Research Article

Association for Psychological Science

Psychological Science
2016, Vol. 27(7) 1027–1035

DOI: 10.1177/0956797616645673
pss.sagepub.com
SAGE

The Power of the *Like* in Adolescence: Effects of Peer Influence on Neural and Behavioral Responses to Social Media

Lauren E. Sherman[1,2,3], Ashley A. Payton[4], Leanna M. Hernandez[2,4], Patricia M. Greenfield[1,3], and Mirella Dapretto[2,5]

[1]Department of Psychology, University of California, Los Angeles; [2]Ahmanson-Lovelace Brain Mapping Center, University of California, Los Angeles; [3]Children's Digital Media Center @ Los Angeles, University of California, Los Angeles, and California State University, Los Angeles; [4]Interdepartmental Neuroscience Program, University of California, Los Angeles; and [5]Department of Psychiatry and Biobehavioral Sciences, University of California, Los Angeles

Abstract

We investigated a unique way in which adolescent peer influence occurs on social media. We developed a novel functional MRI (fMRI) paradigm to simulate Instagram, a popular social photo-sharing tool, and measured adolescents' behavioral and neural responses to *likes*, a quantifiable form of social endorsement and potential source of peer influence. Adolescents underwent fMRI while viewing photos ostensibly submitted to Instagram. They were more likely to *like* photos depicted with many likes than photos with few likes; this finding showed the influence of virtual peer endorsement and held for both neutral photos and photos of risky behaviors (e.g., drinking, smoking). Viewing photos with many (compared with few) likes was associated with greater activity in neural regions implicated in reward processing, social cognition, imitation, and attention. Furthermore, when adolescents viewed risky photos (as opposed to neutral photos), activation in the cognitive-control network decreased. These findings highlight possible mechanisms underlying peer influence during adolescence.

Keywords

adolescent development, social cognition, social influences, risk taking, neuroimaging, open materials

Received 9/12/15; Revision accepted 3/31/16

Social media are immensely popular among adolescents: Nearly 90% of American teens report being active users, and young people have continually outpaced other age groups in adopting new media (Lenhart, 2015). Given this prevalence, it is unsurprising that parents, educators, and the popular press have expressed concerns about the effects of social media on social-skill development and interpersonal interactions. Frequently, these concerns manifest themselves in questions about the effect of social media on the developing brain. Nonetheless, few studies have examined neural mechanisms underlying any kind of social-media use (Choudhury & McKinney, 2013; Mills, 2014).

The neural correlates of social-media use are particularly important to understand in the context of adolescence, and not only because adolescents are enthusiastic users. Adolescence is especially important for social cognitive development; it is theorized to be a sensitive period during which young people are uniquely attuned to the complexities of interpersonal relationships (Baird, 2012; Blakemore & Mills, 2014). Subcortical regions functionally associated with emotion processing and reward undergo considerable changes and reorganization during puberty (Brenhouse & Andersen, 2011; Sisk & Foster, 2004). The dopaminergic system and related regions in the striatum are implicated in

---

Corresponding Author:
Lauren E. Sherman, Department of Psychology, UCLA, 1285 Franz Hall, Box 951563, Los Angeles, CA 90095-1563
E-mail: lsherman@ucla.edu

potential mechanisms underlying two common features of adolescence: escalation in risk-taking behaviors and increased desire to spend time with and earn the approval of peers (Steinberg, 2008). For example, when adolescents completed a risky driving task alone or in the presence of peers, the presence of peers was associated with increases in both risk taking and activity in the nucleus accumbens (NAcc), a hub of reward circuitry (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011). Smith, Chein, and Steinberg (2014) replicated these behavioral effects when peers were virtually connected, demonstrating that peer influence also occurs online (see also Cohen & Prinstein, 2006).

Less is known about how features unique to social media contribute to peer influence. For example, digital and in-person communication differ significantly in their affordance for quantifiable interactions. Whereas in-person communication is necessarily qualitative and involves subjective interpretation, many online environments allow for feedback that is purely quantitative. For example, a feature of most social media tools is the ability to *like* an image, text, or other piece of information, allowing for a simple, straightforward measure of peers' endorsement. For adolescents, who are particularly attuned to peer opinion, this *quantifiable social endorsement* may serve as a powerful motivator. Furthermore, quantifiable social endorsement provides a unique research opportunity: Although it is a form of interaction that occurs in the real world, it is simple enough to be experimentally manipulated.

The present study is, to our knowledge, the first to replicate social media interaction in the MRI scanner; however, important earlier work using behavioral and functional MRI (fMRI) methods has demonstrated how peer endorsement biases values (e.g., Campbell-Meiklejohn, Bach, Roepstorff, Dolan, & Frith, 2010; Izuma & Adolphs, 2013; Klucharev, Hytönen, Rijpkema, Smidts, & Fernández, 2009). In these studies, adults rated stimuli, then learned how other people rated the same stimuli, and finally rated the stimuli a second time. Participants changed their ratings to conform to those of peers or experts and showed greater NAcc activation during trials on which they agreed with these individuals than during trials on which they did not agree. Our study differs from previous work in that adolescents viewed content posted on social media simultaneously with information about its popularity—much as content is typically experienced online. We thus tested whether initial impressions were colored by the content's popularity and explored the overall effects of positive peer opinion on brain responses.

