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Role of Telehealth Adoption in Shaping Perceived Quality of Care: Empirical Analysis

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Abstract

Drawing upon computer-mediated theory and hyperpersonal model, this study investigates the interplay of relationships underlying the adoption of telehealth, patient-perceived quality, and specialty risk categories driven by COVID-19. We identify the mechanism of the positive influence of telehealth adoption that different strategies of telehealth adoption (i.e., doctors who adopt telehealth and only accept video visits, doctors who adopt telehealth and accept both video visits and in-person visits, and doctors who do not adopt telehealth) is the driving force for the improvement of patient's perception quality. Further, our empirical results show that the connection between the degree of doctors' telehealth adoption and patients' perceived healthcare quality is operating through the pandemic phases. *Finally, our results suggest that the adoption of telehealth is more beneficial for a doctor with high-risk specialties than in low-risk specialties during the emergence phase of the pandemic outbreak.*

Keywords: COVID-19; Telehealth; Perceived Quality; Healthcare Decision Support

Introduction

The novel coronavirus (COVID-19) pandemic presents significant economic and social challenges worldwide due to the uncertainties inherent in the disease spread and dynamics (Abu-Rayash and Dincer 2020). The enormous scale of the crisis has naturally caused fear, uncertainty, and anxiety across the globe, presenting unprecedented challenges for financial institutions (Bhar and Malliaris 2020; Ferneini 2020), public administration and institutional actors (Bowen et al. 2017; Dutta and Fischer 2021; Yang 2020), businesses (Goddard 2020; Roggeveen and Sethuraman 2020), the wellbeing of individuals (Kar et al. 2020; Mamun et al. 2020), and healthcare providers (Ness et al. 2021; Sultana et al. 2020) alike. With the need for social distancing (i.e., staying home and away from others as much as possible to help prevent disease spread), there is a critical need to understand the mechanisms capable of providing stakeholders and organizations with the means for optimal alternatives to in-person meetings and interactions. This topic becomes especially relevant in the case of patient-provider relationships when patients seeking care need to frequently interact with doctors, including those in high-risk specialties. To combat the spread, the

practice of social distancing encourages the distribution of health-related services and information via electronic information and telecommunication technologies commonly referred to as telehealth. The COVID-19 pandemic introduced the practice of social distancing and encouraged the distribution of healthcare services via technology-enabled means commonly referred to as telehealth or telemedicine. During the pandemic, telehealth services provided a feasible alternative to in-person doctors' visits by delivering necessary care while minimizing the transmission and exposure risk of COVID-19 virus to protect medical practitioners and patients. According to the CDC guidelines, the benefits of telehealth adoption include reducing staff exposure to ill persons, preserving personal protective equipment, and minimizing the impact of patient surges on facilities[1]. While the benefits of telehealth cannot be underestimated, lacunae exist in understanding the impact of its adoption on patients' perceptions of the quality of care provided. Past literature defines perceived quality as "the customer's perception of the overall quality or superiority of a product or service with respect to its intended purpose, relative to alternatives" (Zeithaml 1988). We, therefore, raise the following research question: *What is the impact of the adoption of telehealth by doctors on patients' perception of quality of care amid COVID-19 pandemic?*

Finding answers to this question is important because collaboration between healthcare providers and telemedicine platforms could be crucial in combating the rapidly growing pandemic issues as well as help provide better response to other disasters associated with reduced in-person interactions. Given the limited resources during COVID-19, the current and projected demand for medical care is much higher than the available supplies. Telehealth thus presents an efficient way to coordinate supply with demand without potentially sacrificing the quality of care. Furthermore, many medical organizations endorse telehealth, consider it to be highly beneficial in healthcare, and try to accelerate the adoption of telehealth *(Doraiswamy et al. 2020)*. They argue that telehealth has several advantages that include cost savings, convenience, the ability to provide care to people with mobility limitations or those in rural areas, and improved patient health outcomes. However, some doctors have expressed concerns about the applicability of telehealth technology in the field. Critics say that doctors are unable to perform all aspects of treatment and examination while using telehealth; others are worried that the lack of face-to-face interaction may result in obstacles to building healthy relationships between doctors and patients, which is considered essential for effective healthcare delivery (Ellimoottil et al. 2018). Supporting these notions, a recent Deloitte survey showed that 33% of doctors are worried about medical mistakes associated with virtual healthcare, while 28% of patients who did not choose to use telehealth said that their hesitation comes from concerns about the quality of care[2]. These concerns reinforce the critical need for understanding whether telehealth presents a viable alternative to in-person healthcare services.

