How Do Peer Awards Motivate Creative Content? Experimental Evidence from Reddit

Gordon Burtch,[a] Qinglai He,[b] Yili Hong,[c] Dokyun Lee[a]

[a] Questrom School of Business, Boston University, Boston, Massachusetts 02215; [b] Wisconsin School of Business, University of Wisconsin-Madison, Madison, Wisconsin 53706; [c] C.T. Bauer College of Business, University of Houston, Houston, Texas 77204
Contact: gburtch@bu.edu, https://orcid.org/0000-0001-9798-1113 (GB); heqinglaii930@gmail.com, https://orcid.org/0000-0002-4967-6453 (QH); yilihong@uh.edu, https://orcid.org/0000-0002-0577-7877 (YH); leedokyun@gmail.com, https://orcid.org/0000-0002-3186-3349 (DL)

Abstract. We theorize peer awards' effects on the volume and novelty of creative user-generated content (UGC) produced at online platform communities. We then test our hypotheses via a randomized field experiment on Reddit, wherein we randomly and anonymously assigned Reddit's Gold Award to 905 users' posts over a two-month period. We find that peer awards induced recipients to make longer, more frequent posts and that these effects were particularly pronounced among newer community members. Further, we show that recipients were causally influenced to engage in greater (lesser) exploitation (exploration) behavior, producing content that exhibited significantly greater textual similarity to their own past (awarded) content. However, because the effects were most pronounced among new community members, who also produce content that, in general, is systematically more novel than that of established members to begin with, this process yields a desirable outcome: larger volumes of generally novel UGC for the community.

History: Accepted by Chris Forman, information systems.
Supplemental Material: Data files and the online appendix are available at https://doi.org/10.1287/mnsc.2021.4040.

1. Introduction

Platforms deploy a wide spectrum of tools and incentives to facilitate and motivate users to produce more user-generated content (UGC) and UGC of greater value to the platform's audience (Hukal et al. 2020). Literature on this subject has explored many approaches, including financial incentives (Cabral and Li 2015, Burtch et al. 2018, Khern-am-nuai et al. 2018), social norm–based interventions (Burtch et al. 2018), user incentive hierarchies (Goes et al. 2016), and awards or badges (Gallus 2017, Frey and Gallus 2018). To date, however, the bulk of this prior literature has focused its attention on UGC that is perhaps best characterized as informational in nature. Prior work has considered, for example, users' production of online reviews (Cabral and Li 2015, Burtch et al. 2018, Khern-am-nuai et al. 2018), encyclopedic content (Gallus 2017, Frey and Gallus 2018), and knowledge-exchanged in question and answer communities (Goes et al. 2016). However, a large segment of UGC is entertainment- and interest-based, focusing more on elements such as humor, fictional writing, or art (McKenzie et al. 2012, Wu and Zhu 2018). UGC novelty is a key factor that drives content consumption in these settings (Wu and Huberman 2007, Carmel et al. 2012), which, in turn, means that

novelty is also a focus in content production (Huberman et al. 2009).

Because of the diverse array of interests and preferences among content consumers on these platforms, rule-based, centrally provided incentives are difficult to codify and implement. Platform operators, such as Reddit, thus, often rely on discretionary mechanisms, allocated by members of the crowd in a scalable, decentralized manner. We consider one such mechanism here, a variation of the traditional, organization-provided award: the peer award. Peer awards enable individual users to recognize their peers' contributions at their own discretion and at any time. Peer awards are different from traditional awards in a number of important respects. First, because they are allocated at the discretion of a single individual in the community, the degree to which the awarding individual's preferences reflect or align with those of the broader community is not clear to the recipient. Second, peer awards are typically provided without explanation, often by an anonymous benefactor. As prior work has pointed out that the influence of awards depends crucially on "the reputation and the image of the institution offering the award as well as on the individual achievement yielding the award" (Kosfeld and Neckermann

2011, p. 97), the motivational benefits of peer awards are not altogether clear. Accordingly, we seek to assess peer awards' motivational influence here.

We also consider the unique potential of peer awards to facilitate the production of novel subject matter and material in UGC given the aforementioned importance of content novelty for engagement (Carmel et al. 2012). Peer awards may foster novel content in at least two ways. First, by helping to retain newer community members, peer awards may encourage contributions from individuals with new ideas and perspectives (Lampel et al. 2006, Perretti and Negro 2007, Toubia and Netzer 2017). Second, by building recipients' self-efficacy and intrinsic motivation, they may set the stage for established community members to explore and experiment with new ideas and subject matter (March 1991), fostering creativity (Malik and Butt 2017). Conversely, to the extent that peer awards provide a signal of audience preferences, peer awards may encourage new community members to engage in exploitation, to persist in producing their novel (compared with longer-tenured peers) subject matter. We, thus, address the following research questions: (1) To what extent are peer awards effective at motivating larger volumes of content contributions from community members in creativity-oriented UGC settings? (2) To what extent do the effects of peer awards accrue to new community members in particular? (3) Do peer awards induce systematically more exploration or exploitation behavior in community members' content production?

To evaluate these questions, we conducted a randomized field experiment on Reddit, leveraging its native peer award feature, Reddit Gold. We purchased and randomly allocated Gold Awards (anonymously) to 905 unique posts/users in three creative writing–oriented subreddits. We examined the effect that peer awards had on the quantity of content subsequently produced by recipients. Further, we examined the extent to which award receipt drove recipients toward exploration versus exploitation behavior in terms of both the domain of their subsequent contribution (i.e., the same subreddit in which the award was received versus alternative subreddits) and the semantic similarity between subsequent content and awarded content.

Our results demonstrate a clear positive effect of peer awards on the quantity of UGC that recipients produce. Compared with control subjects, treated subjects were 6.3% more likely to contribute additional content in the two weeks following treatment ($p < 0.01$), and award recipients authored posts that were 40.7% ($p < 0.001$) longer, on average, over the same period. Further, we find that the motivational effects manifest asymmetrically upon new members. Finally, we find evidence that award receipt causes recipients to engage in greater exploitation behavior, broadly. Treated subjects were significantly more likely to post content to the same subreddit on which the award was received and significantly *less* likely to post in other subreddits and crafted content that was significantly more similar (based on textual similarity measures) to their own past (awarded) content. Collectively, our results suggest that peer awards have positive collective benefits for the community; they help to retain new members, and they encourage those new members to produce more of their (relatively novel and, thus, more desirable) content.[1] In addition to empowering users to recognize their peers, peer awards also provide a useful revenue stream for the platform.

Our study contributes to prior research in a number of ways. Extending the prior literature on interventions to motivate UGC contribution (Cabral and Li 2015, Gallus 2017, Burtch et al. 2018, Frey and Gallus 2018, Khern-am-nuai et al. 2018, Huang et al. 2019), our work highlights how peer awards can be useful for fostering more content and more novel content in particular. Peer awards are particularly useful for attracting and retaining new community members. We also find that peer awards encourage an exploitation response on the part of those affected new members, and this response is desirable because new users provide systematically more novel content to begin with. Therefore, this paper also contributes the literature on the role of incentives in motivating exploitation (versus exploration) behaviors (Eisenberger and Rhoades 2001, Ederer and Manso 2013) in the context of creative content production.

2. Theory and Hypotheses
2.1. Peer Awards and UGC Production
A great deal of work has documented the positive impacts of different platform incentives on the production of user-generated content. For example, prior work has examined the efficacy of financial incentives (Cabral and Li 2015, Khern-am-nuai et al. 2018), social norm–based interventions (Chen et al. 2010, Burtch et al. 2018), user incentive hierarchies (Goes et al. 2016), badges (Ramirez 2017), and awards (Restivo and Van De Rijt 2012, Gallus 2017) as alternative means of motivating users in digital settings to produce more output. It is the latter work on which we build most directly, as we consider a relatively understudied form of award, namely the peer award.

Perhaps the most notable example of work studying the effects of awards on individuals' production of UGC is that by Gallus (2017). Randomly assigning a centrally administered symbolic award to various Wikipedia editors, Gallus found that recipients' productivity rose and that the award was particularly useful

for the retention of newly joined editors. There are a number of reasons to believe that peer awards, like more traditional awards, are useful for motivating an increased quantity of content production on the part of recipients (Ramirez 2017). First, peer awards deliver substantive validation and encouragement to recipients (Gallus 2017), implying that content creators' effort and work are recognized by their community (Frey and Gallus 2018). This recognition can increase recipients' self-efficacy and perception of their competence. Second, receipt of a peer award, like a traditional award, has the potential to induce generalized reciprocity. Third, peer awards may confer status in the community, making recipients more visible to peers. Recipients may expend greater effort to maintain that status or prestige.

There are a number of unique aspects of peer awards that distinguish them from traditional awards, which may, thus, lead to very different effects. First, peer awards are not provided by a centralized authority; rather, they communicate approval from a single peer in the community, who may hold niche preferences. Thus, whereas traditional awards may be interpreted as conveying extensive, broad appreciation and recognition from a broader collective, peer awards instead reflect intense appreciation from a single party. This may be a boon for the platforms that tend to employ peer awards given the open-ended nature of content they facilitate and the highly heterogeneous consumer preferences they seek to address. However, the fact that peer awards do not clearly or necessarily represent broad opinion may also imply relatively weaker motivational effects than what has previously been observed with traditional awards. Second, peer awards are often provided anonymously and without rationale (this is the default setting on Reddit, for example) despite that the motivational effects of traditional awards have been argued to depend on the reputation of the institution offering the award and on the individual achievement that led to the award (Kosfeld and Neckermann 2011). Although traditional awards are well defined, well justified, and regularly scheduled in their provision, peer awards are subjective and discretionary in their assignment. As a result, the positive effects of peer awards on user productivity may, in fact, be rather small if not absent altogether.

Nonetheless, there are also unique aspects of peer awards that may make them particularly motivating for recipients; their delivery timing and source both lend them well to the fostering and maintenance of intrinsic motivation. Some recipients may perceive traditional awards as an instrumental tool that the organization or platform employs to elicit desirable behavior (Morgan 1984). In extreme cases, such a perception may lead recipients to view awards as a tool of control, undermining their autonomy and thereby diminishing their intrinsic motivation (Deci and Ryan 2002). Such perceptions are more likely to manifest when awards are preplanned, and contributors are aware of them in advance of task performance (Deci et al. 1999). By contrast, peer awards are not preplanned; individual members of the community assign the award following task performance at their own discretion. Award assignors' motives are, thus, more likely to be viewed as pure because they are unlikely to have a significant personal interest in the recipient's subsequent contributions. Peer awards are, thus, more likely to foster and maintain recipients' intrinsic motivations.