Specifically, we investigated the neural correlates of viewing photos with many or few *likes* to assess the role of quantifiable social endorsement in peer influence. We recruited adolescents to participate in an "internal social network" that simulated Instagram, a popular photo-sharing tool. Participants submitted their own Instagram photos, and they believed that all photos would be seen and liked by peers. We tested the possibility that the number of likes appearing under each photo would affect participants' responses. We hypothesized that participants would tend to like photos liked by more peers and refrain from liking less popular photos. We also hypothesized that neural responses to popular and unpopular photos would differ. Given previous research suggesting that peer presence heightens NAcc response (Chein et al., 2011), we predicted that viewing other people's photos that had a greater number of likes would similarly elicit greater NAcc activation. Evidence linking NAcc response to social evaluation (Meshi, Morawetz, & Heekeren, 2013) and sharing information about the self (Tamir & Mitchell, 2012), as well as the well-documented role of the NAcc in reward and reinforcement in general, suggests that viewing one's own popular photos would also elicit greater NAcc activity.

Peer influence is very important during adolescence; it is a means by which adolescents learn how to behave appropriately in their sociocultural environment. However, peer pressure can be maladaptive when it reinforces dangerous behaviors, such as drunk driving or drug use. Furthermore, young people frequently post content online depicting risky behaviors, and this may affect their peers' tendency to engage in such behaviors (Huang et al., 2014). Thus, we also investigated whether quantifiable social endorsement specifically influenced responses to risky behaviors by including photos depicting these behaviors. Well-established theories of adolescent risk taking suggest that the NAcc interacts with neural regions implicated in cognitive control during risky decision making (Casey, 2015; Steinberg, 2008). Accordingly, we directly compared adolescents' neural activity as they viewed risky images and neutral images to examine whether exposure to risky content online would influence activity in cognitive-control regions, regardless of the supposed popularity of the photos.

Method

Participants and fMRI paradigm

Thirty-four typically developing adolescents (18 female; age range = 13–18 years) participated in the present study. Two of these 34 participants were excluded from fMRI data analysis, 1 because of scan-console malfunction and 1 because of excessive motion. The sample size reflects the maximum number of participants that we were able to recruit given available funding, as well as timing constraints imposed by an institutional upgrade of the MRI magnet. Participants completed written consent in accordance with the institutional review board at the University of California, Los Angeles.

During recruitment, participants were informed that they would be involved in a study examining the brain's responses during social-media use. Participants were asked to submit photos from their own accounts on Instagram, a popular social-media tool used for sharing photos on mobile devices and the Internet. They were told that all of these photos would be combined to form an internal social network, that every participant would see a feed of these photos in the MRI scanner, and that the photos would appear as they did on Instagram. In reality, participants saw only some of their own photos while in the MRI scanner; all other stimuli were selected by the study team from among publicly available images on Instagram. During the laboratory visit, each participant was instructed that approximately 50 other adolescents had already viewed the feed of Instagram photos. This step was taken to establish the size of the audience, and to standardize how many likes would be regarded as many or few, irrespective of the size of a given participant's own social network. Participants were told that they could see how many times each photo was liked by previous participants and that the feed would be updated after their visit to reflect any new likes they contributed. In reality, the number of likes displayed under each image was assigned by the study team, as described later in this section.

The social-media task was presented to participants in the scanner using magnet-compatible 3-D goggles (VisuaStim; Resonance Technology, Inc., Northridge, CA) with a resolution of 800 × 640 pixels. The task mimicked the experience of browsing Instagram on a smartphone: Participants viewed a feed of photos, each of which was accompanied by text indicating how many other people had already liked the image. Photos were displayed one at a time on a white background accompanied by two on-screen buttons prompting the participant to choose "♥Like" to like the image or "→Next" to move on to the next image without liking it (Fig. 1). Images were presented for 3,000 ms, with an interstimulus interval that varied between 1,000 and 11,000 ms.

Participants saw 148 unique photos. These included 42 risky images and 66 neutral, nonrisky images. Risky photos depicted alcohol, cigarettes, marijuana, smoking paraphernalia, rude gestures, or adolescents (male and female) wearing provocative or skimpy clothing. Neutral photos depicted typical images (e.g., pictures of friends, food, and possessions) found on the social-media profiles of adolescents. Participants also saw 40 of the images they had submitted from their own Instagram accounts.

Across participants, all neutral and risky images were assigned both a popular value of 23 to 45 likes and an unpopular value of 0 to 22 likes. Two versions of the imaging paradigm were created: In Version 1, half of the photos in each category (risky, neutral) were displayed with a high number of likes and half were displayed with a low number of likes. In Version 2, the displayed popularity was opposite that in Version 1 (i.e., if a photo was displayed with many likes in Version 1, it was displayed with few likes in Version 2). Thus, half of the participants saw Version 1 of each image and half saw Version 2 of each image; this allowed us to hold the content and the aesthetic quality of the images constant while manipulating popularity.