Our hypothesis formulation is rooted in extensive prior literature that addresses the interplay between telehealth adoption, perceived quality, and doctor specialties that are especially at risk amid COVID-19. Specifically, we draw upon the hyperpersonal model of computer-mediated communication (CMC) theory and predict that the adoption of telehealth has a positive influence on patients' perceived quality of healthcare (Walther 2007). To test out hypotheses, we collected a unique longitudinal panel dataset (N = 19,585) from Zocdoc, a prominent online health platform that has recently adopted telehealth technology for use by its participating physicians and patients. Our empirical identification strategy follows a variant of the difference-in-differences (DID) specification. Furthermore, to provide deeper insights associated with the mechanism underlying the telehealth-perceived quality link, we engage in extensive mining of unstructured text and examine the mediating role of latent features contained in reviews of patients.

Our study makes the following contributions. First, we aim to contribute to the nascent literature on digital resilience in elucidating the role of telehealth adoption in shaping patients' perceptions of the quality of health services. We also elucidate the mechanism underlying the telehealth-quality relationship by showing the role of latent features of online reviews in facilitating the effect of telehealth. Furthermore, we demonstrate that the role of telehealth can be a double-edged sword for doctors with different levels of adoption and across different specialties. Finally, based on our findings, we provide several insightful implications for policymakers and practitioners.

[1] https://www.cdc.gov/coronavirus/2019-ncov/hcp/telehealth.html
[2] https://www2.deloitte.com/us/en/insights/industry/health-care/virtual-health-care-health-consumer-and-physician-surveys.html

Literature Review

The Health Resources Services Administration defines telehealth as "the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration." Telehealth encompasses various technologies including videoconferencing, store-and-forward imaging, email, streaming media, and other forms of telecommunication.

Using technology to deliver health care has several advantages, including cost savings, convenience, and the ability to provide care to people with mobility limitations, or those in rural areas who don't have access to a local doctor or clinic. For these reasons, the interest in telehealth use has grown significantly even before the COVID-19 pandemic (Dorsey and Topol 2016). According to Harvard Business Review, 76 percent of hospitals in the U.S. connect doctors and patients remotely via telehealth, up from 35 percent a decade ago[3].

Telehealth has become even more essential during the coronavirus (COVID-19) pandemic. Clinics and hospitals rapidly restricted access to emergency care to reduce the risk of disease transmission. For patients, fears of catching the virus during in-person medical visits have led to a greater interest in technology to provide and receive health care. In reaction to the cumulated patient load, several countries relaxed their laws and regulations pertaining to the use of telehealth. Insurance companies have now started reimbursing expenses for patient care delivered via telehealth (Cason and Brannon 2011). Healthcare providers and platforms, therefore, start expanding their health care delivery by providing telehealth services.

While many are optimistic about the potential of virtual care, others in the industry still have some concerns. For example, when there is a lack of face-to-face connection between patients and doctors that may damage the therapeutic bond between the two parties. And some remain doubtful of the extent to which virtual care delivers on the above-mentioned advantage. Others express concern that clinicians are unable to perform all aspects of physical examination while using telehealth (Ellimoottil et al. 2018).

Patients' perception of care quality refers to patients' subjective view of services received (Larrabee and Bolden 2001; Organization 2000). It is not limited to clinical outcomes, but instead decided based on a holistic experience throughout the continuum of care (Reynolds 2009). Many health services researchers believe that perception of quality should be a component of evaluating medical outcomes (Davies and Ware Jr 1988). Practically, health services evaluators have also routinely used patient ratings of the outcome of treatment to measure treatment efficacy in clinical trials (Weaver et al. 1997). A recent study in the field of Information System also reveals that the patients' online ratings can be used to reflect offline population's perception of physician quality (Gao et al. 2015).

