Research Paper

Association of COVID19-induced anosmia and ageusia with depression and suicidal ideation

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ABSTRACT

Background: Clinical reports from patients suffering from the novel coronavirus (COVID-19) reflect a high prevalence of sensory deprivation or loss pertaining to smell (dysosmia/anosmia) and/or taste (dysgeusia/ageusia). Given the importance of the senses to daily functioning and personal experience, the mental health consequences of these symptoms warrant further attention.

Methods: A cohort of Reddit users posting within the /r/covid19positive subforum ($N = 15,821$) was leveraged to analyze instantaneous risk of transition to a state of suicidal ideation or depression using Cox proportional-hazards models. Risk transition was defined by posts made in suicide- or depression-related forums, or mentions of relevant phrases with and without mention of anosmia/ageusia in /r/covid19positive. Self-diagnosis of COVID-19 was also modeled as a separate and simultaneous predictor of mental health risk.

Results: Mention of anosmia/ageusia was significantly associated with transition to a risk state. Users with a history of anosmia/ageusia-related posts and who self-identified as COVID-19 positive had 30% higher instantaneous risk relative to others. The highest increase in instantaneous risk of suicidal ideation or depression occurred more than 100 days after first posting in /r/covid19positive.

Limitations: Use of self-diagnosed disease as well as a broad array of anosmia/ageusia-related terminology may entail both information bias and overestimates of symptom incidence.

Conclusions: The specific effects of COVID-19 on the senses may have long-term implications for patient mental health well-being beyond the primary recovery period. Future work is needed to investigate the longitudinal mental health burden of residual COVID-19 symptom presentation.

The ability to perceive our environment is a central component to the human experience. From birth, the availability of the basic senses can be thought to establish a baseline of expected interaction with the environment that informs and alters emotional and mental states through multiple channels (Rouby et al., 2016). But what happens when one or more of these channels are lost, and how does it impact mental health? Although much less prominent in the literature compared with visual and auditory-based investigations, research has shown that olfactory impairment (anosmia) is associated with a decrease in patient-perceived quality of life, concomitant with heightened scores for clinical depression (Deems et al., 1991; Joo et al., 2015; Seo et al., 2009) and suici-

dal ideation (Joo et al., 2015). Given the physiological ties of olfaction with gustation, those suffering from anosmia may also experience a loss or impairment of taste (ageusia). It stands to reason that ageusia, or a combination of anosmia and ageusia, as comorbidities of disease may be important risk factors for depression and suicidal ideation.

The spectrum of symptoms caused by COVID-19 varies considerably between individuals. Clinical records have indicated that anosmia and ageusia present as two of the most prevalent symptoms (Hannum et al., 2020; Vaira et al., 2020) with anosmia considered a diagnostic marker for the disease (Rocke et al., 2020). While significant improvement occurs quickly in some cases, studies have reported long-term impairments that exceed two weeks post-onset (Hannum et al., 2020), and over six

months in a minority of cases (Hopkins et al., 2021; Lee et al., 2020). Given the ubiquity, persistence, and disruptive nature of these effects, the potential impact on the mental health of the afflicted warrants further consideration.

The connectivity and ubiquity of the internet as a platform for communication and information exchange serves as a rich source to interrogate behavior and mental health. Indeed, the breadth and accessibility of information promotes information-seeking behaviors that in turn permit statistically robust investigations on the internet activities of individuals. Specifically, this includes the ability to study alterations in activity patterns as potential consequences of the ongoing pandemic situation. A recent study looking at Google Trends search information across 8 nations, including the United States, found a strong correlation between the frequency of searches for olfaction-related information and COVID-19 infection (Walker et al., 2020). A testament to the collective leverage of the internet as a help-seeking tool within the context of the exposure, the World Wide Web also is known to house a variety of resources and platforms for mental health-related discussion.