To assign likes to participants' own images, author L. E. Sherman divided the 40 photos into groups on the basis of content (e.g., a people group or an objects group, depending on the participant). Then, each of the groups of photos was randomly split into two halves; one half was assigned many likes, and the other half was assigned few likes. Thus, the content of the popular and unpopular images was similar. Half of each participant's own photos appeared with 23 to 45 likes, and the other half appeared with 0 to 22 likes. Note that likes were not distributed continuously and evenly across the spectrum of 0 to 45. We did not expect neural and behavioral responses to vary linearly as the number of likes increased; instead, we hypothesized that participants would display qualitatively different responses to popular images than to unpopular images. Thus, we used a bimodal distribution of likes in which the majority was clustered between 30 and 45 likes (popular photos) or between 0 and 15 likes (unpopular photos). We chose to use a bimodal distribution to clearly differentiate popular and unpopular images. Of the 148 photos displayed during the scan, only 8 were depicted with intermediate values of 23 to 29 likes and 8 were depicted with 16 to 22 likes; these 16 images were included to avoid any suspicion among participants that might be caused by the obviously bimodal distribution. In light of our experimental manipulation, our categorical analyses reflect the difference between popular and unpopular images.

During the scan, participants were asked to view the images as they appeared and to decide whether they personally liked each image using the criteria they would normally use when deciding to like pictures on Instagram. Participants selected "♥Like" or "→Next" by pressing one of two buttons on a button box.

Data acquisition and analyses

Neuroimaging data were collected using a 3-T MRI scanner (Trio; Siemens Healthcare, Erlangen, Germany). The social-media paradigm was presented during a functional echoplanar, T2*-weighted gradient-echo scan lasting 11 min and 44 s (repetition time = 2,000 ms, echo time = 28 ms, flip angle = 90°, matrix size = 64 × 64, 34 axial slices, field of view = 192 mm, 4-mm slices with a 1-mm interslice gap). Button-press data were recorded in E-Prime

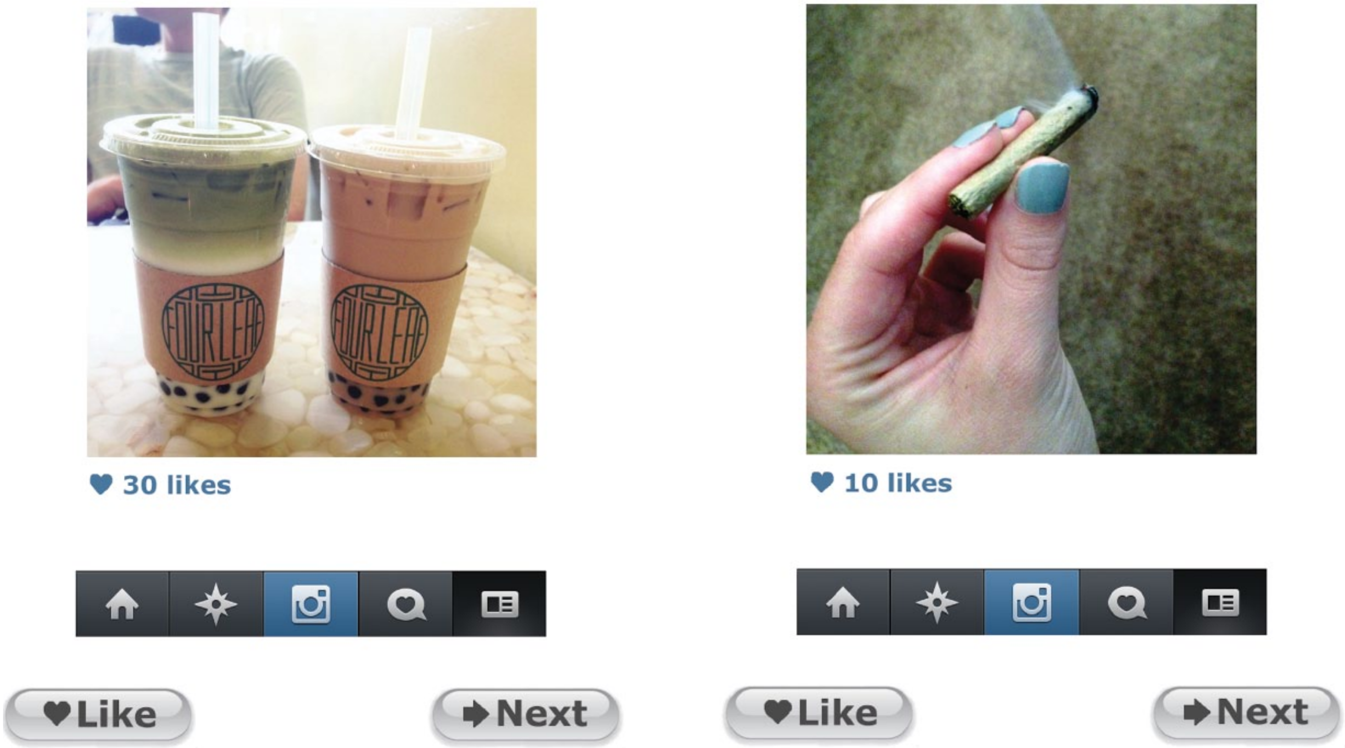

Fig. 1. Two examples of stimuli presented during the imaging paradigm. Participants saw innocuous photos of adolescents or everyday objects (e.g., the coffee drinks on the left) or images of objects related to risky behavior (e.g., the marijuana cigarette on the right) or adolescents engaging in risky behaviors. Images appeared as they would have in the Instagram app on a smartphone in the year 2014: The number of likes was displayed underneath each photo next to a heart icon, and the Instagram menu buttons were displayed beneath the likes. Finally, there were two buttons allowing participants to like an image ("♥Like") or to move on without liking the image ("→Next").