The inherent technical basis of telehealth has greatly changed the way of healthcare delivery, but a strong relationship with doctors and patients must be maintained, regardless of the mode (Onor and Misan 2005). For telehealth, patient perceived quality reports are even more important since it is the only source of information that can record how they were treated and if the treatment received met the patients' expectations of care. If many patients, for example, are not happy with their healthcare services being provided remotely, the telehealth mode of communication is likely to not only irritate patients, but also could lead to inefficient use of the available resources. Healthcare organizations are expected to continue to develop more technology-based care and formulate comprehensive policies to meet the needs of patients and providers[4]; thereby, reinforcing the need to focus on offline means of healthcare delivery such as telehealth.

Doctors' online ratings and reviews provide unfiltered data on patients' perceptions of health care services (Hodgkin 2009; Jain 2010; Mostaghimi et al. 2010). Different from structured surveys, unstructured reviews allow patients the freedom to express their feelings and views of their doctors on their own terms. Several platforms (e.g., Zocdoc, RateMDs, Healthgrades, Yelp, etc.) allow individuals to review their doctors in an anonymous (and non-anonymous, too) and unstructured format. These publicly available evaluations can complement existing research on the relationships underlying the mechanisms between patients and physicians. Understating which doctor-patient relationship factors are particularly important to patients

[3] https://www.health.harvard.edu/staying-healthy/telehealth-the-advantages-and-disadvantages
[4] https://www.healthaffairs.org/do/10.1377/hblog20210119.724670/full/

can give both healthcare providers and platforms significate insights and directions to improve patients' experience.

Despite the potential impact of telehealth that bridges online healthcare delivery to offline healthcare services (Agarwal et al. 2010), few studies have explored the impact of physicians' telehealth adoption dynamics on the doctor-patient relationship, especially in response to the global pandemic crisis. Hence, in this paper, we first explore the focal impact of different strategies of telehealth adoption (i.e., doctors who adopt telehealth and only accept video visits, doctors who adopt telehealth and accept both video visits and in-person visits, and doctors who do not adopt telehealth) on patients' perceived healthcare quality. Next, we consider doctor's infection risk level of various specialties as an important factor that can moderate the impact of doctors' telehealth adoption on patients' perceived quality. A complete understanding of the moderating factor helps doctors and the healthcare platform to comprehensively evaluate the effectiveness of their telehealth adoption according to their own characteristics and provides better guidance to adopt appropriate strategies in response to the pandemic.

Hypotheses Development

The conceptual model underlying our research is presented in Figure 1 below.

Relationship between Telehealth Adoption and Perceived Quality

Literature has shown that telehealth increases perceived quality in many cases and also serves as a suitable alternative to traditional methods of medical administration, especially in debilitated and terminal patient populations (Doolittle et al. 2005; Whitten et al. 2004). Reasons that telehealth has the potential to improve patients' perceived healthcare quality include the elimination of travel time, waiting time, and hassles and excessive hold times in arranging appointments with staff through telephone among others.

In addition to the aforementioned external factors, the reason why telehealth enhances patients' perceived quality of care can be explained by hyperpersonal communication theory which describes how (1) information receivers tend to idealize perception of the sender, (2) sender designs enhanced self-presentation. Channels provide options and possibilities for the user to customize the transmitted messages and selected self-presentation (Walther 2007). Although Walther originally tests his theory by comparing text-based computer-mediated communication and in-person communication, the theory can also be applied to video-mediated communication (VMC). Even though nonverbal cues are available in VMC, still have several limitations. Its inability to scan light changes in the visual signs or reach something unavailable in visual forms such as odor becomes communication barriers. Nevertheless, this limitation is used by users as an opportunity to perform selective self-presentation.

