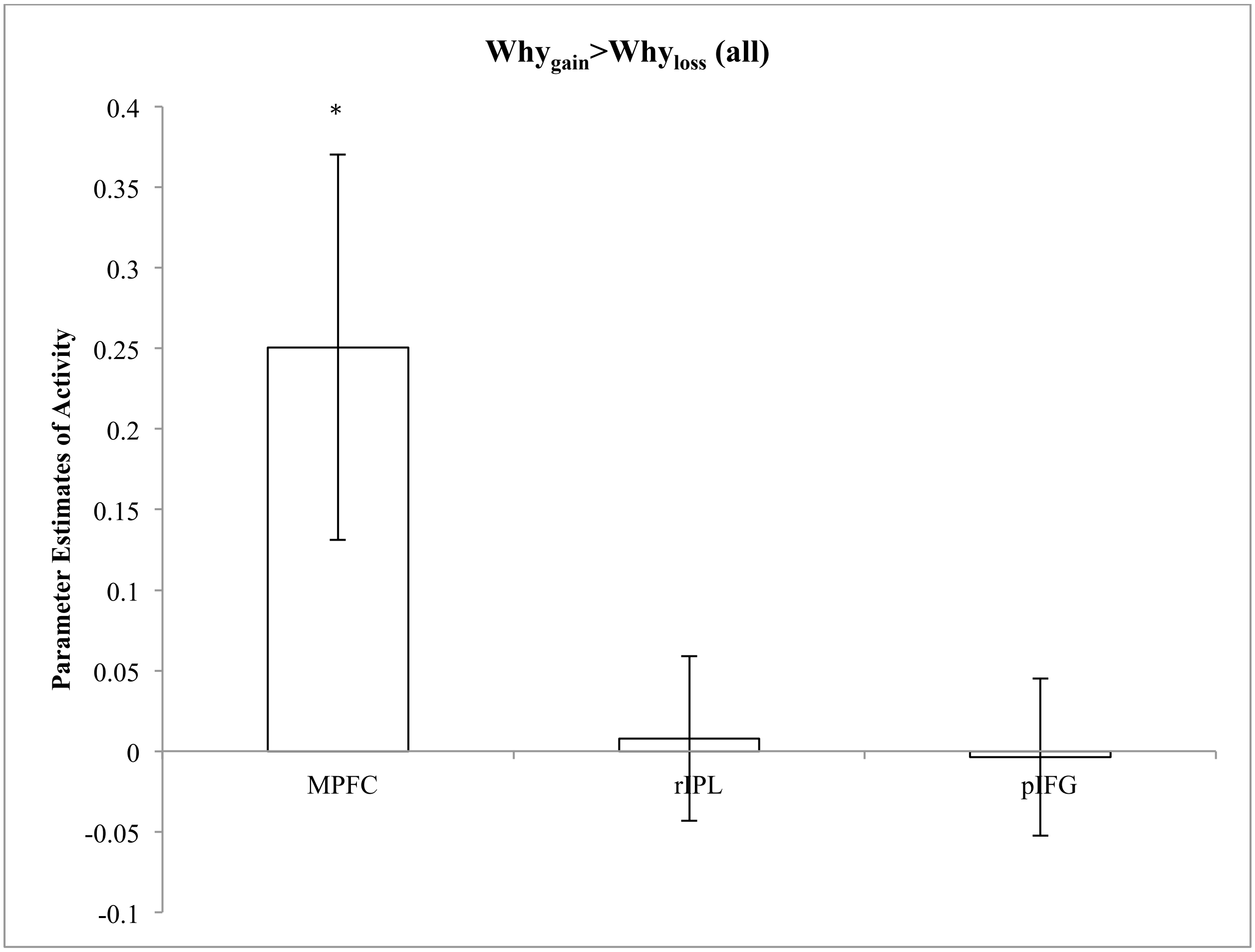
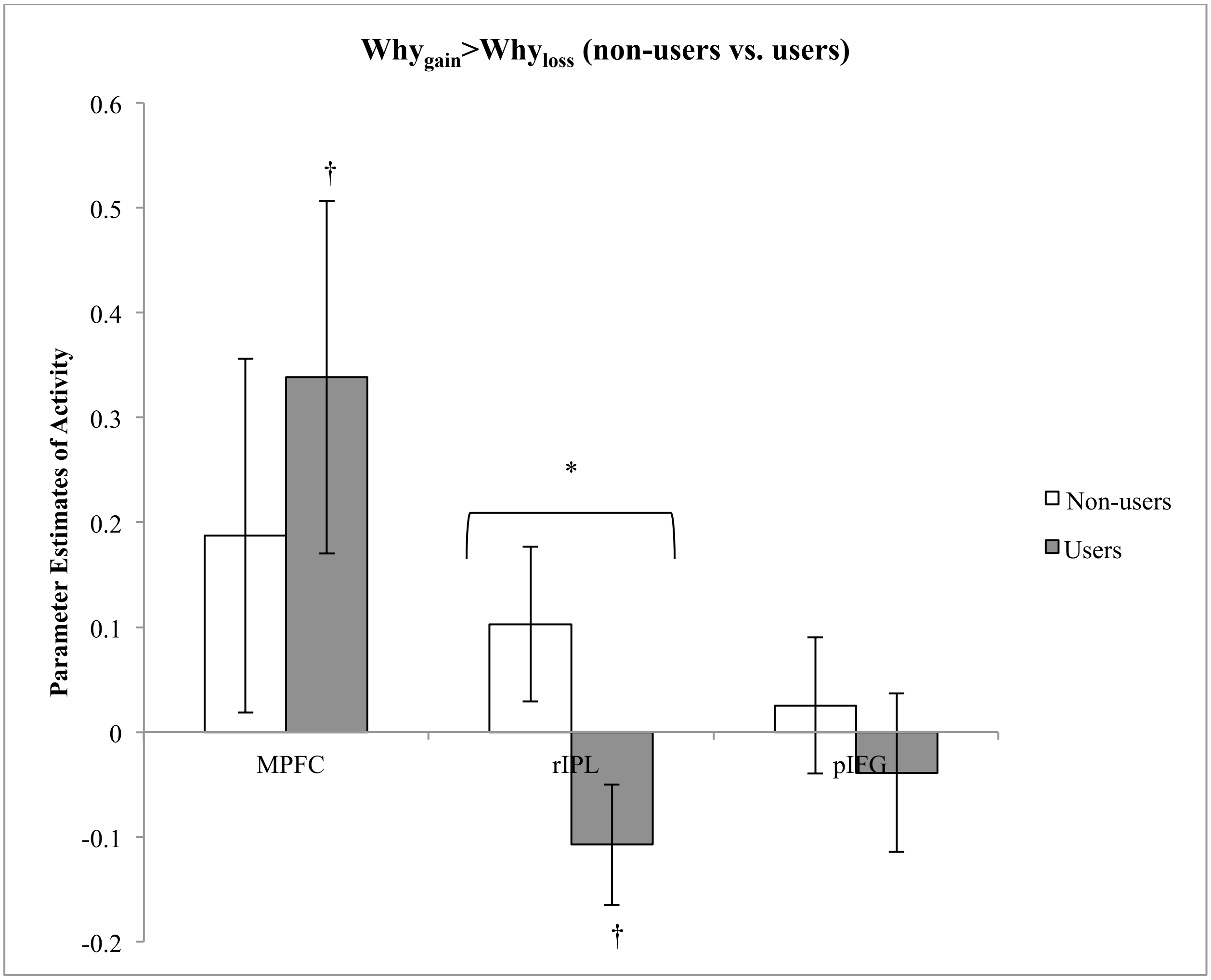


Figure 12. Activity in MPFC, rIPL, and pIFG during Why_{gain} relative to Why_{loss} messages.



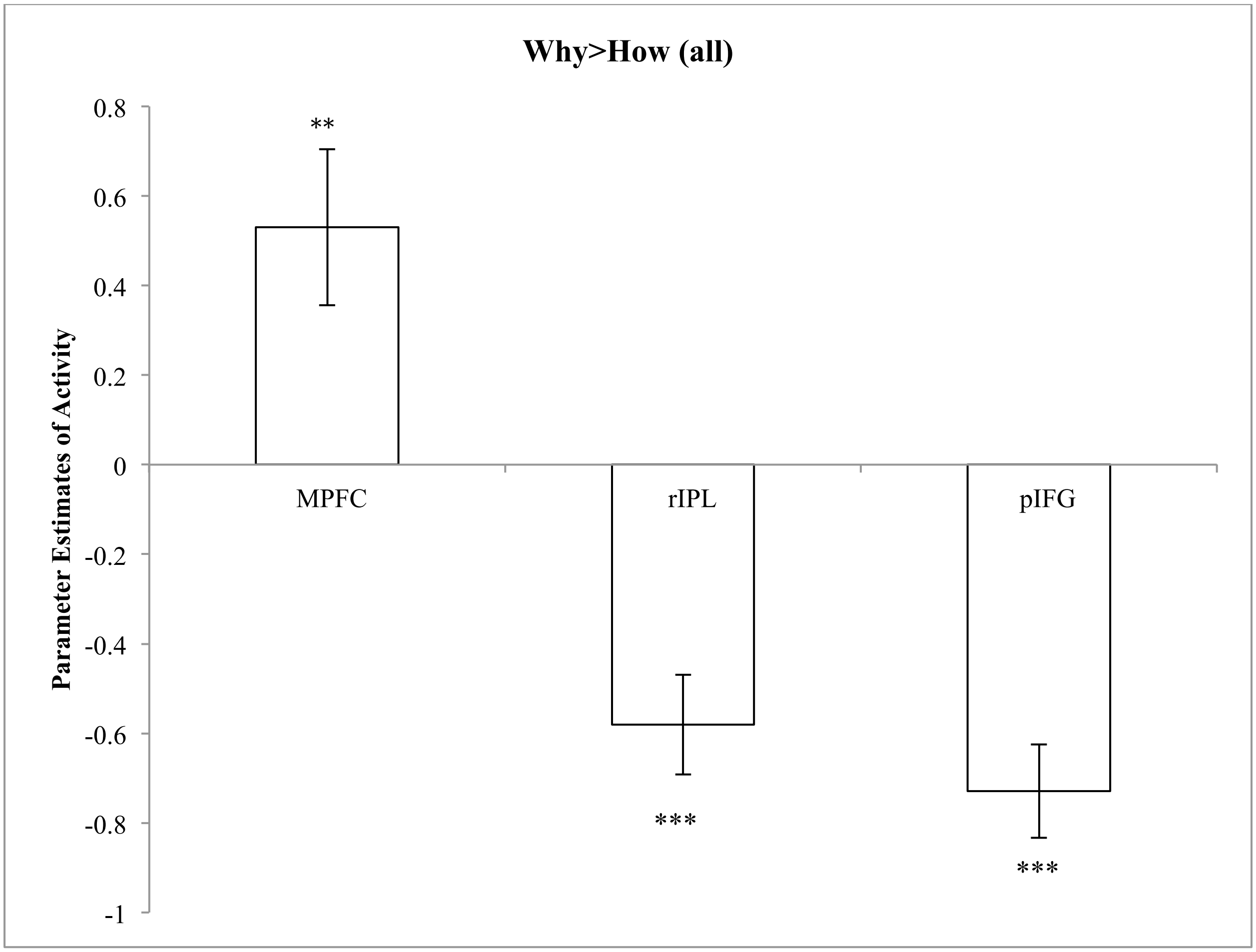
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 13. Activity in MPFC, rIPL, and pIFG during Why_{gain} relative to Why_{loss} messages for users vs. non-users.