(Version 2.0; Psychology Software Tools, Sharpsburg, PA) and converted to IBM SPSS Statistics format for analysis. Binomial tests were used to determine whether participants conformed to peers' responses more often than would be predicted by chance. fMRI data were preprocessed and analyzed using the Analysis of Functional NeuroImages (AFNI; Version 16.0.00) software environment (Cox, 1996) and the Functional MRI of the Brain software library (FSL; Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012). Preprocessing for each individual's data included image realignment to correct for head motion, normalization to the standard stereotactic space of the Montreal Neurological Institute's (MNI) 152-brain template, and spatial smoothing using a 5-mm full-width, half-maximum Gaussian kernel to increase signal-to-noise ratio.

For each participant, linear contrasts were calculated for several planned comparisons. Specifically, we modeled three linear contrasts comparing popular photos (many likes) and unpopular photos (few likes) in all three categories (i.e., neutral photos, risky photos, and participants' photos). In addition to modeling the six types of stimuli at the first level, we included several other parameters. These included the participant's button-press choice and reaction time for each trial and the luminosity of each image as determined using Adobe Photoshop. Group-level random-effects analyses were then conducted across all participants. At the group level, a prethreshold binary mask consisting of all regions exhibiting significant activity for any type of photo, compared with a fixation cross on a white background, was used to restrict our analyses to regions displaying significant task-related activity. Specifically, we first individually contrasted the six types of stimuli (e.g., neutral photos with many likes, neutral photos with few likes, risky photos with many likes) > fixation and then added the maps of each of these individual contrasts (thresholded at $z > 1.7$, corrected for multiple comparisons at $p < .05$) together. The final mask covered a considerable portion of the cortex and subcortex. Along with all of our group contrast maps, it is available for download at NeuroVault (http://neurovault.org/collections/RYSBTTMN/). We performed contrasts examining the effect of popularity (many likes > few likes and the reverse) for neutral photos, risky photos, and participants' photos. We also compared all neutral photos ostensibly submitted by peers with all risky photos ostensibly submitted by peers.

To test our a priori hypothesis that popular photos would elicit significantly greater activation in the bilateral

NAcc than unpopular photos would, we used a small-volume-correction approach. Our functional regions of interest (ROIs), derived from an independent sample of participants completing a monetary-incentive-delay task (Tamir & Mitchell, 2012), consisted of two 8-mm spheres in the left and right NAcc (MNI coordinates: $x = 10$, $y = 6$, $z = -4$, and $x = -8$, $y = 4$, $z = -6$, respectively). AFNI's 3dClustSim was used to determine that a contiguous cluster of 53 or more voxels was necessary to meet statistical criteria within these ROIs. To examine whether the many likes > few likes contrast differed significantly as a function of type of photo (neutral, risky, participant), we extracted parameter estimates (regression coefficients) from the bilateral ROIs for each contrast of interest and performed paired-samples t tests using IBM SPSS.

Results

To determine whether participants were significantly more likely than chance to match the supposed opinions of peers (i.e., to like popular images and to refrain from liking unpopular images), we conducted a series of binomial tests. Across all photos presented during the scan, participants matched their peers significantly more frequently than expected by chance ($p < .00001$). This effect was also significant for each individual type of photo, including neutral images ostensibly provided by peers ($p = .03$), images depicting risk-taking behaviors ostensibly provided by peers ($p = .03$), and the participants' own images ($p < .00001$). The effect was significantly larger for participants' own photos than for either neutral images, $\chi^2(1, N = 3{,}544) = 10.1$, $p = .001$, or risky images, $\chi^2(1, N = 2{,}736) = 6.6$, $p = .01$.

Neural responses also differed according to the number of likes for neutral, risky, and participants' own photos. Figure 2a depicts regions in which activity was significantly greater when photos were depicted as having garnered many versus few likes for neutral, risky, and participants' own photos. The regions of significantly greater activity for many likes compared with few likes differed by photo type. When participants viewed neutral photos with many likes, they showed significantly greater activity in the visual cortex extending to the precuneus and in the cerebellum (see Table S1 in the Supplemental Material available online). When participants viewed risky photos with many likes (compared with risky photos with few likes), significantly greater activity was found in one cluster in the left frontal cortex, extending from the precentral gyrus through the middle frontal gyrus and inferior frontal gyrus (Table S1). When participants viewed their own photos, significantly greater activity in response to photos with many likes (compared with photos with few likes) was observed in several regions (Table S1). These included areas implicated in social cognition, such as the precuneus, medial prefrontal cortex, left temporal pole, lateral occipital cortex, and hippocampus (Mars et al., 2012; Zaki & Ochsner, 2009), as well as reward learning and motivation, including the nucleus accumbens, caudate, putamen, thalamus, ventral tegmental area, and brain stem (e.g., Haruno & Kawato, 2006; Schott et al., 2008).[1] Table S1 includes a complete list of regions. For all three photo types, the reverse contrast (few likes > many likes) yielded no significant activation in the whole brain.