Reddit, a self-described "network of communities based on people's interests", is a popular platform for modern communication and currently supports multiple, separate forums dedicated specifically to mental health and COVID-19 discussion. Depression and suicide are among the psychological constructs that have been studied using Reddit data (De Choudhury et al., 2016), with the /r/SuicideWatch subreddit among the most popular places for those at risk of suicide to meet (Alambo et al., 2019; Low et al., 2020). Moreover, /r/SuicideWatch has been shown to exhibit strong concordance with DSM-5-defined suicidal behavior and ideation with nearly identical performance across other mental health-based Reddit subforums (Gaur et al., 2018). Taken together, the information-seeking behaviors concerning both mental health and the current pandemic are captured simultaneously under one platform, facilitating investigation into the potential impact of life-altering loss of smell and taste symptomology on the depressive and suicidal state of a globally representative population.

The central importance of the senses to the normalized personal expectations of day-to-day life experiences, coupled with the known perniciousness of the COVID-19 symptom milieu, highlights a potential mental health risk factor. This work aimed to investigate the depression and suicide risk associated with COVID-19-induced anosmia and ageusia using data available on the Reddit social network platform. Accordingly, this study hypothesized that the response to both COVID-19-related smell and/or taste loss will be associated with a significantly higher instantaneous risk for depression and suicidal ideation compared with those with COVID-19 who did not experience these symptoms.

1. Methods

1.1. Data extraction and preprocessing

User-generated posts from a Reddit subforum dedicated to people with COVID-19 (/r/covid19positive) were extracted using the PushShift Reddit mirror between March 1, 2020 and December 31, 2020. Information included (i) a uniquely identifying author username, (ii) the date of the post, and (iii) the textual content of each post. In addition, all posts created during 2020 that were made outside of /r/covid19positive by users of the subforum were extracted. From this subset of Reddit users, those who had suffered from COVID-19 were identified based on indication of their ailment through either a relevant Reddit "flare", including "Tested Positive - Me", "Tested Positive", "Presumed Positive - Through Doctor", or "Presumed Positive - Through Test", or through the textual content of their post which included one of the following phrases: "I tested positive", "I'm presumed positive", "I've been positive", or "I've had a positive test". All other flares were examined, but they did not identify a user who suffered from COVID-19. Posts by users who deleted their account from Reddit were removed prior to analysis.

Anosmia and ageusia were identified among /r/covid19positive users based on the presence of any of the following words in post text in /r/covid19positive: "smell", "taste", "anosmia", "ageusia", "dysgeusia", or "hypogeusia". Posts by users who deleted their account from Reddit were removed prior to analysis.

A minority of users reported their age and gender in their posts. Those were extracted using a regular expression which matched the words "female" or "male" in proximity to two digits, or in the format "XXG" or "GXX" where G represents gender (F or M) and XX two digits (e.g., "F25" represents a 25 year old female).

1.2. Measures

Analysis was informed by specific mention of anosmia or ageusia/dysgeusia across user post content as well as by whether or not a user's post or flare indicated COVID-19 infection. The outcome of interest was defined by the transition to a possible risk state such as depression or suicidal ideation (see Introduction for the significance of this transition). This was determined per /r/covid19positive user either through the presence of a user's post in one of three subreddits, /r/depression, /r/depression_help, or /r/SuicideWatch, or through use of at least one of the phrases "suicide", "kill myself", "depression", or "depressed" across any posts for that user, regardless of subforum affiliation.

1.3. Modeling

Cox Proportional-Hazard models were used to analyze the data. Users who did not transition to a risk state were considered censored. Only the first post was considered for users who posted multiple times within /r/covid19positive. Users who mentioned a risk state before their first post on /r/covid19positive were excluded from this analysis. A cumulative hazard curve was generated to visualize instantaneous risk of depression or suicidal ideation over time between users identified as mentioning anosmia/ageusia symptoms.

2. Results

A total of 23,599 postings made by 15,821 users were found in the COVID-19 subforum, /r/covid19positive. Of these individuals, 6113 self-identified as having the disease and 3933 indicated anosmia/ageusia. A random sample of 100 posts which indicated anosmia/ageusia was manually examined, and 91/100 postings indicated that the writer lost their sense of smell and\or taste. Of the users in the COVID-19 positive subreddit, 1306 made suicide- and depression-related posts.

Among all users, 5420 mentioned their age and gender in their posts. The median age of users was 23 years (min: 13, max: 80). 30% were female. A logistic regression model of whether a person will ask about anosmia/ageusia given their age and gender found that both are statistically significantly correlated: The hazard rate for age is 1.03 ($p<10^{-10}$) and for gender is 1.80 ($p<10^{-10}$), indicating that higher ages and females are more likely to indicate anosmia/ageusia.