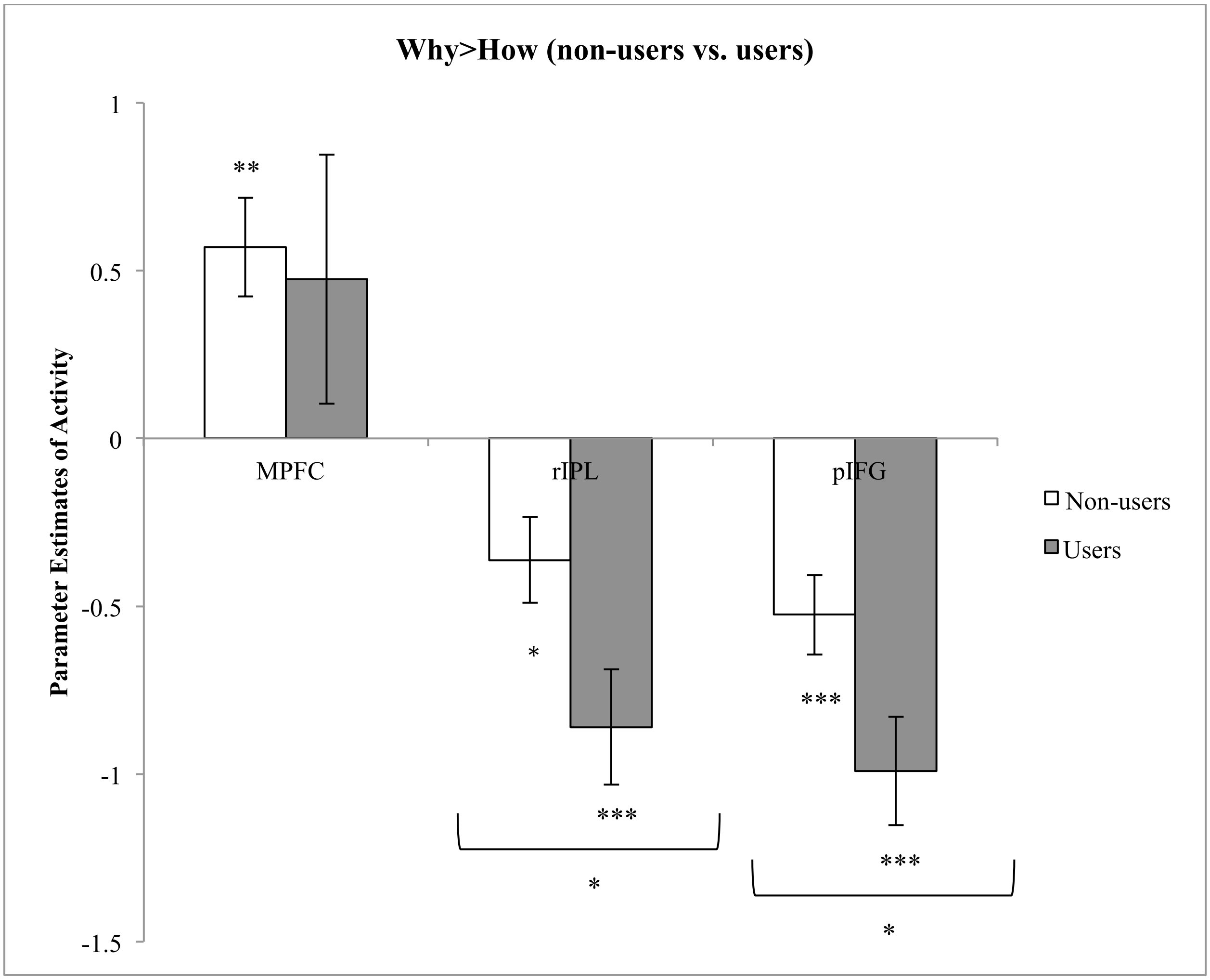
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 14. Activity in MPFC, rIPL, and pIFG during Why relative to How messages.



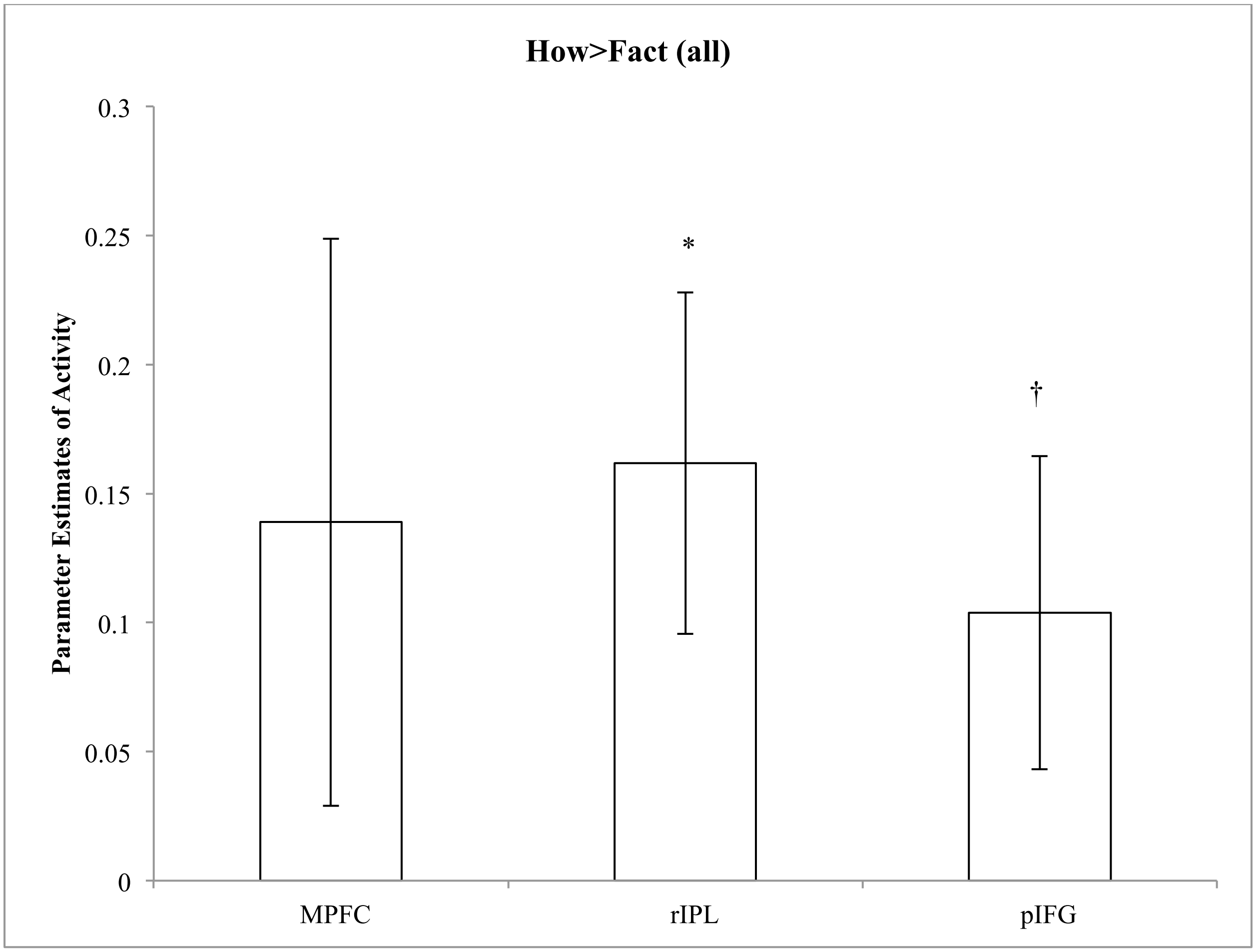
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 15. Activity in MPFC, rIPL, and pIFG during Why relative to How messages for users vs. non-users.



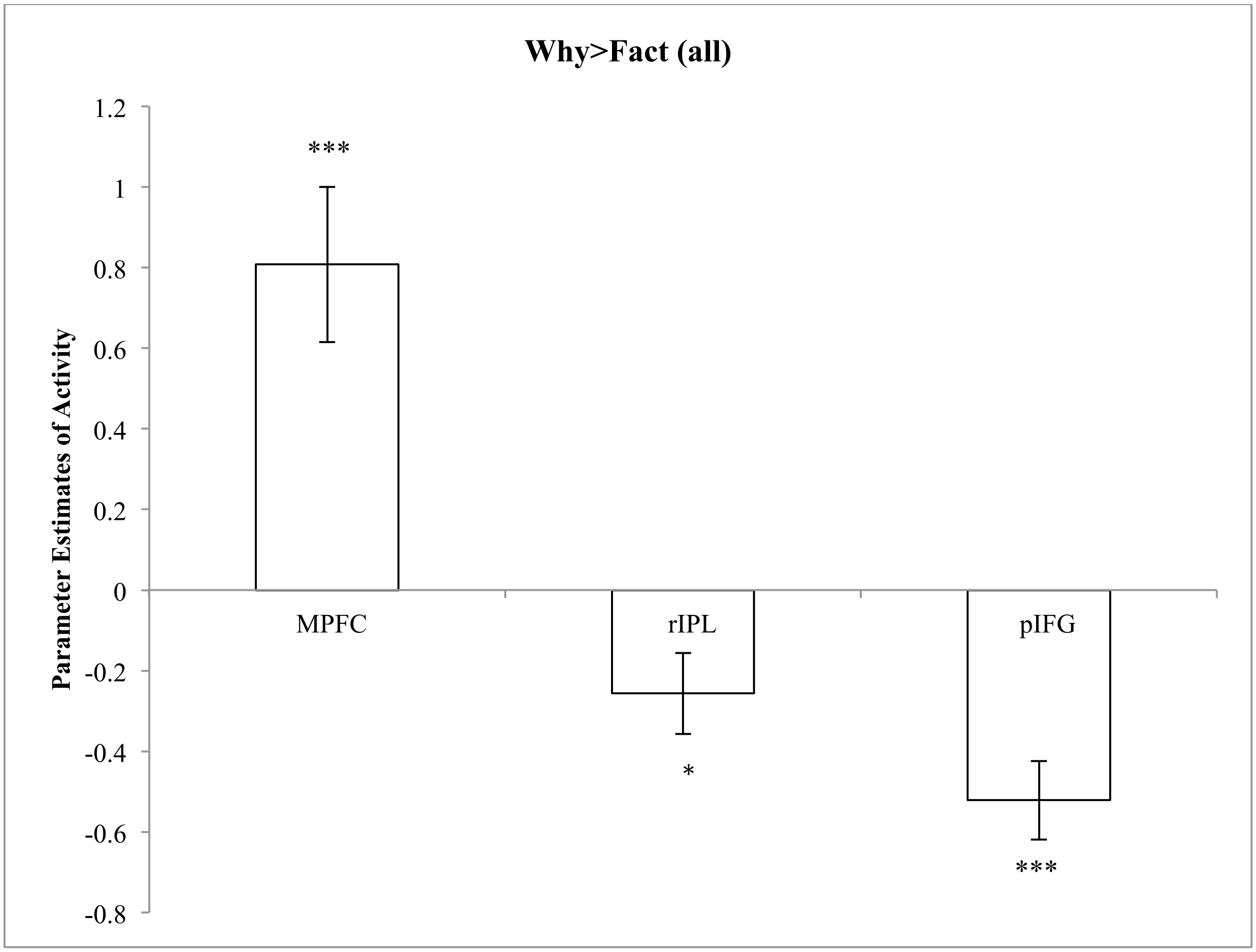
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 16. Activity in MPFC, rIPL, and pIFG during How relative to Fact messages.