Neural responses also differed according to whether the photo depicted risky behavior (Fig. 2b). When participants viewed neutral images (compared with risky images) ostensibly submitted by peers, significantly greater activity was observed in bilateral occipital cortex, medial prefrontal cortex, and the inferior frontal gyrus (for a complete list of regions, see Table S2 in the Supplemental Material). When viewing risky images compared with neutral images (i.e., the reverse contrast), participants demonstrated significantly less activation in a network of regions implicated in cognitive control and response inhibition (e.g., Blasi et al., 2006; Bressler & Menon, 2010; Sherman et al., 2014), including dorsal anterior cingulate cortex, bilateral prefrontal cortex, and lateral parietal cortex (Table S2).[2]

In addition to whole-brain analyses, we conducted ROI analyses on the basis of our a priori hypothesis that photos depicted with many likes would elicit significantly greater activation in the bilateral NAcc than would those depicted with few likes. Consistent with our hypothesis, there was greater activity in the left NAcc when participants viewed neutral images that had many likes than when they viewed neutral images that had few likes. We also observed greater bilateral NAcc activation when participants viewed their own images for the many likes > few likes contrast. For images depicting risk-taking behavior, likes had no effect on brain response in the NAcc ROI. In the right NAcc, activation was significantly greater when participants viewed their own photos than when viewing other people's neutral images, $t(31) = 2.34$, $p = .026$, or risky images, $t(31) = 2.45$, $p = .02$, but did not differ significantly in the left NAcc (for all comparisons, $p > .10$).

Discussion

The present study highlights a new and unique way in which peer influence occurs on social media: through quantifiable social endorsement. We found that the popularity of a photo had a significant effect on the way that photo was perceived. Adolescents were more likely to like a photo—even one portraying risky behaviors, such as smoking marijuana or drinking alcohol—if that photo had received more likes from peers. This effect was