The results of the proportional-hazards model suggested that mention of anosmia/ageusia was significantly associated with a transition to a risk state of suicidal ideation and depression, as well as suicidal ideation and depression separately, herein operationalized as an increased likelihood of subsequently posting on the /r/depression, /r/depression_help, and/or /r/SuicideWatch subreddits. The results remained significant among the subset with self-reported COVID-19-positive diagnoses for predicting transitioned risk states of combined suicidal ideation or depression as well as depression alone, but not suicidal ideation alone. Overall, modeling indicates that those who indicated anosmia/ageusia-related symptology and were also COVID-19 positive had an approximately 30% higher risk of posting on a suicide or depres-

Table 1

Instantaneous risk of altered mental health state among /r/covid19positive users.

	A Suicide or Depression		B Suicide		C Depression	
	Model 1: All users	Model 2: COVID-19 Positive Users	Model 1: All Users	Model 2: COVID-19Positive Users	Model 1: All Users	Model 2: COVID-19Positive Users
N (N transitioned)	15,037 (738)	5822(317)	15,745 (1446)	6088(31)	17,073 (774)	5834(305)
Anosmia / Ageusia	1.314*	1.303*	2.794*	1.748	1.380*	1.300*
COVID-19 Positive	1.414*		2.860*		1.351	
Interaction	0.916		0.377		0.958	

Note: Results of the hazard models to predict posting related to suicide and depression. Model 1 includes all users on /r/covid19positive who posted in this subforum prior to posting in one of the target mental health subforums. Model 2 includes this /r/covid19positive subset of users who also directly indicated (see methods) they were COVID-19 positive. The table is split based on whether both suicide or depression (A), just suicide (B), or just depression (C) was the transitioned risk state considered as the target for analysis. Hazard ratios are reported with corresponding significance thresholds (*p*<0.05*).
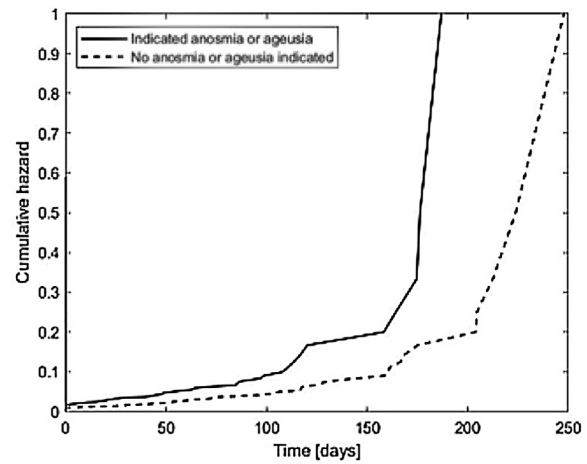
Fig. 1. Cumulative hazard curve for transition to a suicidal ideation or depression risk state

Note. The curve represents instantaneous risk of transition to a depression or suicidal ideation risk state between users who self-identified as having COVID-19 and mentioned anosmia or ageusia compared with those who self-identified as having COVID-19, but did not indicate these symptoms. Time is relative to the first posting in /r/covid19positive. (*n* = 5822).

sion Reddit subforum. See Table 1 and the discussion for specific hazard ratios, associated statistical significance, and their implications.

Results of the cumulative hazard curve (Fig. 1) indicated increasing instantaneous risk with the strongest impacts occurring more than 100 days after initial posting in /r/covid19positive.