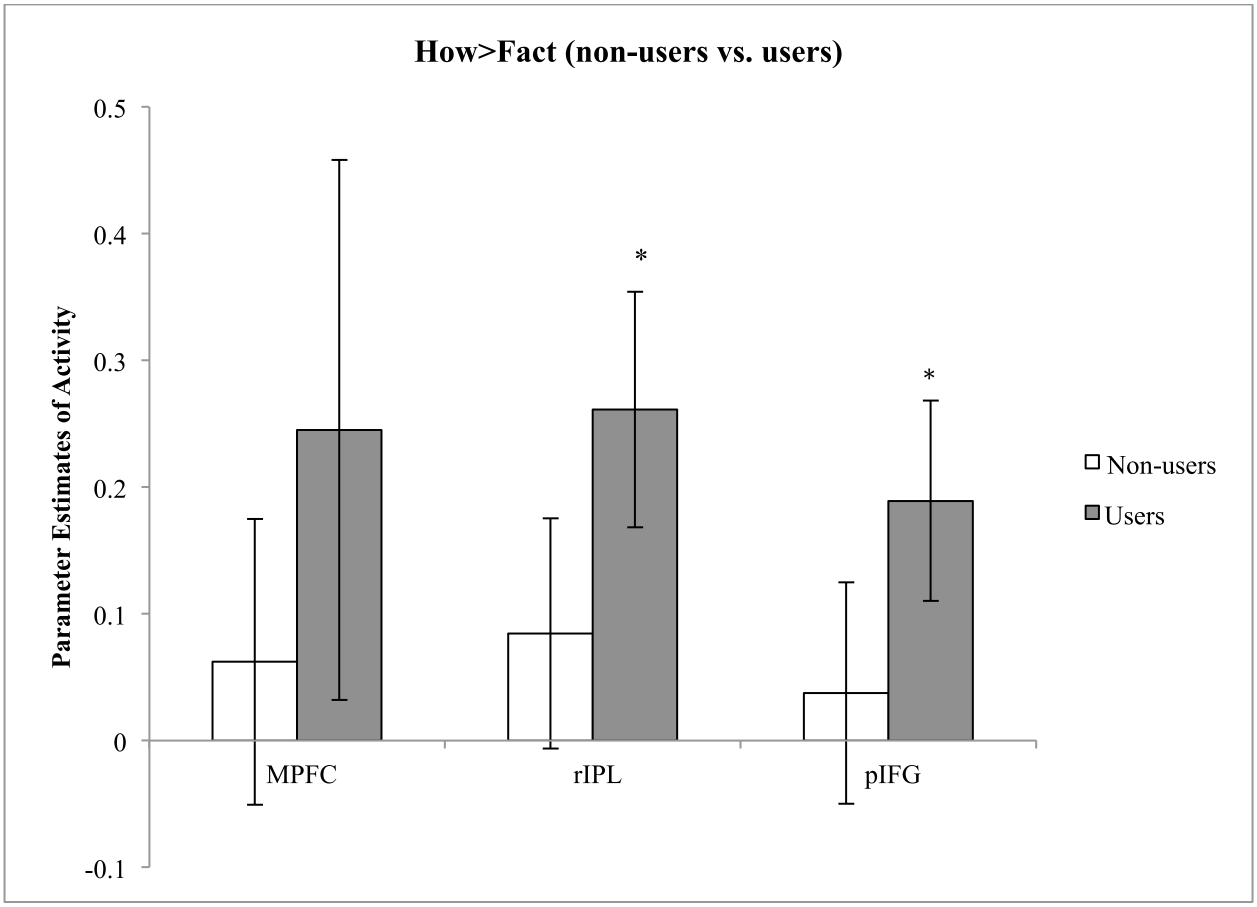
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 17. Activity in MPFC, rIPL, and pIFG during Why relative to Fact messages.



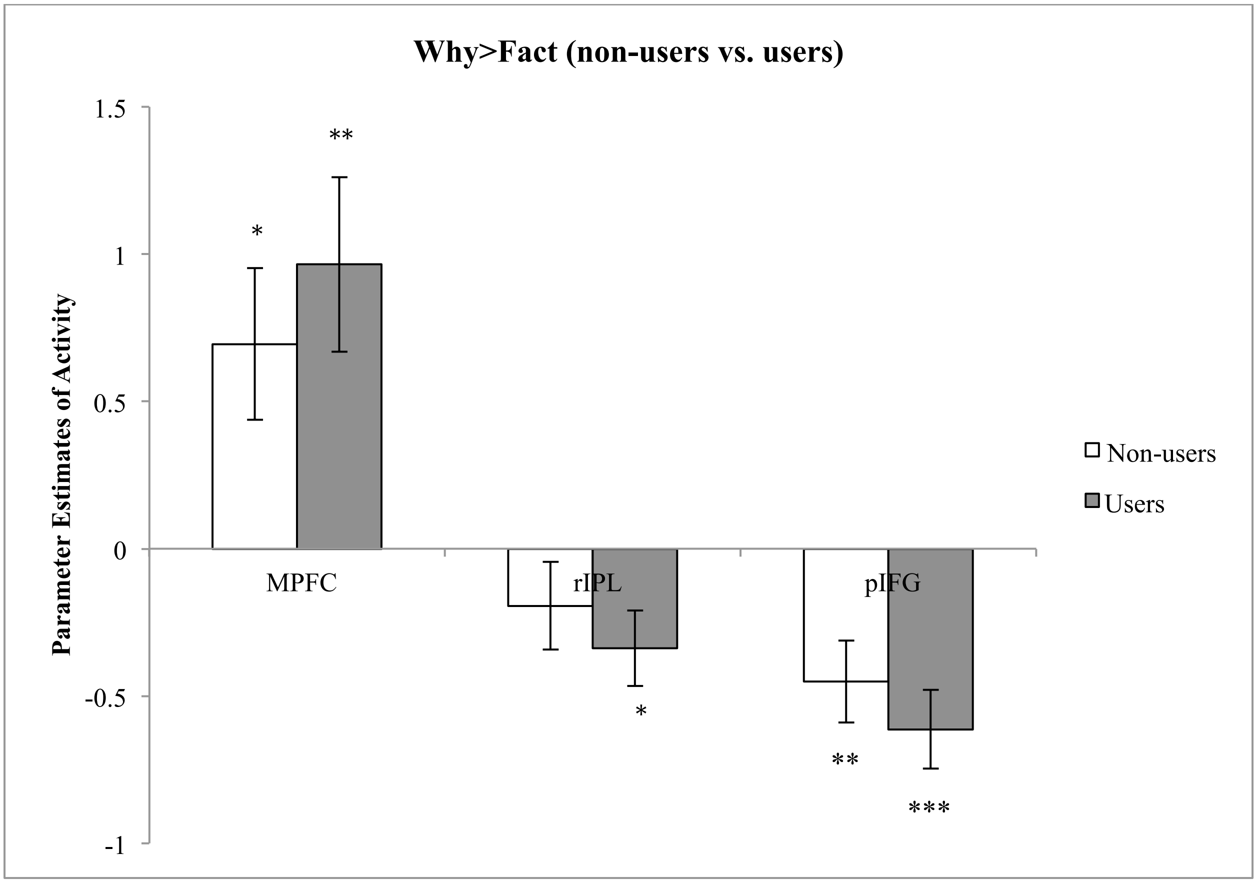
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 18. Activity in MPFC, rIPL, and pIFG during How relative to Fact messages for users vs. non-users.



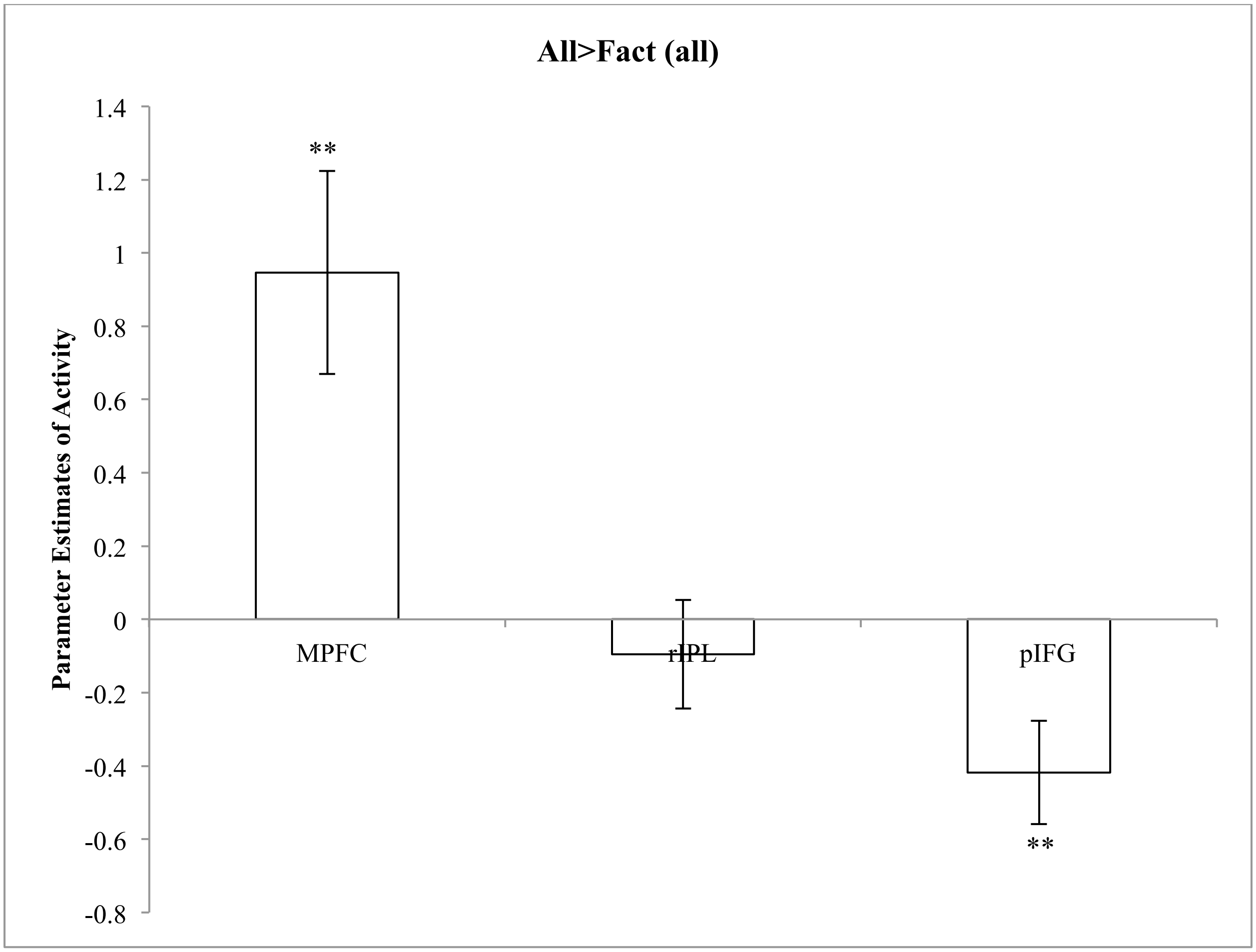
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 19. Activity in MPFC, rIPL, and pIFG during Why relative to Fact messages for users vs. non-users.