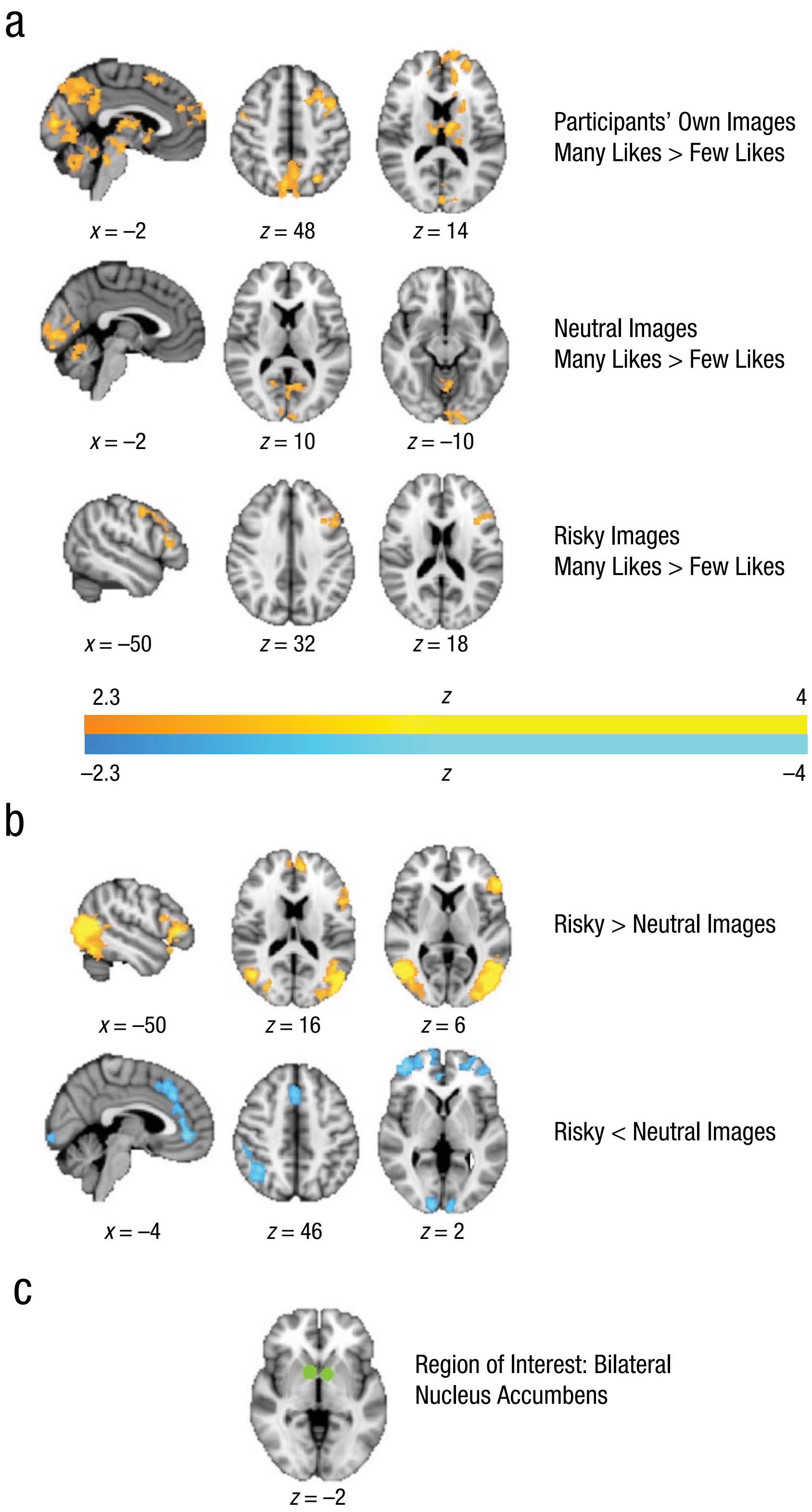

Fig. 2. Neural responses to Instagram photos with many likes compared with photos with few likes. The brain maps in (a) show neural regions with significant activity ($z > 2.3$, cluster corrected at $p < .05$) for the many likes > few likes contrast, for each of the three types of photos. The brain maps in (b) show neural regions with significant activity ($z > 2.3$, cluster corrected at $p < .05$) for the risky > neutral contrast and the risky < neutral contrast. Brain images are shown by radiological convention (i.e., left side of the brain is on the right). The brain map in (c) shows the location of the region of interest in the nucleus accumbens that was identified using a monetary-incentive-delay task in an independent sample of young adults (Tamir & Mitchell, 2012).

especially strong for photos the participants themselves had supplied. Adolescence is a period during which self-presentation is particularly important, including on social media; thus, this significantly greater effect may reflect the relative importance of self-presentation versus providing feedback to others.

Neural responses also differed according to number of likes. For all three types of photos, participants exhibited greater brain activity for photos with more likes. The regions of greater activity included areas implicated in social cognition and social memories, including the precuneus, medial prefrontal cortex, and hippocampus (Mars et al., 2012; Zaki & Ochsner, 2009), as well as the inferior frontal gyrus, which is implicated in imitation (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008). When participants viewed their own photographs or neutral photographs ostensibly submitted by peers, greater activity in the visual cortex was observed in response to photos with many likes compared with photos with few likes, even though we controlled for photos' luminosity and content. The increased activation suggests that participants may have scanned popular images with greater care. Taken together, our imaging findings suggest that adolescents perceive information online in a qualitatively different way when they believe that this information is valued more highly by peers. The exact nature of these changes differs depending on the content depicted in the photo.

Our ROI analysis suggests that the NAcc, an important hub of the brain's reward circuitry, is implicated in the experience of receiving positive feedback on one's own images as well as viewing other people's images that have been endorsed by peers. The NAcc response, like our behavioral effects, was particularly robust for participants' own photos, suggesting that self-presentation can be especially rewarding and a motivation for using social networks (Manago, Graham, Greenfield, & Salimkhan, 2008). The popularity of risky photos (or lack thereof) had no differential effect on NAcc response. However, several participants in our adolescent sample reported no experiences with drugs and alcohol; this lack of familiarity may have contributed to the failure to detect a peer effect in the NAcc when comparing popular and unpopular risky images. Future research should examine the effect of popularity on NAcc response to risky photos in adolescents who report greater experience with drugs and alcohol.

Although quantifiable social endorsement is a relatively new phenomenon, we believe that the implications of this experiment extend beyond the digital context. Quantifiable social endorsement is a simple but nonetheless significant example of sociocultural learning; a like is a social cue specific to adolescents' cultural sphere, and adolescents use this cue to learn how to navigate their social world. Adolescents learn from quantifiable social endorsement in multiple ways, as evidenced by participants' differentiated neural responses to their own and other people's photos. Peers socialize one another to norms in multiple modes, including modeling appropriate behavior (behavioral display) and reinforcing appropriate behavior in other people (behavioral reinforcement; Brown, Bakken, Ameringer, & Mahon, 2008). Social media embody both modes of socialization: Adolescents model appropriate behavior and interests through the images they post (behavioral display) and reinforce peers' behavior through the provision of likes (behavioral reinforcement). Unlike offline forms of peer influence, however, quantifiable social endorsement is straightforward, unambiguous, and, as the name suggests, purely quantitative.

Although the present study does not allow us to directly compare in-person versus online peer influence, our findings are in line with results from previous research suggesting that the presence of peers heightens responses in reward circuitry and leads to differences in behavioral decision making (Chein et al., 2011). Furthermore, the present inquiry is, to our knowledge, the first to document that quantifiable social endorsement, a ubiquitous feature of social media, produces these measurable neural and behavioral effects. Future research should build on our findings to investigate how individual differences in neural response map onto behavioral outcomes: Can individual neural responses predict the degree of conformity that adolescents will demonstrate?