3. Discussion

This study utilized Cox Proportional-Hazards models to separately and jointly quantify the instantaneous risk of depression and suicidal ideation over time as a consequence of COVID-19-induced anosmia and ageusia. Risk was operationalized using user post activity within the respective forums. The results indicated a statistically significantly (*p*<0.05) higher risk (~30%) of posting on the depression or suicide subreddits if self-identifed as suffering from anosmia/aguesia relative to those who posted in these subreddits without these symptoms. This risk was consistent regardless of whether anosmia/ageusia was identified as causally related to COVID-19. Moreover, when delineating between outcomes (as defined in the Methods), suicide and depression risk for anosmia/aguesia sufferers increased substantially to ~180% (*p*<0.05) and ~140% (*p*<0.05), respectively. The particularly large increase in risk of transition to suicidal ideation underlines sensory loss as an important risk factor for future studies that interrogate suicide against the backdrop of such comorbidities that present in various diseases such as Parkinson's, multiple sclerosis, or epilepsy. The results suggest a general association between anosmia/ageusia and increased risk of both depression and suicide. Such increase may be caused by the often lingering nature of anosmia/ageusia, as appreciated in other viral-mediated presentations such as the common cold and flu (de Haro-Licer et al., 2013).

For those identifying as suffering from COVID-19-specific anosmia/ageusia, only depression risk was statistically significantly (*p*<0.05) heightened (30%). Given the few subjects (*n* = 31) who posted in both the /r/covid19positive and the /r/suicidewatch subforums, the ability to detect a statistically significant signal was severely limited. In conjunction with a report on the myriad long-term consequences of COVID-19 on patients' mental constitution (Mazza et al., 2020), the risk of heightened depression discovered here is further evidence of the pandemic's lasting influence. Moreover, detection outside of clinical contexts within a larger, more generalizable population supports a more universal and severe impact of this pandemic on mental health.

The cumulative hazard curve for posting on the depression and/or suicide subforums as a function of self-identified anosmia/aguesia symptomology indicated an interesting trend (Fig. 1). An appreciable uptick in instantaneous risk was observed more than one hundred days subsequent to first posting within /r/covid19positive. One study conducted on N = 402 COVID-19 patients found that 55% of individuals presented with a pathological score for at least one mental health disorder when assessed one month after hospital treatment (Mazza et al., 2020). In addition, Mazza et al., 2020 recorded a higher than average incidence of anxiety, depression, and post-traumatic stress disorder. This alarming presence of psychopathology in the extended wake of COVID-19 illness supports a potential lagged impact on a patient's mental health - a pattern that was seemingly captured at the cohort level in the proportional-hazards model. The likelihood of this dynamic is not unprecedented. Across other disorders/diseases such as epilepsy and cancer, these lagged effects on mental health deterioration are well documented (Brown et al., 2020; Juengst et al., 2017), and the prevalence of health anxiety may be an important catalyst that drives the observed delayed effects to depressive state in COVID-19 survivors (Wu et al., 2020).

This study is not without its limitations. Despite a large number of users and the prior research showing strong consensus between mental health posts and DSM-5-based suicidal ideation and depression, the current study did not utilize traditional measurements of mental health symptoms, i.e. self-report or clinical interviews. Additionally, the current work relied on self-described COVID-19 diagnoses rather than from a positive result from a verified test kit. Although particular users for analysis were identified through activity in /r/covid19positive, anosmia/ageusia was defined by the presence of a constellation of terms describing smell or taste across all subreddits.

Our findings implicate anosmia/ageusia as an important risk factor for depression and suicidal ideation that may show a prolonged and/or delayed impact. Moreover, the current work suggests, through observed statistically significant increases in risk of subsequent post activity on the /r/depression, /r/depression_help, and /r/SuicideWatch subreddits, that sufferers of sensory loss as a direct result of the novel coronavirus are at an increased risk for mental health deterioration and depression. Special attention to the psychological needs of COVID-19 patients both during treatment and through long-term post-recovery follow-up is recommended.

Declaration of Competing Interest

Elad Yom-Tov, Damien Lekkas, and Nicholas C. Jacobson declare that they have no conflict of interest.

CRediT authorship contribution statement

Elad Yom-Tov: Conceptualization, Data curtion, Methodology, Formal analysis, Writing – original draft, Visualization. **Damien Lekkas:** Writing – original draft, Writing – review & editing. **Nicholas C. Jacobson:** Writing – original draft, Writing – review & editing.

Role of funding source

Contributors

EY-T conceptualized the study, collected the data, established the methodology, conducted the formal analysis, visualized the results, and reviewed and edited the manuscript. DL performed the literature review and wrote the manuscript. NCJ wrote, reviewed, and edited the manuscript.

All authors have approved the final article.

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