Thus, although some aspects of peer awards may impede any positive motivational effects, the simultaneous presence of other aspects that may amplify positive motivational effects leads us to hypothesize a positive relationship between receipt of a peer award and the quantity of content that users subsequently produce.

Hypothesis 1. *Peer awards have a positive effect on the volume of UGC that users produce.*

2.2. Peer Awards and Content Novelty

Several studies have attempted to measure the novelty of textual documents. A stream of literature in document retrieval deals with the topic of novelty mining, which seeks to identify documents containing novel, nonredundant information, which may be useful for corporate/competitive intelligence and cybersecurity practices (Tsai et al. 2010). Recently, scholars in marketing (Toubia and Netzer 2017) and strategy (Balsmeier et al. 2017) have also begun to develop text-mining measures to identify innovative, novel ideas, for example, in patents. One common method of quantifying textual novelty in past literature, which we also employ here, relies on vector representations of documents, which are used to calculate distance metrics, for example, Jaccard or cosine distance (Hass 2017).

In the literature on UGC, a number of studies have leveraged such measures to evaluate the association between content novelty and popularity or engagement. For example, Carmel et al. (2012) examine the novelty of blog posts relative to alternative sets of reference posts and show that novelty is an informative predictor of content popularity. Other work demonstrates that the linguistic novelty of Reddit post titles (Lakkaraju et al. 2013) and post content (Mendelsohn and Li 2017) are informative predictors of engagement. Despite their correlational nature, these past studies collectively suggest that UGC novelty is an important determinant of content engagement and popularity, both generally and at Reddit specifically.[2] A natural question we, therefore, explore is the manner and extent to which incentives, namely peer awards, influence the novelty of content that users

produce. Although a number of prior works have sought to measure and evaluate the effects of novelty, little prior work has sought to understand how novelty can be encouraged in UGC production as we seek to analyze in this paper.

We consider two alternative paths by which novel content may manifest. First, new entrants may bring with them novel ideas and perspectives, making them more likely to produce novel material. For example, Perretti and Negro (2007) study the relationship between film production team composition and "genre innovation" in Hollywood. These authors demonstrate that innovation is more likely to occur in the film context when new members enter production teams. These results are generally consistent with prior claims that film producers see greater market success when they blend in novel elements with material (Lampel et al. 2006). Second, as frequently considered in the innovation literature (March 1991), innovation may manifest from individual experimentation and exploration. We, thus, consider each of these two paths to novelty separately, considering whether and to what extent peer awards may be particularly effective for retaining and motivating new community members as well as the extent to which peer awards may induce exploration (exploitation) behavior in the content-generation process.

We first conceptualize that peer awards will have a particularly strong motivating influence upon new community members. Peer recognition and a feeling of inclusion are particularly meaningful for new community members. This is because new members of the community hold fewer community bonds and ties (Ren et al. 2007). Whereas established members are more likely to hold community attachments that motivate their contributions, new members are particularly responsive to peer outreach and expressions of approval and recognition. In this respect, our expectations are consistent with the findings of Gallus (2017) around the effects of more traditional awards on Wikipedia as she observed those awards were indeed particularly useful for the retention of newer editors. If peer awards are indeed particularly influential upon newer community members, this would have desirable implications for content novelty because new members tend to bring new ideas and content. Moreover, an outsized effect on newer community members might even imply the desirability of an exploitation response as this would trigger newer community members to continue producing their relatively (compared with established members) more novel content. We formalize our second hypothesis as follows:

Hypothesis 2. *The relationship between peer awards and UGC contribution volumes is stronger for newer community members.*

March (1991) first defined exploration as "things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation," and he defined exploitation as "such things as refinement, choice, production, efficiency, selection, implementation, execution" (p. 71). The possible effect of incentives on individuals' tendency to engage in exploration versus exploitation was notably raised by March (1991) in that seminal paper on the topic.

A stream of work has subsequently examined those effects empirically, typically within organizational settings involving regular employees, academics, or scientists (Zhou 1998, Azoulay et al. 2013, Ederer and Manso 2013, Lee and Meyer-Doyle 2017). This literature documents that incentives often induce workers to repeat what has worked well in the past (Ederer and Manso 2013), reducing innovative behavior, particularly when an incentive is tightly coupled to a worker's most recent work activities (Azoulay et al. 2013, Lee and Meyer-Doyle 2017). These prior observations are also consistent with much of the literature on individual creativity, which speaks to the undermining influence of extrinsic rewards on creativity. For instance, several studies document that extrinsically motivated individuals generate fewer original ideas (Taggar 2002, Anderson and Gasteiger 2008) and exhibit less creativity (Eisenberger and Armeli 1997, Eisenberger and Rhoades 2001). In the exploration–exploitation literature, recent work has documented that recent declines in performance tend to trigger individuals to engage in exploration to identify a new approach that offers better results (Døjbak Håkonsson et al. 2016).

However, the mechanisms for these negative effects of incentives on creativity that are identified in the literature suggest that peer awards may, in fact, yield an exploration response because peer awards are more likely than traditional awards to foster and maintain intrinsic motivation, as noted earlier, because of their source (peers rather than the platform operator) and discretionary (rather than preplanned) nature. Moreover, the absence of a clear rationale for peer awards may also make them more likely to yield an exploration response, bearing in mind the prior finding that the exploitation response to incentives is systematically weaker when incentives are decoupled from recent work activity (Azoulay et al. 2013, Lee and Meyer-Doyle 2017). And even the individual exploration–exploitation literature has noted that this decision depends crucially on an individual's emotional state such that positive emotions are more likely to drive exploration (Døjbak Håkonsson et al. 2016).

It is also important to bear in mind that the exploitation versus exploration effects of peer awards may depend as well on whether they operate asymmetrically

on newer versus more established community members. The exploration–exploitation literature makes clear that firms and individuals shift between periods of exploration or exploitation behavior, depending on their returns from recent initiatives (Holmqvist 2004, Døjbak Håkonsson et al. 2016). In fact, effective managerial decision making has been shown to depend on managers' ability to maintain attention and to effectively choose when to switch between exploration and exploitation states (Laureiro-Martínez et al. 2013). Firms and individuals experiment until they see promise and then shift to a period of refinement and exploitation. Conversely, when individuals or teams perceive success and reap the benefits of exploitation, this drives a positive emotional response and the building of comfort and confidence, which can, in turn, set the stage for an eventual shift toward exploration (Døjbak Håkonsson et al. 2016).

Because new community members are just beginning their tenure within the community, by definition, they can be characterized as beginning in a period of exploration when the peer award arrives. The signal of success that a peer award conveys may, thus, drive a shift into a period of exploitation. That is, as these individuals seek to learn "what works" in the noisy environment characterized by varied audience interests and preferences, the positive experience of a peer award may give them pause and drive recipients to invest more deeply in the same area. By contrast, an established contributor, well-versed in the community, is more likely to already be in an exploitation phase when the award arrives. Accordingly, such individuals may instead react primarily to the positive emotional effects of the positive feedback, responding with exploration behavior. Thus, given our prior hypothesis that new members are more responsive to peer awards, we expect that an exploitation response will dominate on average. Our third and final hypothesis is, therefore, as follows:

Hypothesis 3. *Peer awards drive an exploitation response in UGC production.*

3. Research Context

To assess these hypotheses, we conducted a randomized field experiment on Reddit, the fifth most visited website in the United States as of September 2020 with more than 430 million monthly active users.[3] Reddit is an ideal empirical context for our research because UGC features centrally on the site, embedding rich, textual content contributed by millions of active users. Reddit organizes posts into topic-specific, user-created communities, termed "subreddits," which cover a wide range of subject matter and to which interested users can subscribe. As of September 2020, there are more than 130,000 active subreddits on Reddit.

Similar to many other UGC platforms, Reddit allows its users not only to post content, but also to comment upon and evaluate peer content using upvotes and downvotes. Users can post stories, links, images, and videos, with which other users can then engage. In July 2010, Reddit introduced a novel feature for users to evaluate peer content: the Gold Award. The introduction of the Gold Award provided a way for users to recognize peers' contributions by badging them (referred to as "gilding"). In addition to the symbolic badge, the award provides a recipient with some modest economic benefits. For one week, the recipient receives an ad-free experience on Reddit and discounted access to certain affiliated service providers. Any Reddit user can purchase and assign a Gold Award to a peer; introduction of the award, thus, has the side benefit of providing Reddit with a novel revenue stream.

A unit of Gold presently costs users $1.99. Upon purchasing a unit, a user can assign it to any peer by gilding the post, comment, or profile page. As shown in Figure 1, once gilded, content is permanently highlighted with a gold badge. Although Gold is supplied anonymously to recipients, recipients can directly message the donor, for example, to say thanks, at which point the award assigner has the option to respond and thereby reveal the assigner's identity.
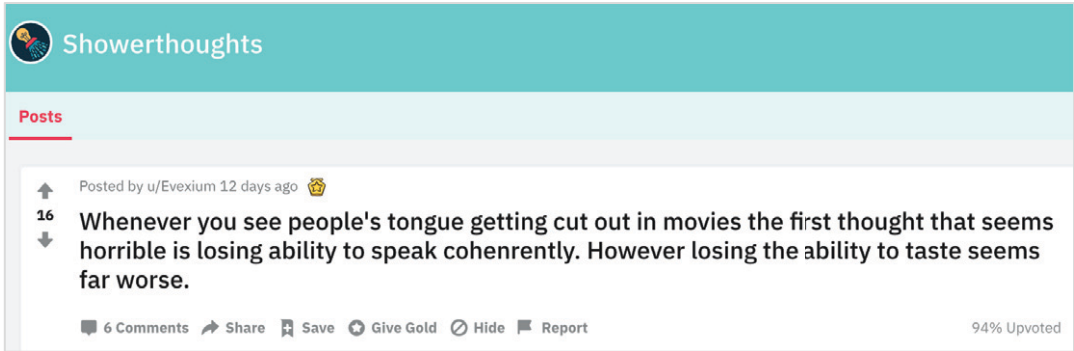
4. Experiment Design
4.1. Procedure
To test the impact of peer awards on user content generation, we leverage the Gold Award as our treatment and conduct a field experiment on Reddit, randomly and anonymously assigning Gold to users' posts over a two-month period.[4] The anonymous nature of the gilding process is ideal for our purposes because we wish to avoid confounding effects deriving from the award assigner's identity (Taylor et al. 2019). Moreover, recipients' ability to reply with a private message of thanks provides us with a way of exploring mechanisms by which the treatment influences their behavior given that recipients' messages often embed comments that speak to the recipient's beliefs, motivations, or interpretations.