Sociocultural learning can be adaptive, in that it allows adolescents to flexibly learn from their environment. In the case of socialization to risky behavior, however, it can also be maladaptive. Multiple theoretical models (Casey, 2015; Steinberg, 2008) posit that risk taking in adolescence arises in part from heightened neural sensitivity to reward combined with immature capacity for cognitive control. In results that are in line with these models, we found that a network implicated in cognitive control (e.g., Seeley et al., 2007) was less active when participants viewed images depicting risky behavior (compared with neutral images). Certainly, viewing photos online does not, in itself, constitute a risk. It is therefore all the more striking that when simply viewing photos of risky behaviors ostensibly taken and posted by peers, adolescents exhibited decreased activation of the cognitive control network, possibly reflecting a mechanism by which peer behaviors disinhibit cognitive control in high-risk scenarios, thereby increasing the likelihood of engaging in risk taking. Future research should examine whether this decreased activation occurs into adulthood as well, or if this finding potentially reflects the immaturity of the prefrontal cortex in adolescence. Likewise, future research can shed light on whether the NAcc response to social reward shown in the present study is particularly heightened in adolescence, in line with previous research on monetary reward (Braams, van Duijvenvoorde, Peper, & Crone, 2015).

Our findings and approach have implications not only for social media researchers, but also for those studying social cognition more broadly. Social media provide a compelling opportunity to examine social interaction in an ecologically valid context. Typically, in the confines of an MRI scanner, social interaction is limited and artificial. Because social media exist on a screen, however, they can be effectively imported into the scanner environment. Our study provides proof of concept for quantifiable social endorsement, a ubiquitous form of online interaction that is easily experimentally manipulated. Future research can build on this foundation to examine how neural responses to quantifiable social endorsement predict individual differences in a variety of behavioral and psychological domains.

Action Editor

Eddie Harmon-Jones served as action editor for this article.

Author Contributions

L. E. Sherman developed the study concept, and L. E. Sherman, M. Dapretto, and P. M. Greenfield contributed to the study design. Data collection was performed by L. E. Sherman, A. A. Payton, and L. M. Hernandez. L. E. Sherman and A. A. Payton performed the data analysis and interpretation under the supervision of M. Dapretto and P. M. Greenfield. L. E. Sherman drafted the manuscript, and M. Dapretto and P. M. Greenfield provided important revisions. All the authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This research was supported by Grants C06-RR012169 and C06-RR015431 from the National Center for Research Resources, by Grant S10-OD011939 from the Office of the Director of the National Institutes of Health (NIH), by National Institute on Drug Abuse National Research Service Award F31-DA038578-01A1 (to L. E. Sherman), and by Brain Mapping Medical Research Organization, Brain Mapping Support Foundation, Pierson-Lovelace Foundation, The Ahmanson Foundation, Capital Group Companies Charitable Foundation, William M. and Linda R. Dietel Philanthropic Fund, and Northstar Fund. Authors are solely responsible for the content, which may not represent the official views of NIH.

Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

Open Practices

All materials have been made publicly available via Open Science Framework and can be accessed at https://osf.io/atj4d. The complete Open Practices Disclosure for this article can be found at http://pss.sagepub.com/content/by/supplemental-data. This article has received the badge for Open Materials. More information about the Open Practices badges can be found at https://osf.io/tvyxz/wiki/1.%20View%20the%20Badges/ and http://pss.sagepub.com/content/25/1/3.full.

Notes

1. The first set of regions also resembled the map for the term “social” on Neurosynth (http://neurosynth.org; a large-scale database of neuroimaging studies that provides meta-analytic reverse-inference analyses) as of January 2016 (Yarkoni et al., 2011). The second set of regions also resembled the map for the term “reward” on Neurosynth as of January 2016.

2. This set of regions also resembled the Neurosynth map for the term “cognitive control” as of January 2016.

References

Baird, A. A. (2012). The terrible twelves. In P. D. Zelazo, M. Chandler, & E. Crone (Eds.), *Developmental social cognitive neuroscience* (pp. 191–207). New York, NY: Psychology Press.

Blakemore, S. J., & Mills, K. L. (2014). Is adolescence a sensitive period for sociocultural processing? *Annual Review of Psychology*, *65*, 187–207.

Blasi, G., Goldberg, T. E., Weickert, T., Das, S., Kohn, P., Zoltick, B., . . . Mattay, V. S. (2006). Brain regions underlying response inhibition and interference monitoring and suppression. *European Journal of Neuroscience*, *23*, 1658–1664.

Braams, B. R., van Duijvenvoorde, A. C., Peper, J. S., & Crone, E. A. (2015). Longitudinal changes in adolescent risk-taking: A comprehensive study of neural responses to rewards, pubertal development, and risk-taking behavior. *The Journal of Neuroscience*, *35*, 7226–7238.

Brenhouse, H. C., & Andersen, S. L. (2011). Developmental trajectories during adolescence in males and females: A cross-species understanding of underlying brain changes. *Neuroscience & Biobehavioral Reviews*, *35*, 1687–1703.

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences*, *14*, 277–290.