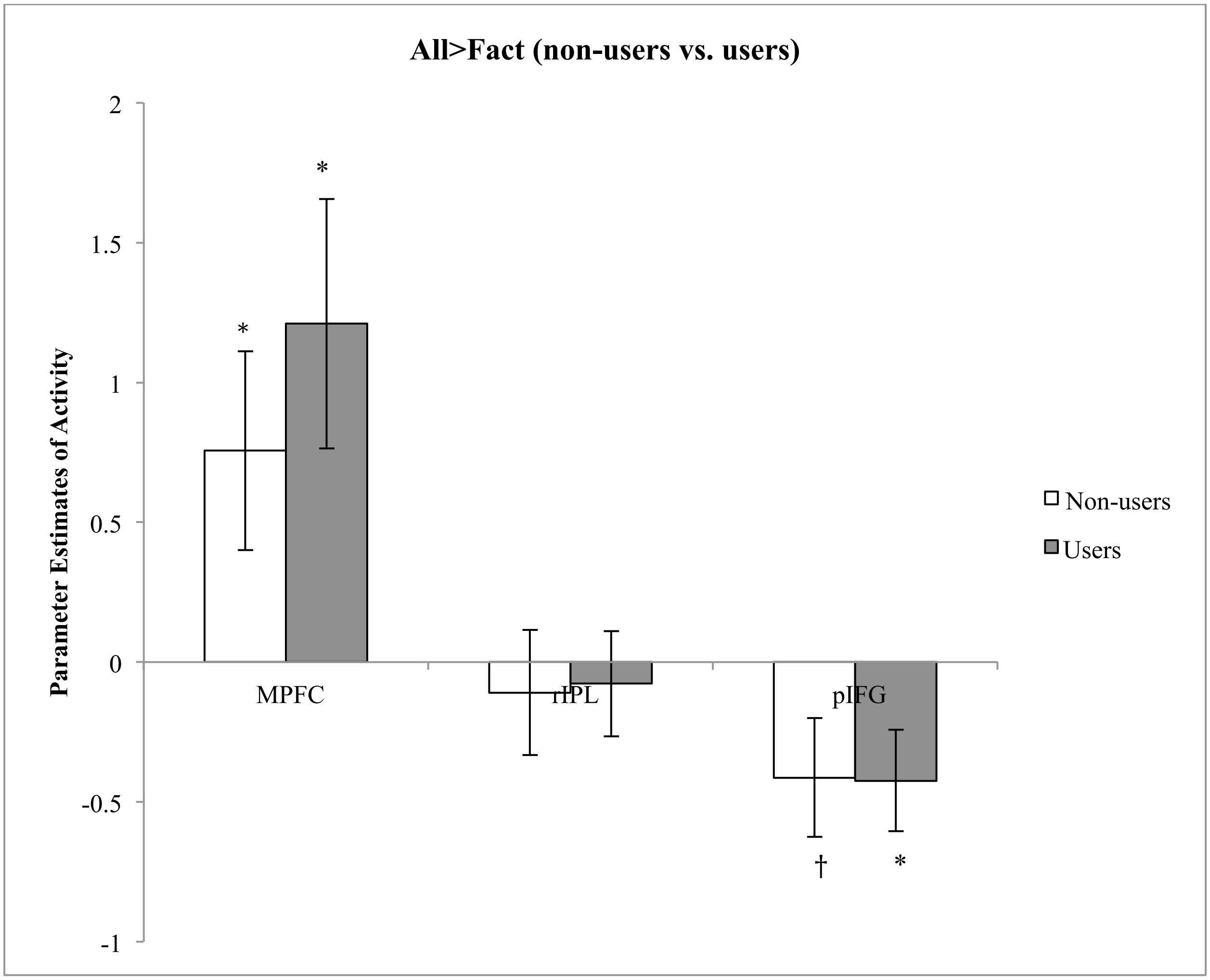
Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 20. Activity in MPFC, rIPL, and pIFG during All relative to Fact messages.



Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 21. Activity in MPFC, rIPL, and pIFG during All relative to Fact messages for users vs. non-users.



Note: † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 22. Correlation between activity in MPFC during All relative to Fact messages and behavior controlling for intentions, $r(28) = .29$, $p = .058$.

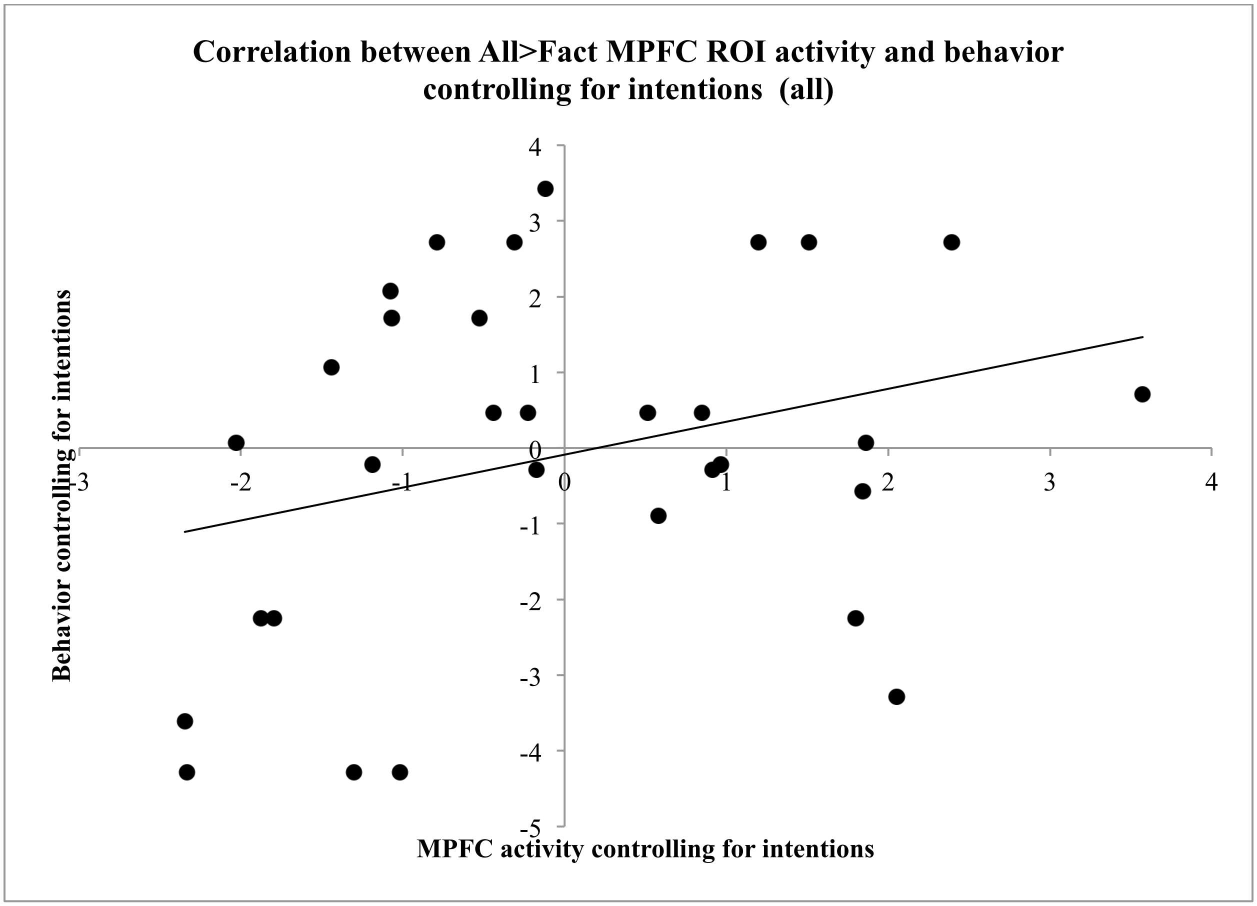


Figure 23. Correlation between activity in MPFC during All relative to Fact messages and behavior controlling for intentions in users, $r(10) = .069$, $p = .41$, vs. non-users, $r(15) = .37$, $p = .065$.

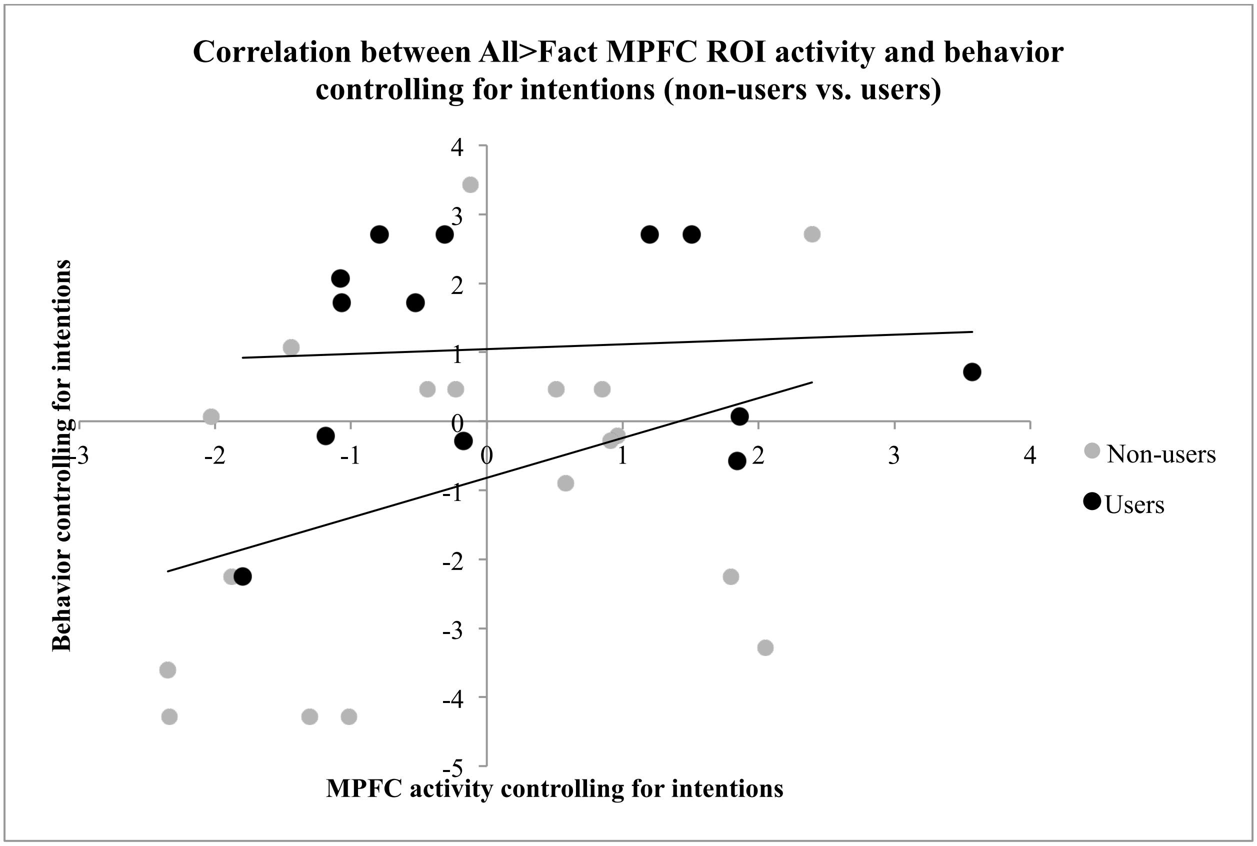


Figure 24. Correlation between activity in rIPL during All relative to Fact messages and behavior controlling for intentions, $r(29) = .32$, $p = .042$.