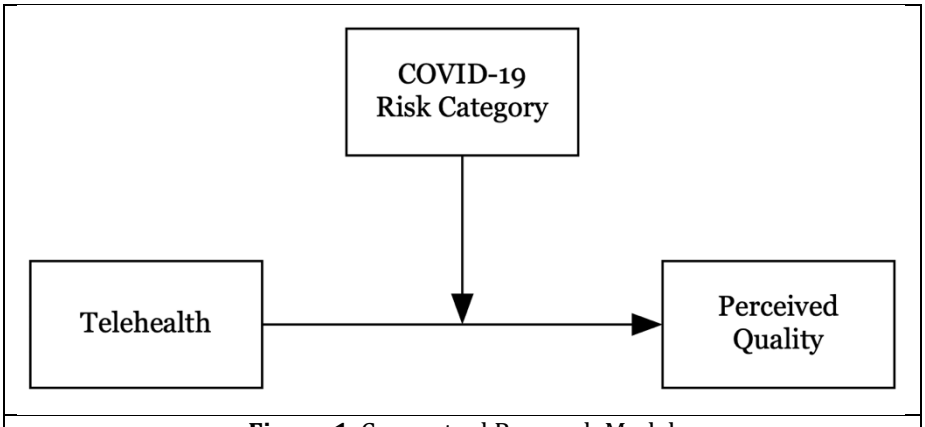

Figure 1. Conceptual Research Model

Further, from the perspective of telehealth adoption, doctors can be grouped into three categories: (i) those who adopt telehealth and only accept video visits, (ii) those who adopt telehealth and accept both video visits and in-person visits, and (iii) doctors who do not adopt telehealth. Building on the aforementioned

theoretical elaborations and prior literature, we expect doctors that adopt telehealth (in either mode) to have, on average, higher scores on perceived quality provided by their patients compared to doctors that do not adopt telehealth. We, therefore, hypothesize:

H1a: For doctors that switch from in-person to online visits only, the adoption of telehealth will lead to an increase in patients' perceived quality of care, on average.

H1b: For doctors that switch from in-person to online and in-person visits (hybrid), the adoption of telehealth will lead to an increase in patients' perceived quality of care, on average.

Further, we turn our attention to the difference in patients' perceived quality between doctors who switch fully from in-person to online visits and those who adopt a hybrid strategy. Previous studies in online and offline channel integration have shown that adding an *additional* option into the set of services provided may inevitably lead to channel conflicts (Verhoef et al. 2015), which in turn could lead to marginal improvements in the perceptions of quality provided. Similarly, for doctors who adopt a hybrid strategy, patients' online and offline visits may be considered under competition to some extent, because both are competing for the investment of doctors' time. During the pandemic, it could be the case that some doctors might be willing to give telehealth a try following examples of others; however, without a clearly delineated adoption strategy. This seemingly harmless approach, on the flip side, may result in cannibalizing doctors' efforts given their potential lack of skills required for being ambidextrous in communicating equally well in both modes. Consequently, conflicts may arise between channels leading us to hypothesize:

H1c: Compared to doctors that adopt telehealth in hybrid mode, doctors that switch to online visits only will observe a higher magnitude of the effect on perceived quality.

Finally, for the hybrid adoption strategy, we argue that the degree (or intensity) of doctors' telehealth adoption (i.e., the ratio between weekly online and offline visits) is positively associated with patients' perceived quality of care, on average. In other words, the more video conferences hybrid adopters participate in, the more experience they will likely acquire, which would ultimately lead to better outcomes for patients. This line of reasoning is consistent with prior research indicating that physicians' online activities can lead to a higher service quantity in offline channels, whereas offline activities may reduce physicians' online services because of resource constraints, such as time and effort, for instance (Wang et al. 2020). Therefore, doctors that use telehealth to a greater extent are more likely to have a better integration of online and offline channels; thereby, making them more comfortable and efficient in switching between the two modes without losing in perceived quality. We, therefore, hypothesize:

H1d: For hybrid adopters, the degree of their telehealth adoption is positively associated with patient's perceived quality of care, on average.

Doctor's specialty risk level moderates the impact of telehealth adoption

Prior literature has indicated that in many instances the physicians' perceived quality measurements differ based on their specialty. For example, generally, obstetrician-gynecologists have been found to report higher patient satisfaction than other specialties, while orthopedics have been found to report lower satisfaction than other specialties (Chen et al. 2017; Patel et al. 2011). And another study found that compared to family doctors, specialty physicians received lower patient satisfaction scores since they lean toward using a doctor-centered communication style that allows for little patient participation (Ruiz-Moral et al. 2006). Further, as the coronavirus continues to spread throughout the United States, health care workers become at the greatest risk — i.e., they get a higher chance of contracting the virus working in environments with ill patients and in close proximity with other doctors. Supporting this notion, recent reports indicate that emergency medicine and anesthesiology specialists, for example, were at higher risk of contracting the coronavirus comparing to cardiology[5] and ophthalmology[6].