Given our interest not only in understanding the effects of peer awards on UGC volumes, but also on UGC content, we purposefully targeted subreddits in which typical user posts predominantly comprise text and in which posts tend to be relatively lengthy. Table 1 presents brief descriptions of the three subreddits as well as the experiment setup. We selected three writing-focused subreddits (i.e., r/hfy, r/nosleep, and r/short-scarystories) as content on these subreddits are mostly original writings in which users have a relatively high degree of flexibility to create content with various desired characteristics, such as novelty. Writing-focused

Figure 1. (Color online) A Post on 'Showerthoughts' Subreddit That Has Been Awarded Gold

subreddits have become an important influential community on Reddit. For example, r/nosleep is ranked the 44th subreddit in terms of number of subscribers.[5]

Based on the number of new submissions in the three selected subreddits, we sample the posts using stratified randomization to ensure the samples follow the actual content distribution across three selected subreddits. We developed experimental infrastructure, comprising a series of Python scripts, to automate the execution of our field experiment, including collection of user posts and profile data, randomization, balance checks, treatment assignment, and post-treatment data collection. Each aspect was conducted using the Reddit application programming interface (API). The experiment extended over a multimonth period (between January and March 2019) with users gradually being recruited on a day-by-day (iterative) basis. Every 24 hours, our scripts would execute, identifying users who had posted new content to our three subreddits of interest since the last run. The scripts would then consider the identified users for recruitment, depending on a set of recruitment criteria. These recruitment criteria related to (i) whether the user had already entered the experiment previously (in which case the user would be ignored) and (ii) the features of the content the user posted. Thus, upon entering our experiment, any user was considered for treatment intervention or control only once. The complete experimental procedure, implemented every 24 hours, is detailed next.

First, given the large volume of daily posts on Reddit, with each iteration, we limited our attention to posts created on our three subreddits of interest over the prior 24-hour period. This step ensured that the posts (and associated users) considered in our experiment were still visible and of interest to the Reddit community at the time of treatment. Second, to ensure users were not treated repeatedly or randomized into competing experimental conditions, we filtered out all posts submitted by users who had previously entered into the experiment (e.g., on any prior iteration). Additionally, we filtered out some posts based on content features. Specifically, we filtered posts that had a low or negative number of net votes (an indication of lack of quality from other Redditors and, therefore, not plausible potential candidates for an organic Gold Award) to ensure treatment would not appear suspicious to the recipient or other users. We also filtered posts that were excessively short to ensure sufficient content for meaningful textual analysis.

Third, we retrieved each post author's meta information, including date of registration, overall link karma,[6] and comment karma[7] for use in randomization balance checks. Fourth, with user-level metadata and the post information extracted in the first step, we performed stratified (by subreddit) randomization, assigning newly identified post creators into a control or treatment group. This stratified (block) randomization ensured that posts were allocated between treatment and control groups in a balanced manner both across and within subreddits. If a user had multiple posts selected for the experiment on a given day, we would rerun the randomization until the user had only one post selected in either the treatment or control group. Note as well that we limited our treatment proportion to no more than 15% of posts in a given subreddit as we wished to avoid

Table 1. Experiment Setup

Subreddit	Description	Treatment group	Control group
r/hfy	Sci-fi, fantasy, and all other stories with a focus on humans	139	139
r/nosleep	Realistic horror stories	639	638
r/shortscarystories	Original short horror stories	127	128
Total number of users entering the experiment		905	905

raising concerns among members of the subreddit that our experiment was taking place. Finally, after confirming balanced randomization, we gilded each post in the treatment group, updated the list of recruited users, and manually confirmed that each treated post was, in fact, gilded successfully by visually inspecting the gilded posts through Reddit's browser interface.

Our experiment script was evaluated via two pilot tests on Reddit in October and December 2018 to ensure smooth execution. We began our full-scale execution on January 2, 2019. The experiment was conducted over the course of two months and completed on March 2, 2019. The users in the pilot tests were excluded from the full-scale experiment and associated data analysis. Our final sample for analysis comprises 1,810 Redditors (905 treated, 905 control). Each of these users was randomly assigned to either treatment or control in each 24-hour iteration. We evaluated randomization efficacy by assessing balance on content characteristics (i.e., $Intervention\_Post\_Score_i$), user characteristics (e.g., $Tenure_i$ and $Premium\_User_i$), users' prior positive feedback from the Reddit community (e.g., $Link\_Karma_i$, $Comment\_Karma_i$), and users' pre-experiment content generation activity (e.g., $Num\_Posts\_Before_i$, $Num\_Posts\_Before\_SS_i$, $Num\_Sub\_Before_i$). As shown in Table 2, pairwise t-tests on all factors in our final estimation sample yield insignificant differences in means.

4.2. Measures

We collected posts and comments submitted by all 1,810 users. Our main observation window extends from two weeks prior to a user's entry into our sample to two weeks following entry. A longer term dynamic

analysis is reported as additional findings. We construct several measures that enable us to evaluate our treatment's effects on user content-generation behavior, reflecting changes in user motivation (reflected by UGC quantity, namely posting volumes and post length) and changes in users' exploitation versus exploration behavior. We operationalize the latter based on the community in which a user posts (the subreddit in which treatment took place versus other subreddits) and based on measures of textual novelty, consistent with prior work (Carmel et al. 2012, Hass 2017).

Our UGC quantity outcomes are defined as follows. *Posted* is a binary indicator of whether users created any new posts during the two weeks after the treatment. *N_Posts* is a count measure of the number of posts generated by a user over the two weeks following the experimental intervention. We also consider the length (in characters) of textual content users produce on a per-post basis following the intervention, *Length*. If users do not post any content, all three measures take on a value of zero. For those users who create multiple new posts, *Length* takes on their average character length.

Our UGC exploration–exploitation outcomes are defined as follows. First, for each of the UGC quantity measures described, we further differentiate between whether the content is posted to the subreddit to which the Gold Award was given or to other subreddits. The former reflects a revisiting and possible refinement of the same subject matter and content domain, whereas the latter reflects a shift to explore and experiment with new subject matter and content domains. These alternative dependent variables are

Table 2. Randomization Check

N	Variable	Description	Mean (control)	Mean (treated)	t-statistic	p-value
1,810	$Intervention\_Post\_Score_i$	Net votes of post created by user i as of the time the treatment is assigned	43.401 (3.773)	46.696 (3.937)	−0.604	0.546
1,810	$Tenure_i$	The number of days elapsed after user i registered on Reddit	572.168 (24.088)	527.601 (21.759)	1.373	0.170
1,810	$Premium\_User_i$	Dummy variable, one if user i is a premium user, zero otherwise	0.025 (0.005)	0.019 (0.005)	0.959	0.338
1,810	$Comment\_Karma_i$	Comment karma represents user i's cumulative comment score on Reddit	2878.041 (323.033)	2971.07 (403.825)	−0.180	0.857
1,810	$Link\_Karma_i$	Link karma represents user i's cumulative post score on Reddit	1485.064 (120.662)	1534.081 (139.469)	−0.266	0.790
1,810	$Num\_Post\_Before_i$	The number of posts created by user i during the two weeks prior to the experiment	1.643 (0.112)	1.550 (0.121)	0.563	0.574
1,810	$Num\_Posts\_Before\_SS_i$	The number of posts created by user i under the treated subreddit during the two weeks prior to the experiment	0.295 (0.023)	0.283 (0.023)	0.374	0.709
1,810	$Num\_Sub\_Before_i$	The number of subreddits user i posts content on during the two weeks prior to the experiment	1.090 (0.058)	0.970 (0.056)	1.474	0.141

Note. Standard errors are reported in the parentheses.

named as explained in the prior paragraph with appended suffixes: *SS* refers to the same (on which the user was recruited into the experiment) subreddit, whereas *OthS* refers to other subreddits.

For our textual novelty measures, it is first important to define the reference set. As Carmel et al. (2012) note, novelty may be considered relative to at least two alternative reference sets of content. Content may be novel with respect to the same authors' own prior content, which those authors refer to as *self-novelty*, or it may be novelty with respect to other authors' content, which those authors refer to as *contemporaneous novelty*. Textual self-novelty is a natural focus for our analyses of exploration–exploitation behavior.[8]

To operationalize self-novelty, we use a common approach from the text-mining literature. Many textual novelty measures have been proposed over the years, predominantly based on measures of dissimilarity between new and past content (Allan et al. 2003, Soboroff and Harman 2005). A well-established approach in this literature employs the cosine distance between numeric representations of textual content in vector space. To construct such a measure, it is first necessary to construct vector representations of each piece of content within some embedding space, which is itself constructed based on a broader corpus of (historical) content.

To construct our embedding spaces, we consider three alternative techniques based on historical Reddit posts that were created prior to our experiment. We first utilized term frequency–inverse document frequency (TF-IDF) (Salton and Buckley 1988, Robertson 2004, Wang et al. 2019). TF-IDF is a scaled matrix that captures the frequency with which each word (term) from the data set occurs in each document. The raw term frequencies are scaled by the inverse of document frequency in order to down-weight words that are common across all documents and, thus, not very informative or useful in characterizing content. Intuitively, if a word is highly unique and only exists in a single document, its raw value is retained. In contrast, if a word appears across many documents, it is scaled down quite a bit.[9] Taking the cosine distance between two document vectors under a TF-IDF representation captures similarity in terms of scaled term frequencies.

Next, we employed latent semantic indexing (LSI) (Landauer and Dumais 1997, Hass 2017, Wang et al. 2019), also known as latent semantic analysis. Unlike a TF-IDF–based representation that focuses on vocabulary and ignores information about term co-occurrence across documents (and, thus, ignores semantic information), LSI seeks to reduce documents to a set of latent topics based on co-occurrence information. LSI reduces the term–document matrix to a set of latent topics (a lower rank approximation of the original document–word matrix) using singular value decomposition. A document is, thus, represented by a vector in the lower dimension (topic) space. Again, taking the cosine distance between two documents in the lower dimensional space captures similarity in terms of latent topic occurrence.

In addition to TF-IDF and LSI, we used a neural network–based document-embedding method called Doc2Vec (Le and Mikolov 2014, Lau and Baldwin 2016). Doc2Vec is an unsupervised method that takes as input a set of unlabeled documents (corpus) and finds a vector representation for each document, usually sized between 100 and 700. The neural network objective function is set up such that the semantic-spatial similarities between the words—and, by extension, the semantic-spatial similarities between chunks of text, that is, a document—are preserved in this lower dimensional vector space. In other words, each document is embedded in this space such that semantically similar documents are embedded near each other. Unlike TF-IDF– and LSI-based analyses, Doc2Vec can benefit by first training the model on a larger corpus beyond the content collected in our experiment and "transferring" learned estimates for further fine-tuning by our data set. This approach utilizes current advances in neural networks to ascertain similarities among documents.