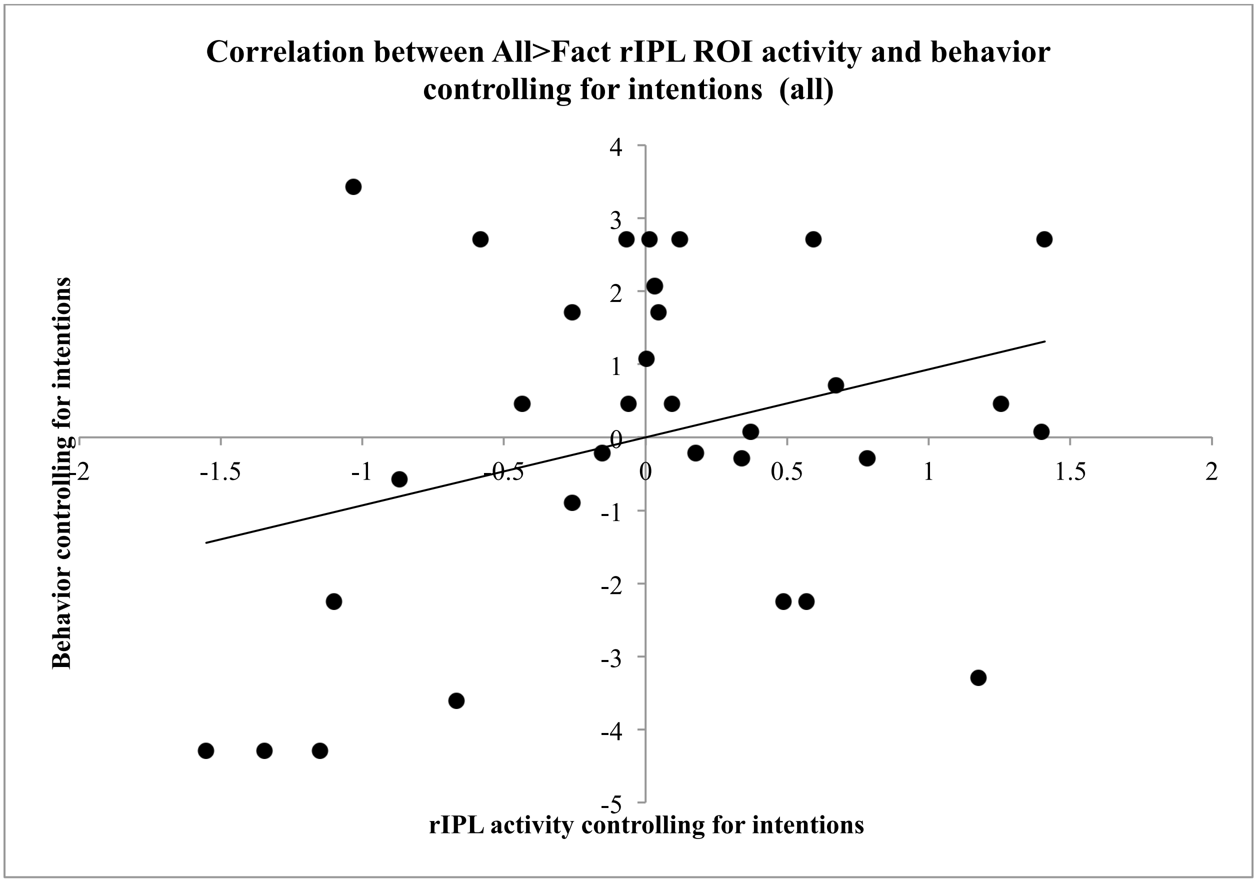


Figure 25. Correlation between activity in rIPL during All relative to Fact messages and behavior controlling for intentions for users, $r(11) = .32$, $p = .14$, vs. non-users, $r(15) = .26$, $p = .14$.

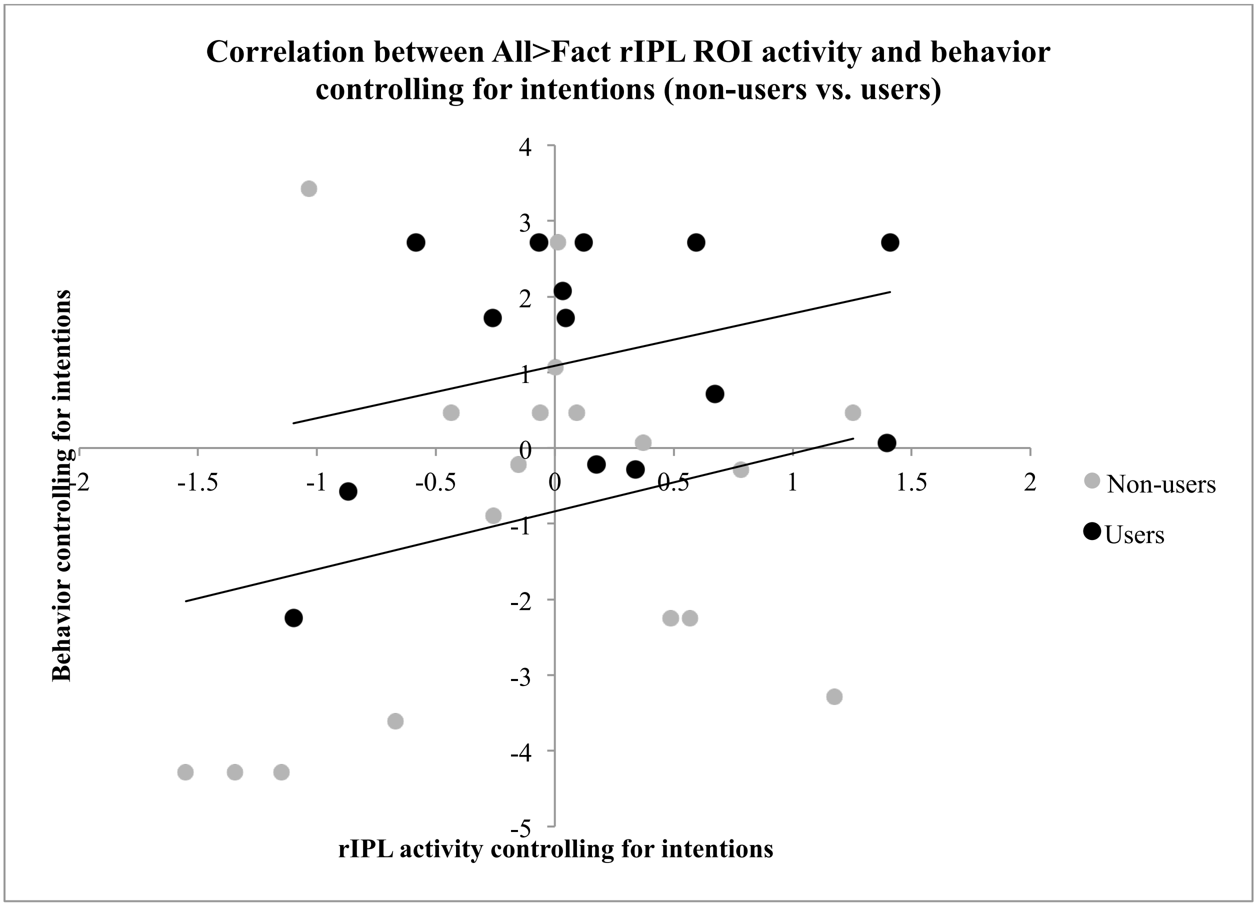


Figure 26. Correlation between activity in MPFC during Why relative to Fact messages and behavior controlling for intentions, $r(28) = .32$, $p = .041$.

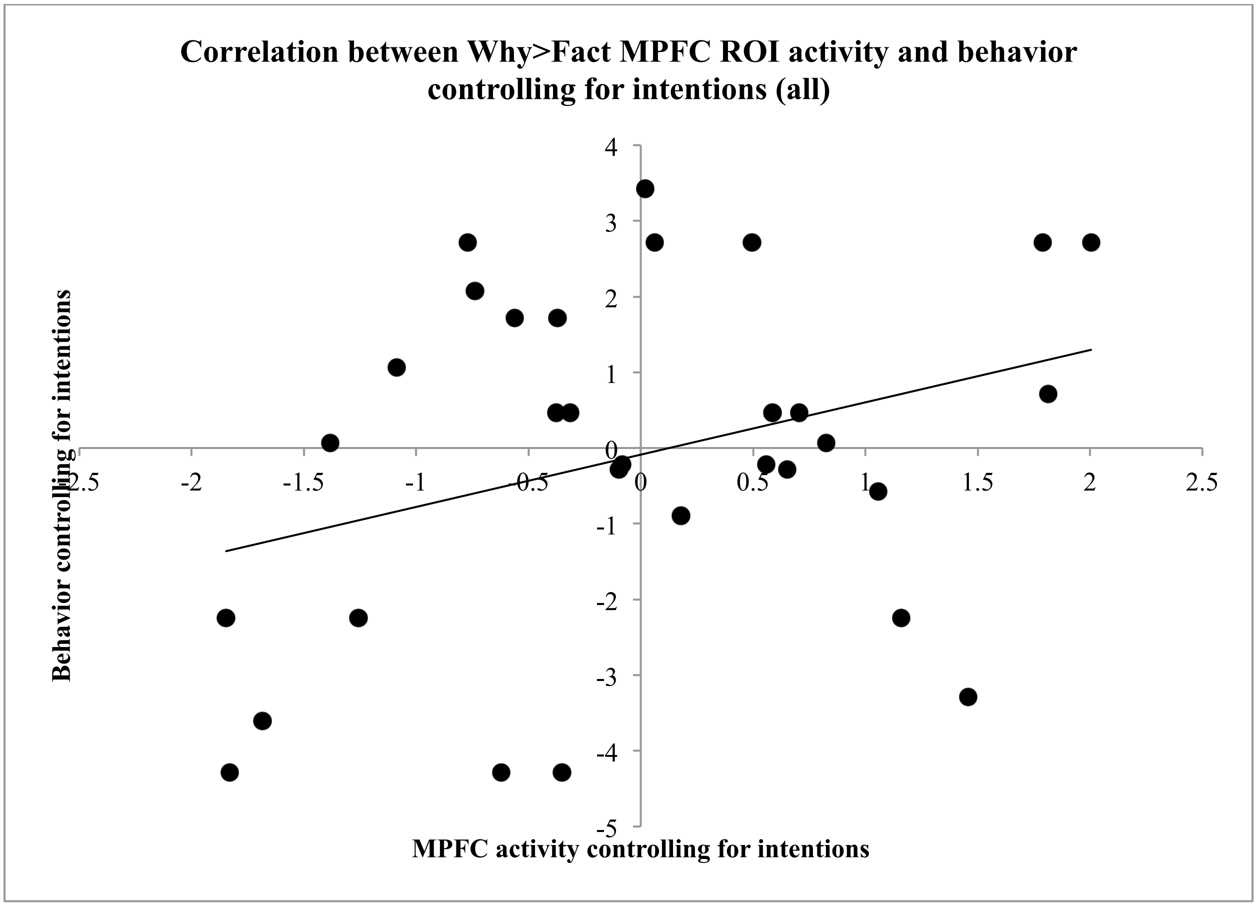


Figure 27. Correlation between activity in MPFC during Why relative to Fact messages and behavior controlling for intentions in users, $r(10) = .22$, $p = .24$, vs. non-users, $r(15) = .36$, $p = .069$.