From the patient perspective, it is imperative for them to feel safe when interacting with healthcare providers during in-person visits. This notion becomes even more important when patients need to interact with doctors who are more likely than others to have a higher patient flow and consequently have a higher chance of being exposed to COVID-19. If those high-risk professions can provide their medical services via

[5] https://www.medscape.com/viewarticle/930553
[6] https://www.beckersasc.com/anesthesia/preprint-finds-3-specialties-at-higher-risk-of-contracting-covid-19-4-takeaways.html

telehealth while maintaining the quality of services that they provide, patients' perceptions can be enhanced with the sense of feeling safe and being taking care of. For example, dermatologists can be seen as a specialty that needs close contact with patients. With telehealth, patients can speak with the dermatologist via video call. The only thing they might need to do is to send pictures of the issue, in advance. Therefore, driven by higher perceptions of safety, it is feasible to expect that the perceived quality of services provided by doctors in high-risk specialties via telehealth would be higher:

Hypothesis 2. The relationship underlying telehealth adoption and perceived quality link will be moderated (dependent on) the risk-category of doctors' specialty, such that telehealth adopters in higher risk category will have higher perceived quality scores.

Research Methods and Dataset

Data

In this study, we collect data from Zocdoc.com, an online physician appointment-booking and review website launched in 2007. To collect data from the platform we used a combination of Python-based libraries including but not limited to Pandas, NumPy, Beautiful Soup, Selenium. The original ratings, which we use as a measure of perceived quality – our *dependent* variable, were recorded as integers from 1 to 5 (no outliers detected) and included no missing values at the review level. For the purpose of our analysis, we then aggregated the ratings at means at the weekly level for each doctor. The average number of observations per doctor was 7.3 (min 1, max 51). Perceived quality has been operationalized with online ratings in the previous literature (Gao et al. 2015; Ho et al. 2017; Wolf 2012).

Zocdoc claims to currently serve around 40% of the US population across different cities and physician specialties. Figure 2 (below) presents a screenshot of our focal platform. Patients can search for physicians by various criteria (e.g., insurance, specialty, location, etc.) and get access to physicians' appointment books and easily make an appointment online.

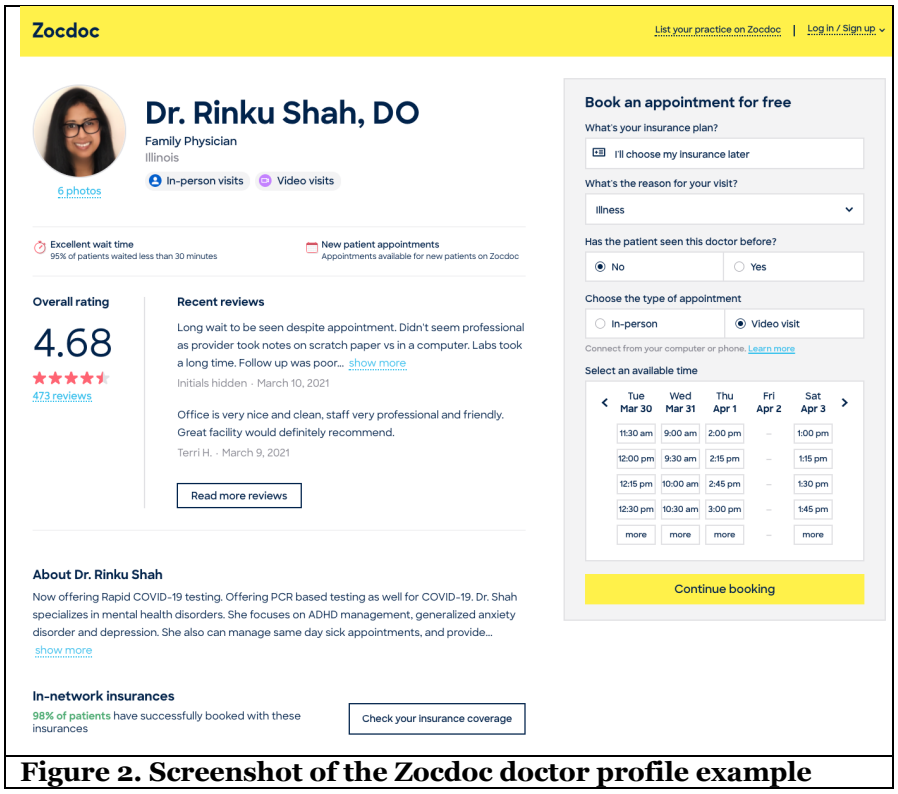

Figure 2. Screenshot of the Zocdoc doctor profile example

In reaction to the pandemic, the United States administration opens up access to telehealth services during this coronavirus outbreak. On April 3rd, 2020, Zocdoc has added telehealth appointments to its platform

in response to the spike in demand for virtual care. With the new function, patients can choose to schedule video visit appointments or in-person visits with doctors.