The operationalization of our three measures of textual novelty is described as follows. For TF-IDF– and LSI-based measures, the reference corpora (global word lists) are drawn from the three focal subreddits on which our intervention posts were generated (both treated and control posts). This was done to account for the extreme degree of content heterogeneity across different subreddits. The resulting document representation is limited to a smaller subspace with greater resolution to discriminate different documents. This approach also has the benefit of eliminating the possibility that the reason we observe greater content similarity or novelty is strictly because of *where* content is being posted after treatment. That is, if we observe that users are more likely to post in the same subreddit as a result of being treated, we might then observe reduced textual novelty simply because the topic domain is now more likely to be the same. By requiring the document space to incorporate all subreddits in the data, we eliminate this explanation. The increased content similarity would reflect an additional change in the content, not attributable to the chosen subreddit/context.

Because Doc2Vec is a neural network–based method with many parameters, there is a benefit of using large data to pretrain the parameters (Le and Mikolov 2014). Lau and Baldwin (2016) empirically compare the performance of a Doc2Vec model trained on domain corpora with a model trained on larger external corpora (i.e., English Wikipedia and Associated Press English

news articles). They found that Doc2Vec works robustly in both scenarios. Considering that a small body of data were collected in our experiment, we used a pretrained Doc2Vec model based on the large English Wikipedia data set to create our embedding space and then further fine-tuned it based on our data set. The pretrained model leveraged in our study has also been widely utilized in research involving song lyrics (Yu et al. 2019) and debate analysis (Lawrence et al. 2017).

Our analysis is limited to those users who created at least one post in the posttreatment period as our text-based similarity measures are otherwise undefined. Our conditional sample in this analysis, thus, includes 607 subjects. This is important to note because this implies a caveat that any effects we observe may emerge because of from *whom* the treatment elicits content and not just solely because of changes in the behavior of individuals who continue to post. We later address this possible threat of selection through the application of matching techniques.

For all three measures, we recover vector representations of the intervention post (treated or control) as well as all posttreatment posts that the user created on the same subreddits. We then calculated the pairwise cosine similarity between the intervention post and each post that was created by the user on the same subreddit after the intervention. For users who created more than one post after the intervention, we took the average over the resulting values. Ultimately, this leaves us with three "average cosine similarity" values for each of the 607 subjects: one based on TF-IDF, one based on LSI, and one based on Doc2Vec, that is, $TFIDF\_Score_i$, LSI_Score_i, and, $Doc2Vec\_Score_i$. The descriptions and summary statistics for all variables used in the subsequent analyses are presented in Table 3.

5. Results

We begin by considering the average treatment effect of peer awards on the motivation of users to contribute as measured by the quantity of content produced. Subsequently, we examine the average effect of the treatment on our measures of exploration versus exploitation (where a user posts and the textual novelty of *what* a user posts). We then examine heterogeneity in these effects, considering the distinction between new versus longer tenured community members. Finally, we present a series of secondary analyses, exploring (i) the duration and dynamics of the treatment effects, (ii) whether and to what extent the treatment-induced content is systematically more (or less) popular among members of the community, and (iii) suggestive evidence of the mechanisms underlying the observed effects. In this final set of analyses, we provide qualitative evidence of treated users' perceptions based on messages they sent in reply to the award,

which is consistent with our overarching narrative that an asymmetric influence on new community members, who, in turn, are induced to engage in exploitation, yields systematically more novel content for the community, which, in turn, is more popular.

5.1. Descriptive Evidence

We begin with a model-free evaluation of mean differences between the treatment and control groups, considering the number of posts users create and the length of those posts. Figure 2(a) demonstrates that users are significantly more likely to submit subsequent content in the treatment condition as compared with users in the control condition (the bars indicate a 95% confidence interval). Figure 2(b) indicates that treated users also generate lengthier content. Taking posts across all subreddits into account, the treatment group generates posts with an average length of 527 words. In contrast, posts created by the control group have an average length of 407 words. This descriptive evidence indicates that peer awards are effective for motivating users, in general, to produce larger volumes of content, consistent with Hypothesis 1.

In each panel of Figure 2, we break the results down by whether content is produced in the same subreddit as the intervention post or a different subreddit. Here, we also see evidence that the effects manifest most strongly within the intervention subreddit. This descriptive evidence is consistent with Hypothesis 3, suggesting an average exploitation response as the new content that treated users produce appears to arrive primarily in the same subject matter domain.

Finally, Figure 3 provides descriptive evidence of the treatment's relationship with our textual novelty measures. The figures depict overlaid kernel density plots that compare the distribution of cosine similarity values, per user, distinguishing between individuals in the treatment group and those in the control. Based on Figure 3, (a)–(c), it is apparent that the treated group produces content that yields systematically higher cosine similarity with intervention content across all three of our measures ($TFIDF\_Score$, LSI_Score, and $Doc2Vec\_Score$).
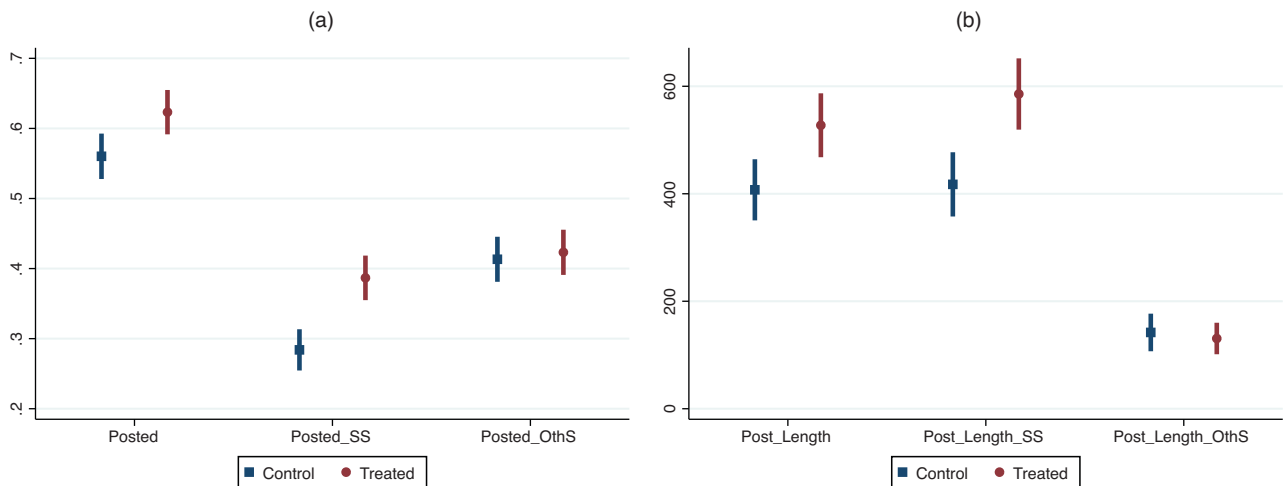
This observation is consistent with an average exploitation response as in the results related to the domain in which content is created. That is, treated subjects appear to produce content that is systematically less novel (more similar) to their intervention posts than control subjects. In Figure 3(d), we plot mean values for the treatment and control groups across all three measures and observe a descriptively similar result in each case; the similarity value is systematically higher in the treatment group.

5.2. Main Results
5.2.1. Treatment Effect on UGC Quantity. We next report on our econometric analyses of the relationships

Table 3. Variables and Descriptive Statistics

N	Variable	Description	Mean	Standard deviation	Minimum	Maximum
1,810	$Posted_i$	Dummy variable, one if user i has a post during the two weeks after the treatment, zero otherwise	0.592	0.492	0	1
1,810	$Posted\_SS_i$	Dummy variable, one if user i posted under the treated subreddit during the two weeks after the treatment, zero otherwise	0.335	0.472	0	1
1,810	$Posted\_OthS_i$	Dummy variable, one if user i has a post on subreddit beyond the treated one during the two weeks after the treatment, zero otherwise	0.418	0.493	0	1
1,810	N_Posts_i	The number of posts user i generated during the two weeks after the treatment	2.791	6.885	0	182
1,810	$N\_Posts\_SS_i$	The number of posts user i generated under the treated subreddit during the two weeks after the treatment	0.684	1.420	0	12
1,810	$N\_Posts\_OthS_i$	The number of posts user i generated on subreddits beyond the treated one during the two weeks after the treatment	2.107	6.497	0	176
1,810	$Length_i$	The average lengths of posts created by user i in words during the two weeks after the treatment	467.388	893.398	0	6,498.5
1,810	$Length\_SS_i$	The average lengths of posts under the treated subreddit created by user i in words during the two weeks after the treatment	501.556	970.953	0	6,866
1,810	$Length\_OthS_i$	The average lengths of posts on subreddits beyond the treated one created by user i in words during the two weeks after the treatment	136.324	494.536	0	6,191
607	$TFIDF\_Score_i$	The average cosine similarity score derived from the TF-IDF representation-based distance between postexperiment posts and treatment post created by user i	0.305	0.179	0.001	0.879
607	LSI_Score_i	The average cosine similarity score derived from the LSI representation-based distance between postexperiment posts and treatment post created by use i	0.660	0.204	−0.003	0.969
607	$Doc2Vec\_Score_i$	The average cosine similarity score derived from the Doc2Vec representation-based distance between postexperiment posts and treatment post created by user i	0.864	0.098	0.325	0.989
607	$Score_i$	The average net votes of posts under the treated subreddit created by user i during the two weeks after the treatment	112.70	422.06	0	7,985.714

Figure 2. (Color online) The Effect of Peer Awards on UGC Production

in question. We first investigate the motivational quantity effects, evaluating our binary indicator of whether a user posts again during the two weeks following treatment, *Posted*. We estimate the effect of our treatment on this outcome via a linear probability model (LPM). In Equation (1), users are indexed by I, and ε_i is the residual.

$$UGC\_Production_i / UGC\_Novelty_i$$
$$= \alpha + \beta \cdot Treatment_i + \varepsilon_i. \qquad (1)$$