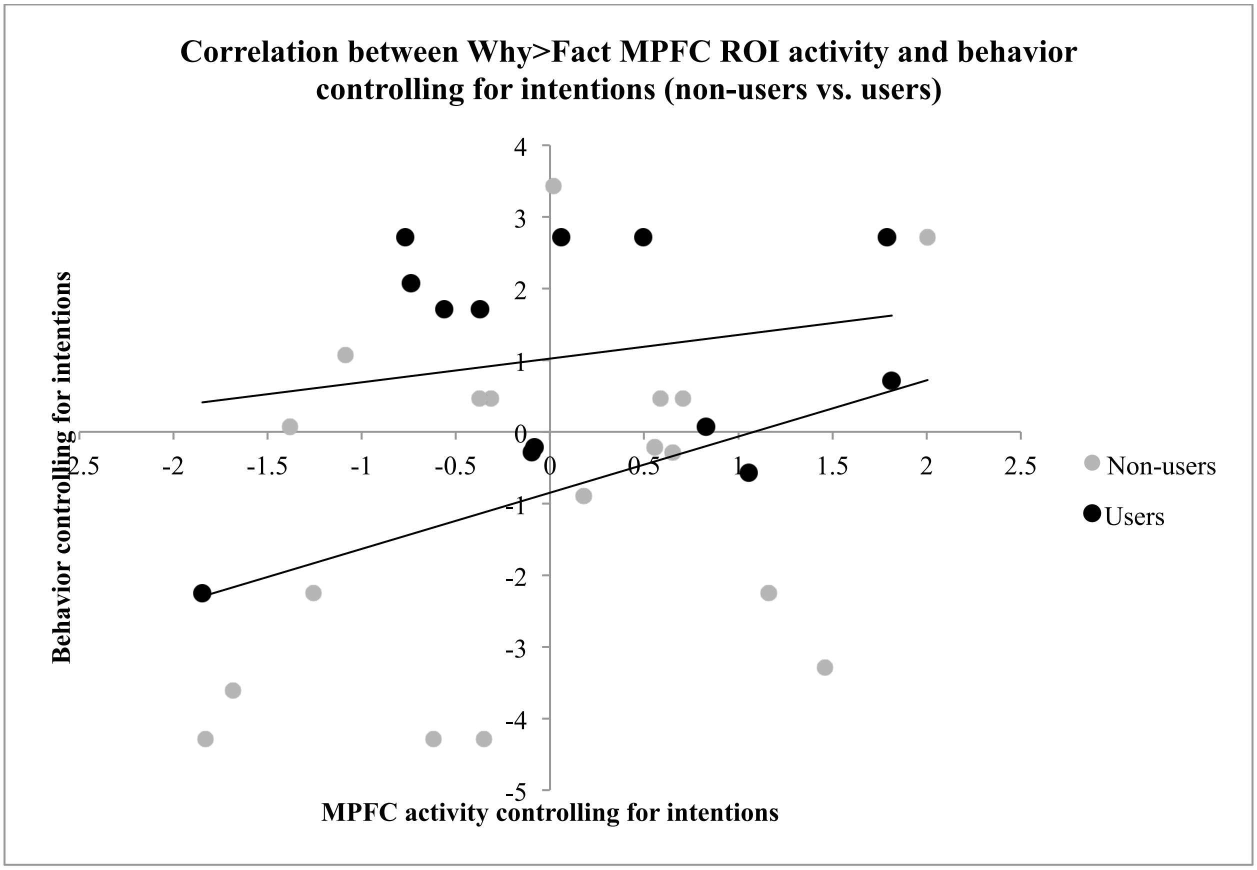


Figure 28. Correlation between rIPL activity during Why messages relative to Fact messages and behavior controlling for intentions, $r(29) = .28$, $p = .063$.

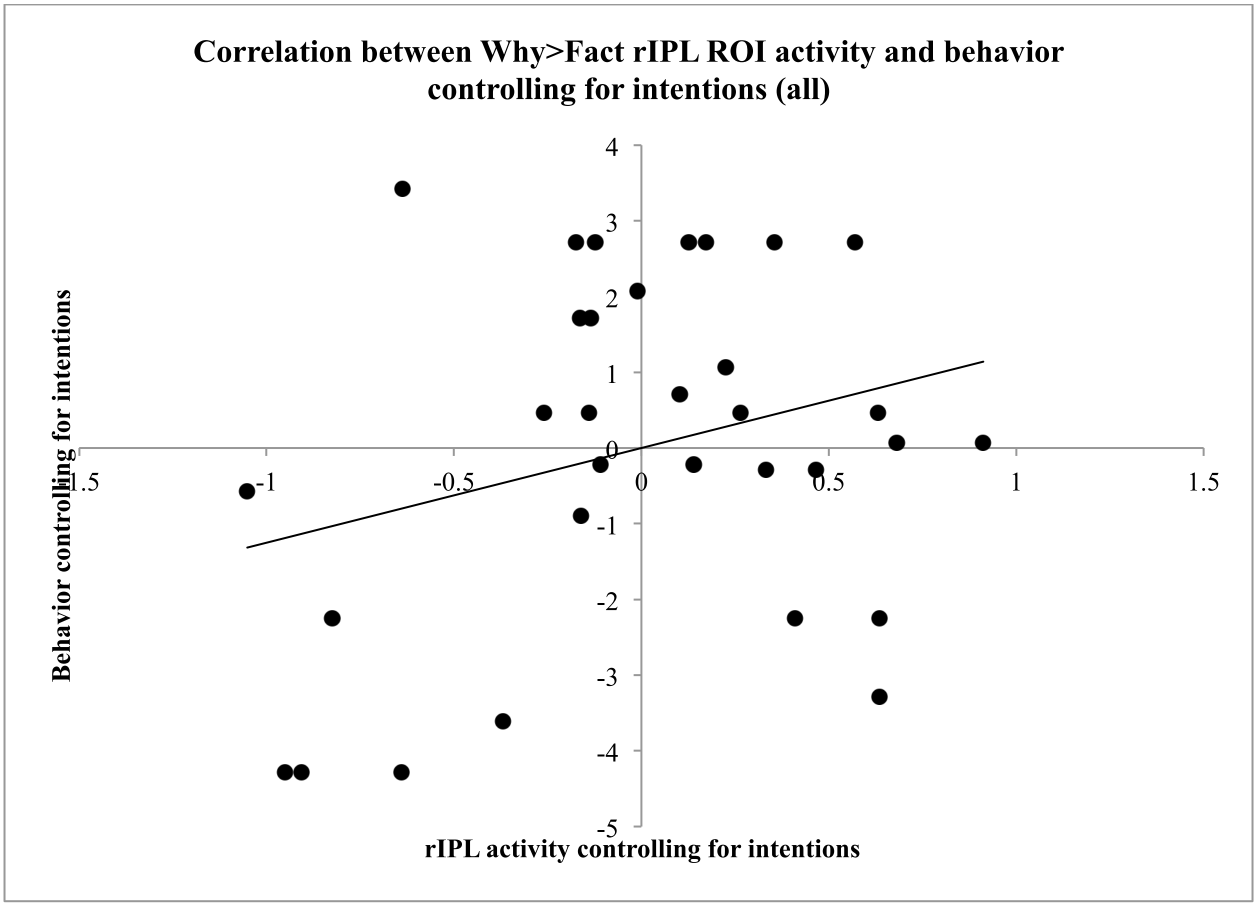


Figure 29. Correlation between activity in rIPL during Why relative to Fact messages and behavior controlling for intentions in users, $r(11) = .38$, $p = .092$, vs. non-users, $r(15) = .28$, $p = .13$.

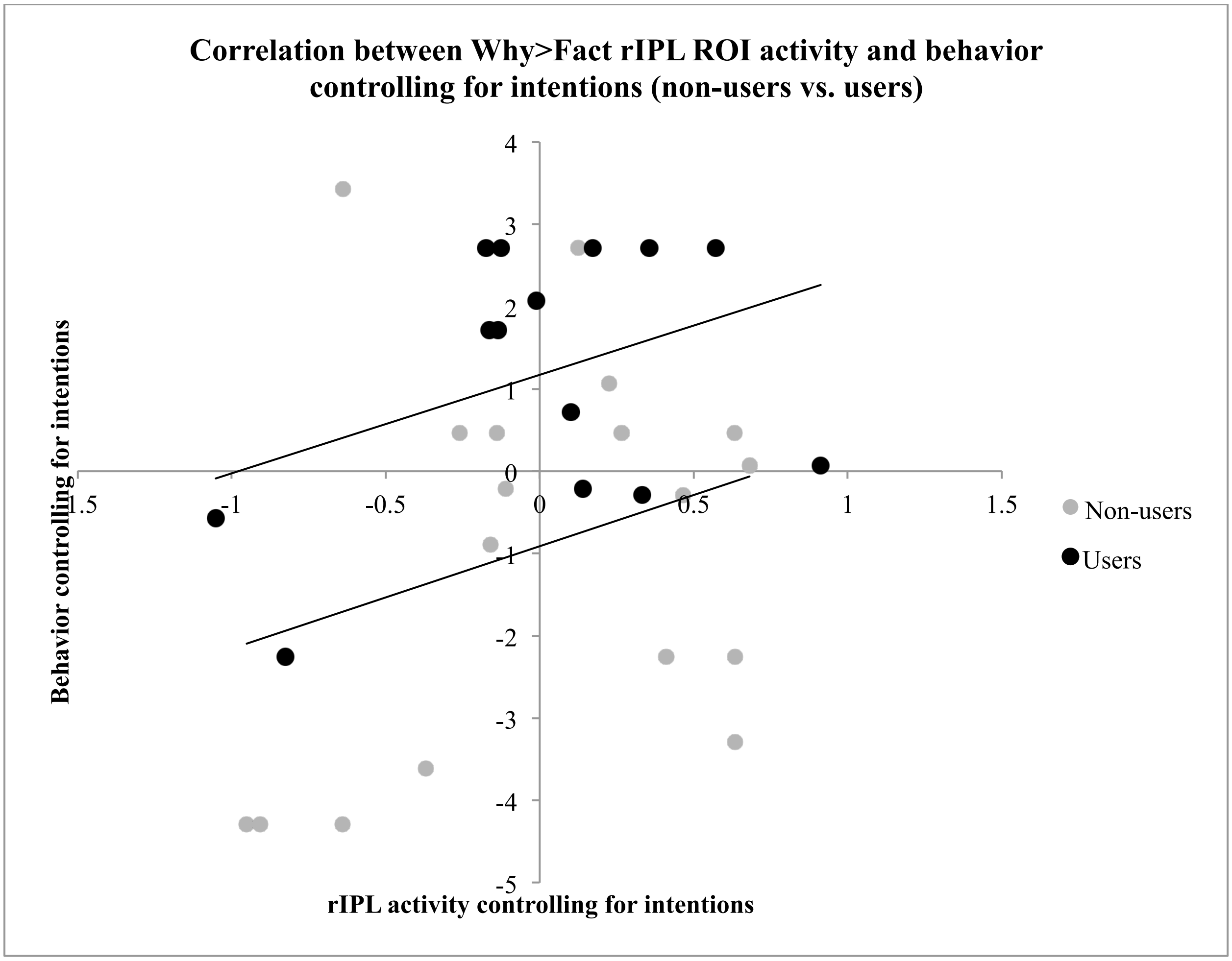


Figure 30. Correlation between rIPL activity during How messages relative to Fact messages and behavior controlling for intentions, $r(29) = .28$, $p = .068$.