We collect both doctor profile data and patient review data. Doctor profile data includes acceptance of in-person visits, acceptance of video visits, specialties, gender, and office location. In this study, we only consider those doctors who only accept video-visit and those who only accept in-person visits. The reason is that for those who accept both types of visits, we might not be able to identify the time and efforts those doctors allocate to the two types of patient visits.

Our dataset contains 13,608 physicians with 135 specialties. Among them, 543 doctors that switch from in-person to online visits only (206 male and 337 female), 4,691 doctors switch partially from in-person to online and in-person visits (hybrid) (2,348male and 2,343 female), and 8,374 doctors choose only to accept in-person visits (4,628 male and 3,746 female).

Following prior studies in online healthcare platforms, we controlled for several factors found to be associated with patients' perceived quality. Firstly, we controlled for several basic physicians' features including (1) gender, (2) specialty, and (3) geographic location (i.e., states) (Shukla et al. 2021). Second, we controlled for the word count of reviews that signal patients' efforts on performance evaluation (Xu et al. 2021). And finally, we control for weekly COVID-19 cases at the state level as an environmental factor (Scott et al. 2021).

Patient review data include rating score, review content, review written time, whether the visit is a video visit, and patients id. For review data, we use reviews written between the first week of January 2019 and the first week of January 2021. Our rationale to constrain the dataset between these dates is rooted in the prior literature that suggests using fixed pre- and post-intervention intervals to better capture the effect of interest. For example, one study used 5-weeks before and 17-weeks after the intervention (Khurana et al. 2019), and another one used 3-months periods before and after the intervention for identification of the focal effect (Liu et al. 2020). Our decision is also consistent with the different phases of the pandemic, where the focal effect is best captured during the initial surge of the COVID-19 cases and most of the U.S. population was under lockdown (Wosik et al. 2020). Once the lockdown restrictions were lifted, most of the practitioners and patients were able to return to in-person appointments, which results in the decline of telehealth services[7]. To account for potential confounding of time intervals, we conduct robustness checks to verify if our results are robust across different time windows; expanding the windows to 12 and 24 months produces similar results.

To measure COVID-19 risk associated with different specialties, we adopt an approach presented by Visual Capitalist[8]. Their score is calculated using O*NET, a database maintained by the Department of Labor that describes various physical aspects of different occupations, on three attributes: (1) How much does this job require the worker to be in contact with others to perform it? (2) To what extent does this job require the worker to perform tasks in close physical proximity to others? (3) How often does this job require exposure to hazardous conditions? This method assigned each attribute an equal weight, then aggregated them to

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Rating	41,049	4.818	0.683	1.000	5.000
Weekly online/offline visits ratio	41,049	0.022	0.144	0.000	1.000
Risk	41,037	81.481	12.181	29.400	94.600
Controls					
Word Count	41,049	28.507	29.624	0.000	586.000
Covid Cases	41,049	780.702	1927.262	-12.000	9740.000

Table 1. The summary of patient review data

[7] https://www.statnews.com/2020/09/01/telehealth-visits-decline-covid19-hospitals/
[8] https://www.visualcapitalist.com/the-front-line-visualizing-the-occupations-with-the-highest-covid-19-risk/

arrive at a final COVID-19 Risk Score between 0 and 100, while 100 representing the highest possible risk and 0 representing the lowest risk.

The summary of patient review data is shown in Table 1.

Perceived Quality Trends: Parallel Assumption Test

Figure 3 depicts the average rating of doctors that switch fully to telehealth (denoted G0, green curve), doctors that switch partially to telehealth (denoted G1, red curve), and doctors that maintain only in-person visits (denoted G3, blue curve) from October 2019 to September 2020). In the pre-telehealth period, the rating of all groups is roughly following a similar trend. That gradually decreases from October 2019 to December 2019 and increases from December 2019 to April 2020. We acknowledge the fact that the pre-treatment trends are not perfectly parallel, a sign attributed to the possible noise in the data. We accept this fact as a limitation in our initial analysis. To account for this in the future, we will conduct a battery of robustness checks following the best practices in public health research (Wing et al. 2018).