The results of this estimation appear in Table 4. We report the results of our LPM on users' general UGC contributions across Reddit in column (1). We estimate that treated users are 6.3% more likely to submit content in the two weeks following treatment ($p < 0.01$) compared with users in the control group. When we consider whether a user submits content to the same subreddit (column (2)), we observe that the estimated effect increases to 10.3% ($p < 0.01$). Unsurprisingly, the result is consistent when we employ an alternative estimator, namely logistic regression (columns (3) and (4)). In column (5), we present the results of an estimation that accounts for the joint nature of the decision to post elsewhere versus the same intervention subreddit, namely a bivariate probit regression. There, we again observe that the effects manifest primarily in the treated subreddit and not elsewhere. These results are consistent with the model-free evidence reported, which indicates support for Hypothesis 1 on the motivating effects of peer awards and also partial support for Hypothesis 3, that peer awards drive, on average, an exploitation response. However, we evaluate the latter hypothesis more comprehensively via subsequent estimations.
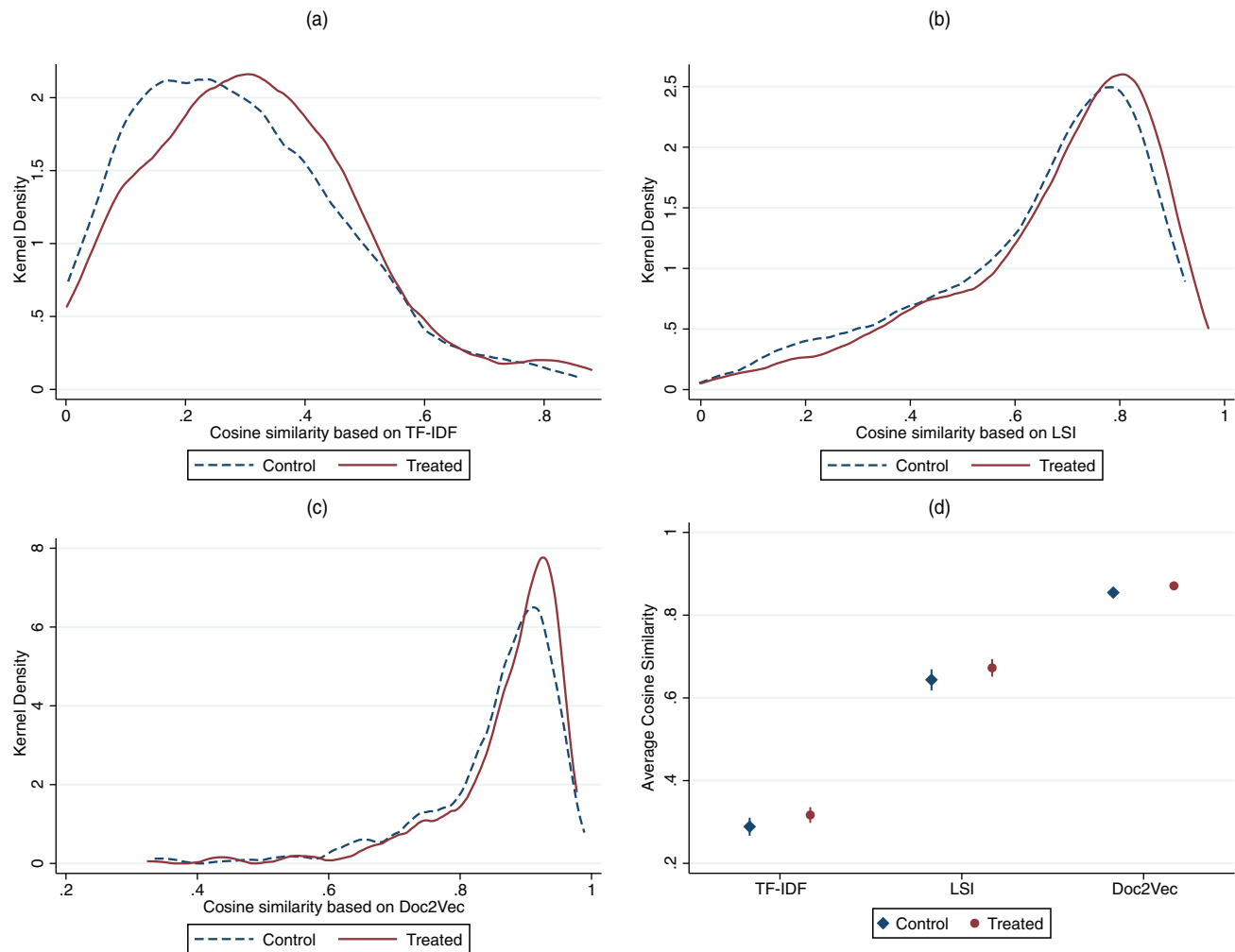
Our next set of analyses consider the effect of treatment on the number of posts a user creates. The outcome in this case is a count measure, *N_Posts*. We,

therefore, begin with a linear regression model as in Equation (1) but replacing our outcome with the natural log of *N_Posts*. We then also consider alternative estimators that account for the count nature of the outcome, namely a Poisson regression. Further, as before, we consider an estimator that accounts for the jointly determined nature of the decision to contribute toward the same versus other subreddits, that is, bivariate Poisson regression. The results of these regressions appear in Table 5. In columns (1) and (2), we report estimates from our log-linear models, which can be interpreted as elasticities. Of particular note here, we estimate that the treatment yields an ~8%–9% increase in the volume of posts a user creates in the intervention subreddit.

The Poisson regression in column (4) indicates a larger estimate, consistent with an approximate 20% ($\beta = 0.185$, $p < 0.1$) increase in posting volumes for treated users. Finally, in column (5), in which we jointly model contributions to the same versus other subreddits, we now observe evidence consistent with a cannibalization effect as we see a systematic rise in posting volumes to the intervention subreddit along with a systematic decline in posting volumes to other subreddits. It is worth noting here that the effect on same-subreddit posting volumes is much larger than the negative effect on other subreddit volumes, which suggests there is still a net increase in total contributions despite the evidence that treatment results in attention cannibalization as part of an exploitation response (Hypothesis 3).

We next consider the treatment effects on the average length of posts that users produce, *Length*, in the posttreatment period. As noted earlier, to accommodate users who did not post content during the two weeks after treatment, we insert a length value of zero, reflecting that zero characters were produced (and, thus, capturing the corner solution). In this analysis, recognizing the right-skewed nature of the variable, we regress the natural logarithm of *Length* onto

Figure 3. (Color online) Descriptive Plots of Differences in Individual Exploitation Measures

our treatment indicator. The results of these analyses are presented in Table 6, columns (1)–(3).

The estimates we report are again consistent with the earlier model-free evidence and our other results thus far. Of course, as noted, it is important to recognize that some users did not post additional content within our window of posttreatment observation. Notably, the provision of no content is not a censoring problem; rather, it is a valid reflection of how much content a user supplied, that is, a corner solution (Burtch et al. 2016). To properly account for the corner solution, we, therefore, also estimate a set of tobit regressions, as suggested by Wooldridge (2002), enforcing a lower bound of zero. These results are presented in columns (4)–(6). Subsequent to the estimation, we recover separate estimates of the marginal effect of our treatment at the extensive margin, that is, $P(y > 0 \mid x)$ at the intensive margin, that is, $E(y \mid x, y > 0)$, as well as the total marginal effect, that is, $E(y \mid x)$.

Our marginal effect estimates indicate that the treatment effect amounts to a 7% increase in posting

probability (p-value < 0.001), that is, the effect at the extensive margin, and a 40.7% increase in post length, conditional on a user posting (p-value < 0.001), that is, the effect at the intensive margin. The former estimate is consistent with our earlier results around "any posting." The latter estimate is perhaps most interesting because it speaks to the treatment effect on a "per character" basis over and above the treatment effect on a user's willingness to post, generally. As before, we also see that these effects manifest most clearly in the intervention subreddit yet not in other subreddits. The totality of evidence again supports Hypotheses 1 and 3.

5.2.2. Treatment Effect on UGC Novelty. We now turn our attention to our three measures of textual similarity. Although the results we present speak, to some extent, about the exploration–exploitation response, by considering whether a user continued to contribute to the same versus a different subject matter area (subreddit), our textual similarity measures provide a somewhat more nuanced operationalization of

Table 4. Treatment Effect on Any UGC Production (DV = Posted; LPM, Logistic and Probit Regressions)

Variables	(1) LPM Posted	(2) LPM Posted_SS	(3) Logistic Posted	(4) Logistic Posted_SS	(5) Bivariate Probit	
					Posted_SS	Posted_OthS
Treatment	0.063**	0.103***	0.261**	0.464***	0.283***	0.025
	(0.023)	(0.022)	(0.096)	(0.100)	(0.061)	(0.059)
Constant	0.560***	0.284***	0.242***	−0.925***	−0.571***	−0.219***
	(0.017)	(0.015)	(0.067)	(0.074)	(0.044)	(0.042)
N	1,810	1,810	1,810	1,810	1,810	
F-test	7.45**	21.67***	–	–	–	
Wald χ^2	–	–	7.41**	21.30***	21.41***	

Note. Robust standard errors in parentheses.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; +$p < 0.1$.

exploration–exploitation. We begin by considering statistical significance of the distributional differences that we observed in Section 5.1, our model-free evidence.

Keeping in mind that the similarity measures are clearly nonnormal in their distributions, that we are not aware of the true underlying distributions, and the relatively small size of our sample, we employ a nonparametric Mann–Whitney U test (Çelen et al. 2010, Leibbrandt et al. 2017). A statistically significant test implies that one set of values is drawn from a systematically different distribution than the other. We present the results of these tests in Table 7, column (1), in which we observe statistically significant effects using our TF-IDF–based (p-value < 0.05), LSI-based (p-value < 0.1), and Doc2Vec-based textual similarity measures (p-value < 0.05).

More specifically, we observe that the textual similarity metrics are all systematically higher in the treatment group as compared with the control group. Once again, these results provide support for Hypothesis 3, that users react to peer awards, on average, with an exploitation response. These effects manifest in terms of both where content is created—that is, on which subreddit—and semantic content. Again, we note that, because the textual similarity analysis is conditional on subreddit, that is, the vector representations of historical and new posts are based on subreddit-specific

embeddings, the results here are not redundant to those dealing with the location of posting.

A potential concern with this analysis is that the effects may be influenced by selection on the treatment (recall that our analysis is based only on the sample of users who opted to post content in the posttreatment period). Indeed, in Online Appendix A, we report a series of t-tests, which indicate some systematic differences in the observable characteristics of subjects in treatment who created new UGC in the posttreatment period versus subjects in control who did so. Among these systematic differences, perhaps the most notable is the difference in user tenure; we see that treatment users who created new content in the post period had been on Reddit approximately 150 days fewer than users who created content in the control group. This finding is consistent with Hypothesis 2, that the treatment is asymmetrically more influential on newer community members. That said, we provide a more formal analysis of this hypothesis next via moderation tests.