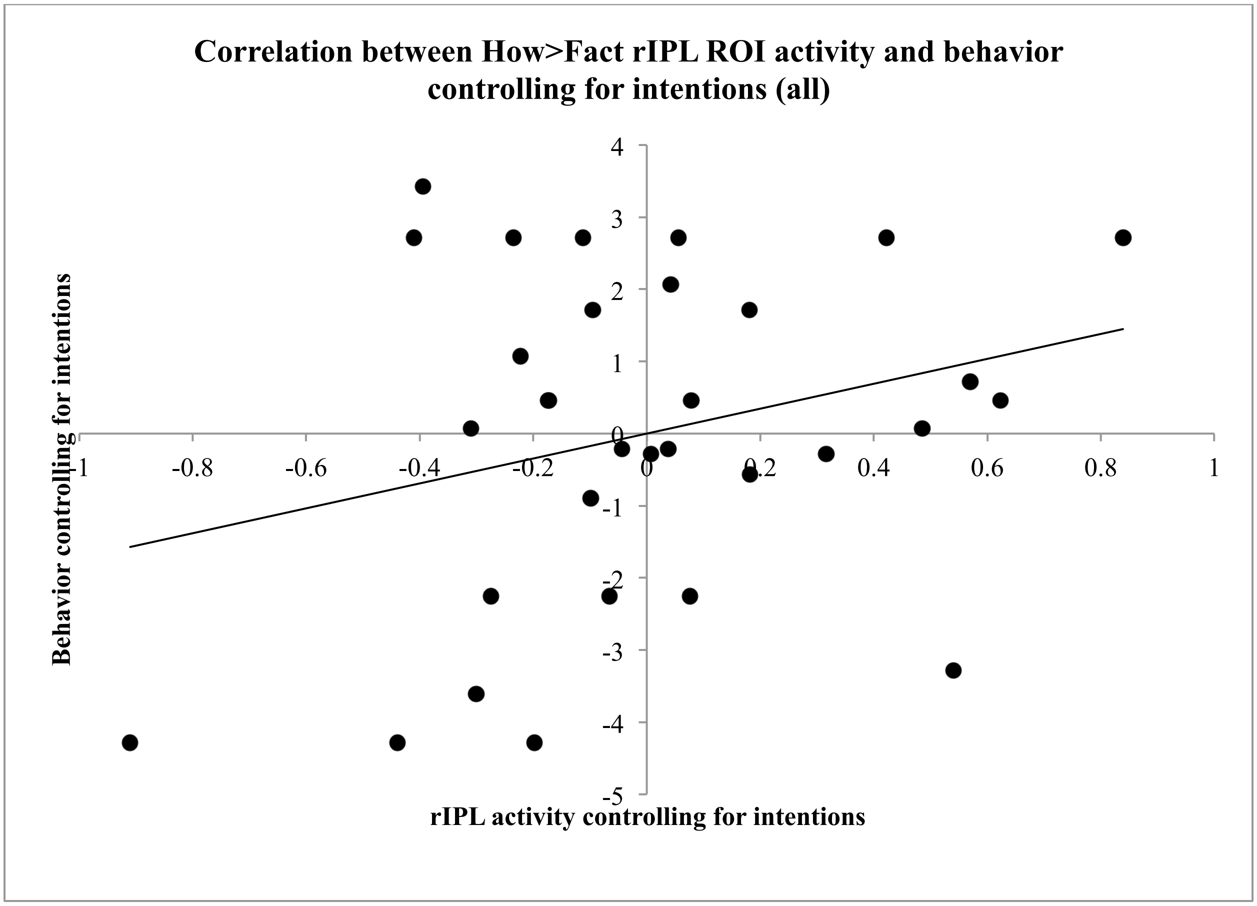


Figure 31. Correlation between rIPL activity during How messages relative to Fact messages and behavior controlling for intentions for users, $r(11) = .12$, $p = .34$, vs. non-users, $r(15) = .17$, $p = .24$.

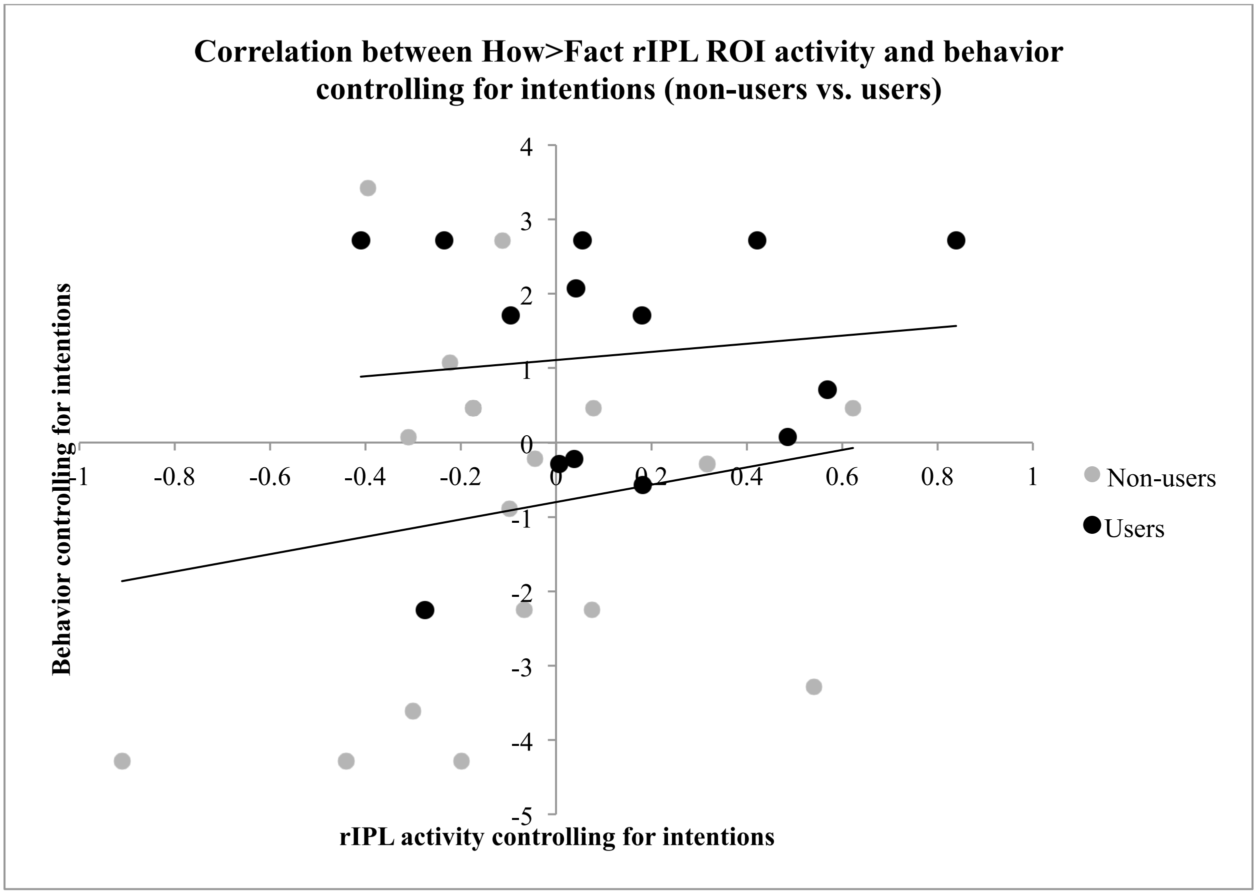


Figure 32. Correlation between MPFC activity during Why_{gain} messages relative to How messages and behavior controlling for intentions, $r(28) = .27$, $p = .072$.

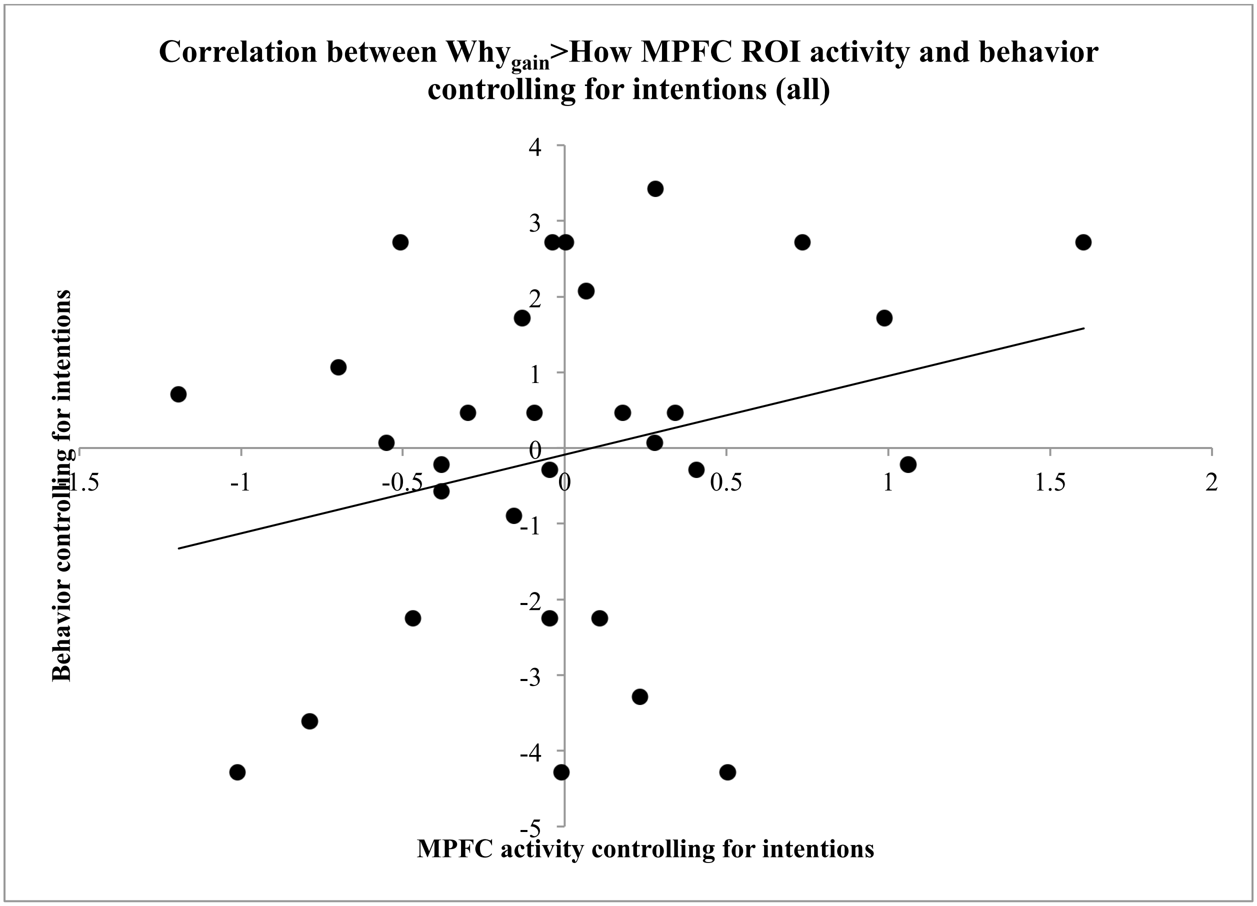


Figure 33. Correlation between rIPL activity during Why_{gain} messages relative to How messages and behavior controlling for intentions, $r(29) = .25$, $p = .091$.