Brown, B. B., Bakken, J. P., Ameringer, S. W., & Mahon, S. D. (2008). *A comprehensive conceptualization of the peer influence process in adolescence*. New York, NY: Guilford Press.

Campbell-Meiklejohn, D. K., Bach, D. R., Roepstorff, A., Dolan, R. J., & Frith, C. D. (2010). How the opinion of others affects our valuation of objects. *Current Biology*, *20*, 1165–1170.

Casey, B. J. (2015). Beyond simple models of self-control to circuit-based accounts of adolescent behavior. *Annual Review of Psychology*, *66*, 295–319.

Chein, J., Albert, D., O'Brien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science*, *14*(2), F1–F10.

Choudhury, S., & McKinney, K. A. (2013). Digital media, the developing brain and the interpretive plasticity of neuroplasticity. *Transcultural Psychiatry*, *50*, 192–215.

Cohen, G. L., & Prinstein, M. J. (2006). Peer contagion of aggression and health risk behavior among adolescent males: An experimental investigation of effects on public conduct and private attitudes. *Child Development*, *77*, 967–983.

Cox, R. W. (1996). AFNI: Software for analysis and visualization of functional magnetic resonance neuroimages. *Computers and Biomedical Research*, *29*, 162–173.

Haruno, M., & Kawato, M. (2006). Heterarchical reinforcement-learning model for integration of multiple cortico-striatal loops: fMRI examination in stimulus-action-reward association learning. *Neural Networks*, *19*, 1242–1254.

Huang, G. C., Unger, J. B., Soto, D., Fujimoto, K., Pentz, M. A., Jordan-Marsh, M., & Valente, T. W. (2014). Peer influences: The impact of online and offline friendship networks on adolescent smoking and alcohol use. *Journal of Adolescent Health*, *54*, 508–514.

Izuma, K., & Adolphs, R. (2013). Social manipulation of preference in the human brain. *Neuron*, *78*, 563–573.

Jenkinson, M., Beckmann, C. F., Behrens, T. E. J., Woolrich, M. W., & Smith, S. M. (2012). FSL. *NeuroImage*, *62*, 782–790.

Klucharev, V., Hytönen, K., Rijpkema, M., Smidts, A., & Fernández, G. (2009). Reinforcement learning signal predicts social conformity. *Neuron*, *61*, 140–151.

Lenhart, A. (2015). *Teens, social media & technology overview 2015*. Retrieved from the Pew Research Center Web site: http://www.pewinternet.org/2015/04/09/teens-social-media-technology-2015/

Manago, A. M., Graham, M. B., Greenfield, P. M., & Salimkhan, G. (2008). Self-presentation and gender on MySpace. *Journal of Applied Developmental Psychology*, *29*, 446–458.

Mars, R. B., Neubert, F., Noonan, M. P., Sallet, J., Toni, I., & Rushworth, M. F. S. (2012). On the relationship between the "default mode network" and the "social brain." *Frontiers in Human Neuroscience*, *6*, Article 189. doi: 10.3389/fnhum.2012.00189

Meshi, D., Morawetz, C., & Heekeren, H. R. (2013). Nucleus accumbens response to gains in reputation for the self relative to gains for others predicts social media use. *Frontiers in Human Neuroscience*, *7*, Article 439. doi:10.3389/fnhum.2013.00439

Mills, K. L. (2014). Effects of Internet use on the adolescent brain: Despite popular claims, experimental evidence remains scarce. *Trends in Cognitive Sciences*, *18*, 385–387.

Pfeifer, J. H., Iacoboni, M., Mazziotta, J. C., & Dapretto, M. (2008). Mirroring others' emotions relates to empathy and interpersonal competence in children. *NeuroImage*, *39*, 2076–2085.

Schott, B. H., Minuzzi, L., Krebs, R. M., Elmenhorst, D., Lang, M., Winz, O. H., . . . Düzel, E. (2008). Mesolimbic functional magnetic resonance imaging activations during reward anticipation correlate with reward-related ventral striatal dopamine release. *The Journal of Neuroscience*, *28*, 14311–14319.

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., . . . Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of Neuroscience*, *27*, 2349–2356.

Sherman, L. E., Rudie, J. D., Pfeifer, J. H., Masten, C. L., McNealy, K., & Dapretto, M. (2014). Development of the Default Mode and Central Executive Networks across early adolescence: A longitudinal study. *Developmental Cognitive Neuroscience*, *10*, 148–159.

Sisk, C. L., & Foster, D. L. (2004). The neural basis of puberty and adolescence. *Nature Neuroscience*, *7*, 1040–1042.

Smith, A. R., Chein, J., & Steinberg, L. (2014). Peers increase adolescent risk taking even when the probabilities of negative outcomes are known. *Developmental Psychology*, *50*, 1564–1568.

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, *28*, 78–106.

Tamir, D. I., & Mitchell, J. P. (2012). Disclosing information about the self is intrinsically rewarding. *Proceedings of the National Academy of Sciences, USA*, *109*, 8038–8043.

Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*, *8*, 665–670.

Zaki, J., & Ochsner, K. (2009). The need for a cognitive neuroscience of naturalistic social cognition. *Annals of the New York Academy of Sciences*, *1667*, 16–30.