We focus here on addressing these imbalances, which raise the possibility of selection on treatment. It is challenging to resolve the selection in our field experiment setting because we lack a second instrument for UGC production. As a commonly used alternative approach, we assess the influence of selection by

Table 5. Treatment Effect on Number of UGC Posts (DV = N_Posts; Ordinary Least Squares and Poisson Regressions)

Variables	(1) OLS Ln(N_Posts)	(2) OLS Ln(N_Posts_SS)	(3) Poisson N_Posts	(4) Poisson N_Posts_SS	(5) Bivariate Poisson	
					N_Posts_SS	N_Posts_OthS
Treatment	0.0531	0.087**	−0.018	0.185+	0.143**	−0.085**
	(0.042)	(0.025)	(0.116)	(0.100)	(0.051)	(0.032)
Constant	0.800***	0.293***	1.035***	−0.476***	−0.224***	0.804***
	(0.030)	(0.017)	(0.094)	(0.078)	(0.043)	(0.022)
N	1,810	1,810	1,810	1,810	1,810	
F-test	1.64	12.01***	–	–	–	
Wald χ^2	–	–	0.02	3.46+	–	
LR χ^2	–	–	–	–	17.36***	

Notes. Robust standard errors in parentheses. Yeo–Johnson power transformation applied to logged outcomes, that is, $\ln(x + 1)$.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; +$p < 0.1$.

Table 6. Treatment Effect on Length of UGC Posts (DV = Ln(Length); Ordinary Least Squares Regression)

Variables	(1) OLS Ln(Length)	(2) OLS Ln(Length_SS)	(3) OLS Ln(Length_OthS)	(4) Tobit Ln(Length)	(5) Tobit Ln(Length_SS)	(6) Tobit Ln(Length_OthS)
Treatment	0.573***	0.745***	0.059	0.997***	2.191***	0.107
	(0.149)	(0.156)	(0.113)	(0.283)	(0.463)	(0.353)
Constant	2.751***	1.979***	1.449***	0.579*	−3.931***	−2.723***
	(0.103)	(0.106)	(0.079)	(0.235)	(0.423)	(0.305)
N	1,810	1,810	1,810	1,810	1,810	1,810
F-test	14.80***	22.68***	0.27	12.39***	22.42***	0.09

Notes. Robust standard errors in parentheses. Yeo–Johnson power transformation applied to construct logged outcomes, that is, $\ln(x + 1)$.
  ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; +$p < 0.1$.

constructing a matched sample of users, via coarsened exact matching (CEM) (Iacus et al. 2012). If sample selection is driving our results, it would be concerning if we observed a decline in the treatment effect strength upon accounting for imbalances on observable features.

We employed k2k CEM and thereby forced the resulting matched treatment and control groups to contain the same number of users. Our matching covariates include all variables listed in Table 2. The matching procedure results in a paired sample of 358 users. The results of *t*-tests we report in Online Appendix A demonstrate that the procedure was effective at removing the imbalance on observable features. Repeating our analyses of textual novelty, this time on the matched sample, we obtain consistent results; see Table 7, column (2). In fact, some of the estimated differences become even larger, which suggests that selection on treatment may, in fact, be attenuating our treatment effect magnitudes.[10]

5.2.3. Differential Effects on New Members. To test our third hypothesis, investigating the heterogeneous impacts of peer awards on newer, less established members of the community, we introduce moderation terms into our regression models. Specifically, we first consider an indicator of whether a recruited user was contributing content to the intervention subreddit for the very first time. Across our sample, 977 users were posting to their intervention subreddit for the first time. We label these users with the indicator *FirstTimer*, and include the interaction between this variable and treatment into our analysis. We, thus, estimate the model in Equation (2). In this regression, the coefficient associated with the main effect of *Treatment*, β_1, is the average treatment effect on users who had contributed to the intervention subreddit at least once prior to our discovering them. The coefficient associated with the interaction term, β_3, is the estimated difference between first-time contributors and longer-tenured members.

$$UGC\_Production_i / UGC\_Novelty_i = \alpha + \beta_1 \cdot Treatment_i + \beta_2 \cdot FirstTimer_i + \beta_3 \cdot Treatment_i \cdot FirstTimer_i + \varepsilon_i.$$

(2)

Note that, because we need to incorporate a moderator term in our analyses of the treatment's effect on textual self-similarity, we cannot employ a Mann–Whitney U test. Accordingly, we employ quantile regressions and, more specifically, median regressions to accommodate the "nonnormal" distribution of the outcome measure for that analysis.

The results of these regressions are presented as follows, considering effects on whether a user posts at all, the number of posts a user makes, and the average length of a user's posts. We present results related to these three outcomes, distinguishing between activity on the same versus other subreddits in Table 8. We observe evidence consistent with Hypothesis 2 for all outcomes. Specifically, we see in column (1) for the bivariate probit regression that, although users who were not first-time posters were systematically more likely to post UGC after receipt of the Gold Award, the effect on first-time posters was significantly larger ($\beta_3 = 0.209$, p-value < 0.1). Similarly, in columns (3) and (4) with our tobit regressions, we see that, although members of longer tenure do post longer content in response to treatment, first-time posters are systematically more responsive ($\beta_3 = 1.724$,

Table 7. Treatment Effect on UGC Novelty (DV = Textual Self-Similarity; Mann–Whitney U Test)

Measure	(1) All users			(2) Matched users		
	Rank sum (control)	Rank sum (treatment)	p-value	Rank sum (control)	Rank sum (treatment)	p-value
TF-IDF score	73,793	110,735	0.042	29,907	34,354	0.023
LSI score	74,076	110,452	0.058	30,150	34,111	0.043
Doc2Vec score	72,763	111,765	0.012	29,904	34,357	0.023
N	257	350	–	179	179	–

Table 8. Heterogeneity Test on First-time Poster for UGC Production (DV = Posted, N_Posts; Probit, Poisson, and Tobit Regressions)

Variables	(1) Bivariate probit		(2) Bivariate Poisson		(3) Tobit	(4) Tobit
	Posted_SS	Posted_OthS	N_Posts_SS	N_Posts_OthS	Ln(Length_SS)	Ln(Length_OthS)
Treatment	0.187*	−0.074	0.055	−0.012	1.397*	−0.429
	(0.088)	(0.087)	(0.066)	(0.045)	(0.643)	(0.511)
FirstTimer	−0.388***	−0.173*	−0.600***	−0.124**	−3.047***	−1.086*
	(0.089)	(0.084)	(0.080)	(0.044)	(0.689)	(0.496)
Treatment × FirstTimer	0.209+	0.189	0.251*	−0.138*	1.724+	1.052
	(0.123)	(0.119)	(0.106)	(0.064)	(0.928)	(0.706)
Constant	−0.377***	−0.129*	0.034	0.866***	−2.373***	−2.159***
	(0.062)	(0.061)	(0.050)	(0.031)	(0.524)	(0.390)
N	1,810		1,810		1,810	1,810
F-test	−		−		15.24***	1.62
Wald χ^2	46.70***		−		−	−
LR χ^2	−		132.10***		−	−

Notes. Robust standard errors in parentheses. For tobit model, Yeo–Johnson power transformation applied to construct logged outcomes, that is, $\ln(x + 1)$.

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; +$p < 0.1$.

p-value < 0.1). Finally, the results in column (2) from the bivariate Poisson regression indicate no evidence of a systematic shift toward the intervention subreddit among users of longer tenure and instead that this effect derives primarily from the response of first-time posters. Specifically, first-time posters who are treated created systematically more posts in the intervention subreddit ($\beta_3 = 0.251$, p-value < 0.05) and systematically fewer posts in other subreddits ($\beta_3 = -0.138$, p-value < 0.05). This last finding is consistent with the notion that the asymmetrically larger influence of peer awards on newer community members drives much of the overall exploitation response we observed earlier (i.e., Hypothesis 3).

Subsequently, we also considered heterogeneity in the effects on textual self-similarity, employing moderated quantile (median) regression. However, upon doing so, we observed no statistically significant moderation in either the total sample or the matched sample. We did, however, continue to observe a significant treatment effect in the baseline group (specifically, using the LSI-based measure in the matched sample and using the TF-IDF measure in the unmatched sample). Taken together, this set of results suggests that, although new users are systematically more likely to respond to peer awards than users of lengthier tenure, in terms of the volume of content they produce, they exhibit no systematic differences in the extent to which their content shifts to be more similar to awarded content.

In general, we observed evidence in support of all three of our hypotheses. Peer awards causally increase the amount of content that users produce, and they also causally induce an exploitation response with recipients systematically being more likely to focus on the awarding subreddit and exhibiting systematic increases (reductions) in textual similarity (novelty).

Further, effects are significantly more pronounced among newer, less recognized community members.

Beyond these heterogeneity analyses related to user tenure, we also considered another form of heterogeneity analysis, reported in Online Appendix D. Specifically, we considered an alternative measure of whether the recipient lacked strong ties with the Reddit community: whether a user had received large positive feedback from the community in the past. Considering that moderator, we observed expected results; users who have not received much engagement in the past respond more.

6. Secondary Analyses

Having established support for our three primary hypotheses, we next explore several secondary analyses that speak to the nuances of the treatment. These analyses include a consideration of (i) treatment effect dynamics in a longer observational window, (ii) qualitative evidence of possible mechanisms behind the treatment effects (as revealed through messages many treated subjects sent in response to our Gold Award), and (iii) whether the treatment ultimately induces users to produce more engaging and popular content. Additionally, we present analyses that confirm the predictions of prior literature in Online Appendix E, namely that new community members produce systematically more (contemporaneously) novel content and that such content is systematically more popular among community members. Collectively, these results support our broader findings that peer awards induce a general increase in the novelty of community content by encouraging newer members to continue participating and producing more content that is similar to their (already) relatively novel material.

6.1. Treatment Effect Dynamics

First, we extend our main sample into a weekly panel data set, capturing user content production in the weeks leading up to and following the intervention post. We use this panel to estimate a dynamic difference-in-differences regression that speaks to the intertemporal effects of our treatment on users' volume of content production. This panel data structure also enables us to assess the stability of our estimates in the presence of user and time fixed effects as well as to assess the parallel trends assumption. Each of these aspects helps speak indirectly to the efficacy of our randomization procedure. We present the estimates of this dynamic regression in Online Appendix B, in which we observe no evidence that the parallel trends assumption is violated. We observe that the treatment effect manifests within the first week after treatment, after which time UGC production begins to return to baseline levels, clearly dissipating after two weeks. What is also of note here, however, is that we do not observe a subsequent dip in UGC production, implying that this is net new content production rather than a simple acceleration in the timing of content production. In the same appendix, we also examine the dynamics of the exploitation effect, observing increases in textual similarity among treated users (relative to the intervention post and control users) in the very next post they create. And the significant effect persists over the next two posts as well.