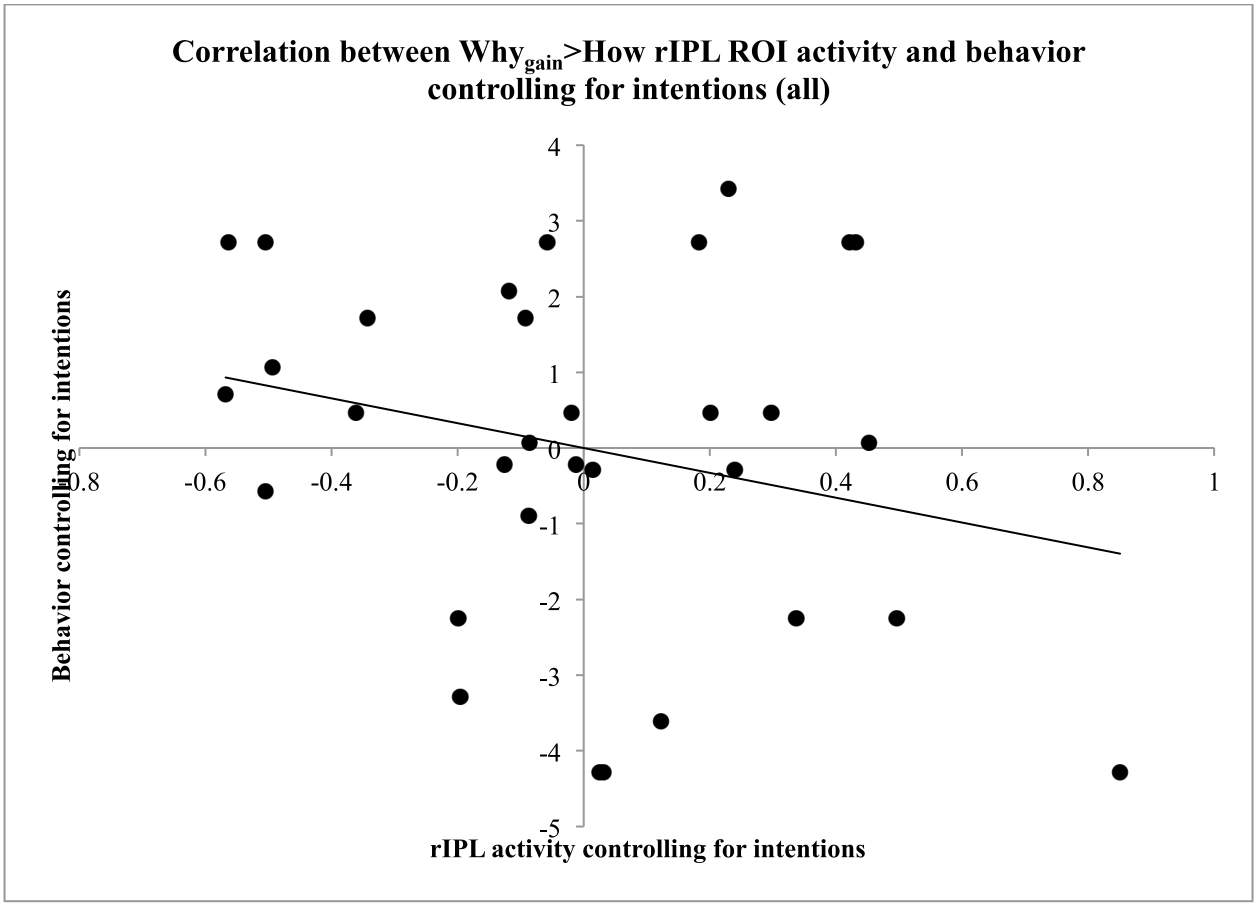


Figure 34. Correlation between MPFC activity during Why$_{gain}$ messages relative to How messages and behavior controlling for intentions for users, $r(10) = .29$, $p = .17$, vs. non-users, $r(15) = .33$, $p = .093$.

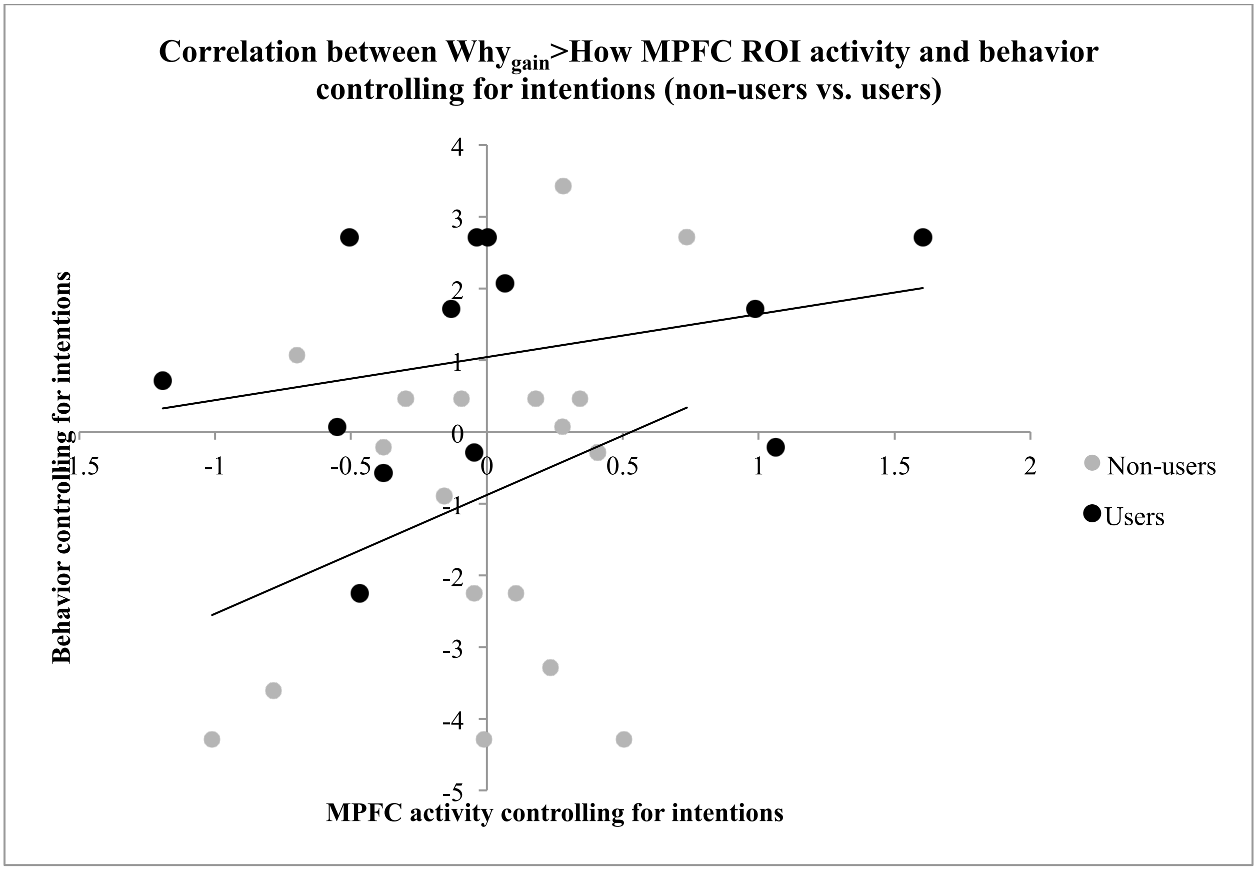
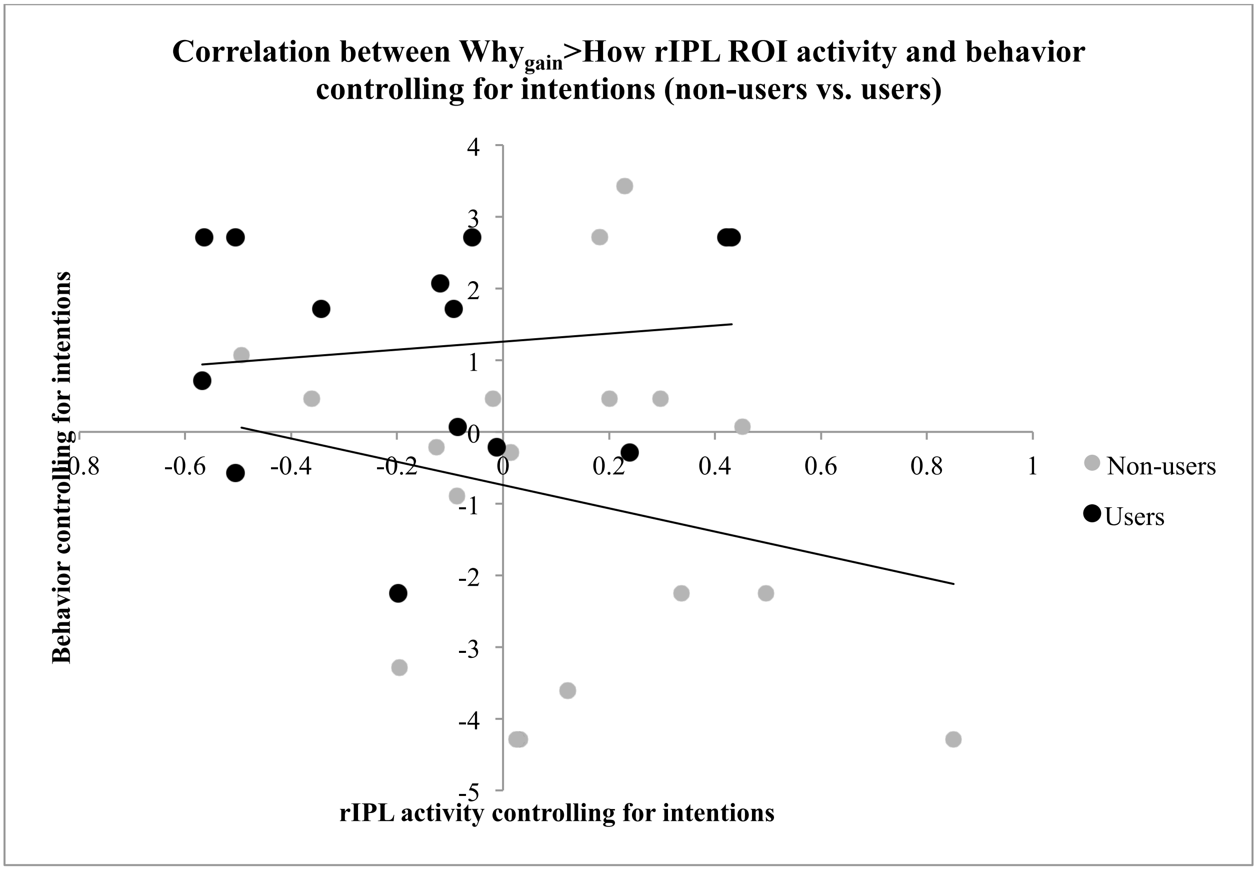


Figure 35. Correlation between rIPL activity during Why_{gain} messages relative to How messages and behavior controlling for intentions for users, $r(11) = .12$, $p = .34$, vs. non-users, $r(15) = -.22$, $p = .19$.



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