6.2. Qualitative Evidence of Treatment Effect Mechanisms

One of the benefits of our data set is that award recipients can send us private messages in reply despite the award having been assigned anonymously. Approximately 53.5% of treated users (484) sent us private messages expressing thanks. Of these, 143 elaborated, discussing the inspiration behind their content, speaking to their plans for future content production, etc. These 143 messages help us understand how recipients perceive peer awards and how those awards influence their future content generation.

Among these users, 22.3% (32) specifically mentioned that the award made them feel confident about their ability, enhancing their perceived self-efficacy, and a large portion of these users were new contributors. For example, one user whose first submission was awarded stated the following: "I am very nervous about my first post. This really gave me a heads up!" In addition to first-time posters, these sorts of messages also included users who indicated they had not posted new material for some time. These responses generally validate our earlier empirical analyses, which indicated the outsized motivational effects for new community members. That is, peer awards present stronger encouragement to users who have relatively low confidence, and these users are particularly appreciative of the peer award.

A second key theme in recipients' messages, consistent with the preceding, was indications of *reciprocity*. Again, this observation is consistent with the notion that peer awards are particularly influential on new members because they help foster community ties and relational bonds (Ren et al. 2007). For example, one award recipient stated, "As a token of gratitude, I will include something you want in my next story." Several users similarly expressed a willingness to create more stories that the anonymous benefactor would like. Some users even made statements indicative of generalized reciprocity, indicating their intent to pay the award forward to other users. As one user stated, "Hopefully, I will make someone else's day."

This qualitative evidence of an increased desire to generate related content following an unexpected, initial success is also consistent with the exploitation response observed through our other analyses. Upon the receipt of unexpected positive feedback, these new, less recognized users calibrate to the reward and seek to capitalize on what appears to be a successful strategy. As our quantitative results show, this is not the case for experienced members.

6.3. Do Peer Awards Induce Users to Create More Popular Content?

The ultimate question of interest, from a platform operator's perspective, is whether peer awards induce recipients to produce more popular, more engaging content. We, thus, consider the relationship between our peer award treatment and the popularity of subsequent content that users produce (after the intervention post). We again measure content popularity using our net upvote *Score* variable. We estimate this regression employing Poisson regression, again cognizant of the right skew in the *Score* distribution. We consider both the total sample and the matched sample as previously. The results are presented in Table 9. In column (1), we observe a clear causal relationship between the treatment and the popularity of subsequent content that a user produces. That is, treatment is significantly associated with a rise in average post *Score*. In column (2), we consider heterogeneity in whether a user was a *FirstTimer* poster and again find results consistent with our second hypothesis; the popularity of new members' content rises in particular.

7. Discussion

7.1. Theoretical Implications

From a theoretical perspective, our work contributes to a large body of literature on platform incentives by investigating the role of peer awards, which have previously received relatively little attention (Ramirez 2017, Burtch et al. 2018, Frey and Gallus 2018). Peer

Table 9. Effect of Treatment on Subsequent UGC Popularity (DV = Score; Poisson Regression)

Variables	Total sample		Matched sample	
	(1) Score	(2) Score	(3) Score	(4) Score
Treatment	0.478[+]	−0.079	0.899*	−0.370
	(0.252)	(0.221)	(0.377)	(0.255)
FirstTimer	–	−0.869***	–	−0.890**
		(0.237)		(0.266)
Treatment × FirstTimer	–	1.366**	–	2.195***
		(0.428)		(0.528)
Constant	4.422***	4.696***	4.126***	4.473***
	(0.136)	(0.166)	(0.142)	(0.178)
N	607	607	358	358
Wald χ^2	3.60[+]	21.18***	5.69*	20.67***

Note. Robust standard errors in parentheses.
   ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; [+]$p < 0.1$.

awards are one of the only few available incentive tools that can be deployed at scale in niche-interest, open-ended contexts that accommodate users' subjective, personal preferences around creative content. Our work, thus, complements prior work in information systems, marketing, and management, not just by examining an understudied incentive tool, but also extending prior work to a context in which content cannot be readily evaluated against an objective, predefined set of criteria as is the case with content such as online reviews (Chen et al. 2017), question and answer communities (Kuang et al. 2019), or online encyclopedias (Restivo and Van De Rijt 2012). By employing a novel, longitudinal randomized field experiment, we establish the causal impacts of peer awards on users' future content production regarding both content quantity and novelty. Moreover, we provide novel empirical evidence about the dynamics and duration of the causal effects, demonstrating that peer awards yield net new content for the host platform rather than simply accelerating the production of content that would have arrived later.

Additionally, our work adds to platform incentive literature by offering a first consideration of the influence of peer awards on the underlying content-generation process, particularly in regard to the individual exploration–exploitation decision. Prior work has mainly focused on UGC production and generic, objective quality with an eye toward informational aspects (Qiao et al. 2017, Khern-am-nuai et al. 2018). Because our work considers a context in which ideal content is not necessarily that which is informative or focused on a particular topic, we consider instead an alternative factor that has been proposed and shown to be predictive of popularity in a variety of UGC settings: content novelty. We also leverage various text-mining methods and large volumes of user content on Reddit to demonstrate the latter results. Methodologically, our study, thus, introduces alternative computational measures to

the information science literature, which can be used to operationalize individual exploration and exploitation behavior in content creation contexts in a scalable way. Finally, our work contributes to the literature on individual exploration and exploitation (March 1991; Lazear 2000a, b; Rhee and Kim 2014; Baumann and Stieglitz 2014), investigating its role in the UGC creation process, an understudied yet relevant context (Lavie et al. 2010).

7.2. Managerial Implications

Our work highlights how peer awards can be useful as a platform incentive for fostering novel content in creative UGC settings, essentially shaping the crowd's contribution activity, to shift community focus toward more desirable content. This is in line with the notion proposed by Hukal et al. (2020), that firms can stimulate activity in new, "thin" areas of the platform through opportunity signals. Our overarching finding is that peer awards are most useful for attracting and retaining new community members. Although the awards also encourage exploitation behavior, this is likely to be desirable because new users, in general, provide systematically more novel content. All of these benefits also come with the added boon of an additional revenue stream for the platform, Reddit. There are also implications for individuals who manage subcommunities within the platform. Moderators can employ peer awards (e.g., anonymously) to recognize and reward content they see as particularly desirable for the community. They can explicitly encourage new community members to remain who produce such content, and they can encourage users to continue producing more content, similar to that which was awarded.

Of course, there are important factors to bear in mind that may limit the benefits of peer awards. For example, although peer awards encourage new users to continue producing their initially more novel content, they may impede long-run exploration behavior. Second, although peer awards are indeed influential, their effects appear relatively short-lived, suggesting they should perhaps not be relied upon in isolation. Finally, they are predominantly effective only in influencing new members of the platform; this suggests that other interventions and policies are needed to sustain the motivation of longer-tenured users and to encourage those longer-tenured users to produce more novel material.

8. Conclusion and Future Work

Our findings imply a number of open questions that future work can seek to address. For example, there is very likely to be heterogeneity across community and subject-matter types as well as alternative peer award designs that would be important to understand. In terms of the former, in information-oriented communities,

such as news or science, the impact of peer awards on UGC production and content similarity may be amplified or reversed. In terms of the latter, heterogeneity may arise depending upon award scarcity and intensity. As users receive more Gold, their excitement over receiving it may decrease, which may diminish the positive impact the awards have on UGC creation. Broadly, it is our hope that this work will stimulate a new stream of research that focuses predominantly on creativity-oriented UGC and the tools available to platform operators that can help shape such content.

Acknowledgments

Endnotes

[1] In Online Appendix E, we provide empirical evidence, based on measures of textual similarity, that indicates (1) new users produce systematically more novel content (compared with peers) and (2) novel content receives systematically more engagement from other members of the community. These observations, although correlational, are consistent with prior literature.

[2] We demonstrate evidence consistent with their result in our own sample in our secondary analyses section.

[3] Please see https://www.redditinc.com/, accessed in September 2020.

[4] A note about ethics and data fair use: (a) institutional review board approval for this experiment was obtained before we carried out the experiment, and (b) data collection in this study follows Reddit's API guidelines and is within the website's terms of use.

[5] Data were retrieved from http://redditlist.com/ in September 2020.

[6] Link karma is a proxy for the user's net cumulative post score.

[7] Comment karma is a proxy for the user's net cumulative comment score.

[8] The platform operator's concern is, of course, contemporaneous novelty. As we ultimately demonstrate, peer awards are particularly effective at motivating new members, and they drive those new members to engage in exploitation behavior. However, if new members generate systematically more (contemporaneously) novel content, this constellation of results may be desirable. To support our interpretation of these results as jointly demonstrating the novelty-inducing benefits of peer awards, in Online Appendix E, we present secondary analyses in which we demonstrate both that (i) new community members generate content that exhibits systematically more contemporaneous novelty (consistent with the prior innovation literature) and (ii) content that exhibits contemporaneous novelty is systematically more popular and attracts systematically more engagement from the community.

[9] In the implementation, following the commonly used weighting approach (Robertson 2004), we apply normalization based on inverse document frequency (IDF), $idf(t) = \log[(1 + n)/(1 + df(4)) + 1$, to accommodate the linear increase of IDF and to prevent divisions by zero.

[10] In Online Appendix C, we also consider an alternative approach to operationalizing textual self-novelty. Rather than considering self-novelty relative to the intervention post, there we consider self-novelty relative to all pretreatment posts. We observe consistent results.

References

Allan J, Wade C, Bolivar A (2003) Retrieval and novelty detection at the sentence level. *Proc. 26th Annual Internat. ACM SIGIR Conf. Res. Development Inform. Retrieval* (Association for Computing Machinery, New York), 314–321.

Anderson NR, Gasteiger RM (2008) Innovation and creativity in organizations: Individual and work team research findings and implications for government policy. Nooteboom B, Stam E, eds. *Micro-Foundations for Innovation Policy*, vol. 18 (Amsterdam University Press, Amsterdam), 249–271.

Azoulay P, Stuart T, Wang Y (2013) Matthew: Effect or fable? *Management Sci.* 60(1):92–109.

Balsmeier B, Fleming L, Manso G (2017) Independent boards and innovation. *J. Financial Econom.* 123(3):536–557.

Baumann O, Stieglitz N (2014) Rewarding value-creating ideas in organizations: The power of low-powered incentives. *Strategic Management J.* 35(3):358–375.

Burtch G, Ghose A, Wattal S (2016) Secret admirers: An empirical examination of information hiding and contribution dynamics in online crowdfunding. *Inform. Systems Res.* 27(3):478–496.

Burtch G, Hong Y, Bapna R, Griskevicius V (2018) Stimulating online reviews by combining financial incentives and social norms. *Management Sci.* 64(5):2065–2082.

Cabral L, Li L (2015) A dollar for your thoughts: Feedback-conditional rebates on eBay. *Management Sci.* 61(9):2052–2063.

Carmel D, Roitman H, Yom-Tov E (2012) On the relationship between novelty and popularity of user-generated content. *ACM Trans. Intelligent Systems Tech.* 3(4):Article 69.

Çelen B, Kariv S, Schotter A (2010) An experimental test of advice and social learning. *Management Sci.* 56(10):1687–1701.

Chen PY, Hong Y, Liu Y (2017) The value of multidimensional rating systems: Evidence from a natural experiment and randomized experiments. *Management Sci.* 64(10):4629–4647.

Chen Y, Harper FM, Konstan J, Li SX (2010) Social comparisons and contributions to online communities: A field experiment on Movielens. *Amer. Econom. Rev.* 100(4):1358–1398.

Deci EL, Ryan RM, eds. (2002) Overview of self-determination theory: An organismic dialectical perspective. *Handbook of Self-Determination Research* (University of Rochester Press, Rochester, NY), 3–33.

Deci EL, Koestner R, Ryan RM (1999) A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psych. Bull.* 125(6):627–668.

Døjbak Håkonsson D, Eskildsen JK, Argote L, Mønster D, Burton RM, Obel B (2016) Exploration versus exploitation: Emotions and performance as antecedents and consequences of team decisions. *Strategic Management J.* 37(6):985–1001.

Ederer F, Manso G (2013) Is pay for performance detrimental to innovation? *Management Sci.* 59(7):1496–1513.

Eisenberger R, Armeli S (1997) Can salient reward increase creative performance without reducing intrinsic creative interest? *J. Personality Soc. Psych.* 72(3):652–663.

Eisenberger R, Rhoades L (2001) Incremental effects of reward on creativity. *J. Personality Soc. Psych.* 81(4):728–741.

Frey BS, Gallus J (2018) Volunteer organizations: Motivating with awards. Ranyard R, ed. *Economic Psychology* (John Wiley & Sons, Hoboken, NJ), 275–286.

Gallus J (2017) Fostering public good contributions with symbolic awards: A large-scale natural field experiment at Wikipedia. *Management Sci.* 63(12):3999–4015.

Goes PB, Guo C, Lin M (2016) Do incentive hierarchies induce user effort? Evidence from an online knowledge exchange. *Inform. Systems Res.* 27(3):497–516.

Hass RW (2017) Tracking the dynamics of divergent thinking via semantic distance: Analytic methods and theoretical implication. *Memory Cognition* 45(2):233–244.

Holmqvist M (2004) Experiential learning processes of exploitation and exploration within and between organizations: An empirical study of product development. *Organ. Sci.* 15(1):70–81.

Huang N, Burtch G, Gu B, Hong Y, Liang C, Wang K, Fu D, Yang B (2019) Motivating user-generated content with performance feedback: Evidence from randomized field experiments. *Management Sci.* 65(1):327–345.

Huberman BA, Romero DM, Wu F (2009) Crowdsourcing, attention and productivity. *J. Inform. Sci.* 35(6):758–765.

Hukal P, Henfridsson O, Shaikh M, Parker G (2020) Platform signaling for generating platform content. *Management Inform. Systems Quart.* 44(3):1177–1205.

Iacus SM, King G, Porro G (2012) Causal inference without balance checking: Coarsened exact matching. *Political Anal.* 20(1):1–24.

Khern-am-nuai W, Kannan K, Ghasemkhani H (2018) Extrinsic versus intrinsic rewards for contributing reviews in an online platform. *Inform. Systems Res.* 29(4):871–892.

Kosfeld M, Neckermann S (2011) Getting more work for nothing? Symbolic awards and worker performance. *Amer. Econom. J. Microeconomics* 3(3):86–99.

Kuang L, Huang N, Hong Y, Yan Z (2019) Spillover effects of financial incentives on non-incentivized user engagement: Evidence from an online knowledge exchange platform. *J. Management Inform. Systems* 36(1):289–320.

Lakkaraju H, McAuley JJ, Leskovec J (2013) What's in a name? Understanding the interplay between titles, content, and communities in social media. *Proc. Seventh Internat. Conf. Web Soc. Media*, 1(2).

Lampel J, Shamsie J, Lant TK, eds. (2006) *The Business of Culture: Strategic Perspectives on Entertainment and Media* (Lawrence Erlbaum Associates, Publishers, Mahwah, NJ).

Landauer TK, Dumais ST (1997) A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psych. Rev.* 104(2):211–240.

Lau J, Baldwin T (2016) An empirical evaluation of Doc2Vec with practical insights into document embedding generation. *Proc. 1st Workshop Representation Learn.* NLP (Association for Computational Linguistics, Berlin, Germany), 78–86.

Laureiro-Martínez D, Brusoni S, Canessa N, Zollo M (2013) Understanding the exploration–exploitation dilemma: An fMRI study of attention control and decision-making performance. *Strategic Management J.* 36(3):319–338.

Lavie D, Stettner U, Tushman ML (2010) Exploration and exploitation within and across organizations. *Acad. Management Ann.* 4(1):109–155.

Lawrence J, Park J, Budzynska K, Cardie C, Konat B, Reed C (2017) Using argumentative structure to interpret debates in online deliberative democracy and erulemaking. *ACM Trans. Internet Tech.* 17(3):Article 25.

Lazear EP (2000a) Performance pay and productivity. *Amer. Econom. Rev.* 90(5):1346–1361.

Lazear EP (2000b) The power of incentives. *Amer. Econom. Rev.* 90(2):410–414.

Le Q, Mikolov T (2014) Distributed representations of sentences and documents. *Proc. 31st Internat. Conf. Machine Learn.* (JMLR.org, Beijing), 32(2):1188–1196.

Lee S, Meyer-Doyle P (2017) How performance incentives shape individual exploration and exploitation: Evidence from microdata. *Organ. Sci.* 28(1):19–38.

Leibbrandt A, Wang LC, Foo C (2017) Gender quotas, competitions, and peer review: Experimental evidence on the backlash against women. *Management Sci.* 64(8):3501–3516.

Malik MAR, Butt AN (2017) Rewards and creativity: Past, present, and future. *Appl. Psych.* 66(2):290–325.

March JG (1991) Exploration and exploitation in organizational learning. *Organ. Sci.* 2(1):71–87.

McKenzie PJ, Burkell J, Wong L, Whippey C, Trosow SE, McNally MB (2012) User-generated online content 1: Overview, current state and context. *First Monday* 17(6).

Mendelsohn J, Li L (2017) Giving gold: Understanding appreciation in Reddit communities. Working paper, Stanford University, Stanford, CA.

Morgan M (1984) Reward-induced decrements and increments in intrinsic motivation. *Rev. Ed. Res.* 54(1):5–30.

Perretti F, Negro G (2007) Mixing genres and matching people: A study in innovation and team composition in Hollywood. *J. Organ. Behav.* 28(5):563–586.

Qiao D, Lee S-Y, Whinston A, Wei Q (2017) Overcoming the crowding-out effect of monetary incentive on pro-social behavior. *Proc. 38th Internat. Conf. Inform. Systems* (Association for Information Systems, Seoul).

Ramirez C (2017) Three essays on non-monetary incentives and employee compensation. Unpublished dissertation, University of California Los Angeles, Los Angeles.

Ren Y, Kraut R, Kiesler S (2007) Applying common identity and bond theory to design of online communities. *Organ. Stud.* 28(3):377–408.

Restivo M, Van De Rijt A (2012) Experimental study of informal rewards in peer production. *PLoS One* 7(3):e34358.

Rhee M, Kim T (2014) Great vessels take a long time to mature: Early success traps and competences in exploitation and exploration. *Organ. Sci.* 26(1):180–197.

Robertson S (2004) Understanding inverse document frequency: On theoretical arguments for IDF. *J. Documentation* 60(5):503–520.

Salton G, Buckley C (1988) Term-weighting approaches in automatic text retrieval. *Inform. Processing Management* 24(5):513–523.

Soboroff I, Harman D (2005) Novelty detection: The TREC experience. *Proc. Human Language Tech. Conf. Conf. Empirical Methods Natural Language Processing* (Association for Computational Linguistics, Vancouver), 105–112.

Taggar S (2002) Individual creativity and group ability to utilize individual creative resources: A multilevel model. *Acad. Management J.* 45(2):315–330.

Taylor SJ, Muchnik L, Aral S (2019) What's in a username? Identity cue effects in social media. Preprint, revised July 15, http://dx.doi.org/10.2139/ssrn.2538130.

Toubia O, Netzer O (2017) Idea generation, creativity, and prototypicality. *Marketing Sci.* 36(1):1–20.

Tsai FS, Tang W, Chan KL (2010) Evaluation of novelty metrics for sentence-level novelty mining. *Inform. Sci.* 180(12):2359–2374.

Wang K, Dong B, Ma J (2019) Towards computational assessment of idea novelty. *Proc. 52nd Hawaii Internat. Conf. System Sci., Hawaii*, 912–920.

Wooldridge J (2002) *Econometric Analysis of Cross Section and Panel Data* (MIT Press, Cambridge, MA).

Wu F, Huberman BA (2007) Novelty and collective attention. *Proc. Natl. Acad. Sci. USA.* 104(45):17599–17601.

Wu Y, Zhu F (2018) Competition, contract, and creativity: Evidence from novel writing in a platform market. Working paper, Harvard Business School, Cambridge, MA.

Yu Y, Tang S, Raposo F, Chen L (2019) Deep cross-modal correlation learning for audio and lyrics in music retrieval. *ACM Trans. Multimedia. Comput. Comm. Appl.* 15(1):Article 20.

Zhou J (1998) Feedback valence, feedback style, task autonomy, and achievement orientation: Interactive effects on creative performance. *J. Appl. Psych.* 83(2):261–276.