Figure 3. Parallel trends

Empirical Model Specification and Analysis

In this section, we present our empirical analysis and results. We begin by examining the impact of doctors' telehealth adoption (using different strategies, i.e., full vs. hybrid) on patients' perceived quality of care.

Model and Results of Hypothesis 1 Testing

Model for Hypothesis 1 a, b, c, d Testing

To identify the impact of telehealth adoption using different strategies on patients' perceived quality of care, we employ a two-group/two-period (2x2) difference-in-differences (DID) model that compares the pre- versus the post-introduction of telehealth appointment function in our target platform for (i) doctors that only accept video visits (denoted G3) and those that accept only in-person visits (denoted G1); and (ii) doctors that adopt hybrid model (denoted G2) those that accept only in-person visits (denoted G1). This is a typical situation in which the DID estimation can be effectively used to estimate the treatment effect (in this case, participating in the adopting telehealth) on a given dependent variable (here, the weekly average of scores ranging from 1 to 5 points of doctors given by patients). Additionally, we compare (iii) doctors that accept online visits only (denoted G3) to those who adopt in hybrid mode (denoted G2).

The DID estimation has the advantage of controlling for unobserved characteristics and combining them with observed or complementary information (Villa, 2012) The differences between the control and the treatment group (the participants) at time *t* are estimated by taking into account both existing differences between the groups before and after the intervention. The identifying assumption is that whatever happened to the control group over time is what would have happened to the treatment group in the absence of deliberation. To achieve this, the data were reshaped into a long format so that two dummy variables were created. The first dummy (*Time*) identifies the time at which the observation was taken (time = 0 if the observation was taken before the intervention and = 1 after). And the second dummy (*Treated*) identifies whether the observation is in the treatment or in the control group (= 1 for participants and =0 for non-participants). For individual *i*, this initial setting performs the following linear regression equation:

$$Rating_{its} = \beta_i Treated_i + \beta_t Time_t + \beta_{2x2} Treated_i \cdot Time_t + \delta X_{its} + Specialty_j + State_s + Week_t + \epsilon_{ijts} + beta0j \quad (1)$$

$$Rating_{its} = \beta_i Treated_i + \beta_t Time_t + \beta_{2x2} Treated_i \cdot Time_t + \delta X_{its} + Specialty_j + State_s + Week_t + \epsilon_{ijts} + beta0j \quad (2)$$

$$Rating_{its} = \beta_i Treated_i + \beta_t Time_t + \beta_{2x2} Treated_i \cdot Time_t + \delta X_{ijts} + Specialty_j + State_s + Week_t + \epsilon_{ijts} + beta0j \quad (3)$$

In Equation (1), *i* indexes each physician group where *Treated*=1 represents doctors who only accept telehealth and 0 presents those who only accept in-person visits. In Equation (2), *i* indexes each physician group where *Treated*=1 represents doctors who accept hybrid strategy and 0 presents those who only accept in-person visits. In Equation (3), *i* indexes each physician group where *Treated*=1 represents doctors who only accept telehealth and 0 presents those who accept the hybrid strategy.

For all Equation (1), (2), and (3), *j* indexes the specialties of doctor *i*, *t* indexes time in week-year periods, and s indexes states. $Rating_{its}$ is the average rating given by patients to doctor *i* at time *t* (the time unit is a week). X_{ijts} is a vector of control variables that includes time-varying covariates known to impact the set of outcome measures we employ. Heteroskedasticity-robust standard errors clustered by physicians are denoted by ε_{it}, which addresses the serial correlation problem and relaxes the assumption that standard errors are identically distributed and independent of each other (Bertrand et al. 2004, Wooldridge 2010). Finally, β_{0j} refers to the intercept of the dependent variable in state *j* and is included to account for the different levels of measurement in the observed number of cases COVID-19 cases (Hamilton 2012).

The estimated coefficients have the following interpretation: β_0 stands for the mean outcome for the control group at t1; $\beta_0 + \beta_1$ refers to the mean outcome for the control group at t2; β_2 is the single difference between participants and control group at t1; $\beta_0 + \beta_2$ stands for the mean outcome for the participants at t1; $\beta_0 + \beta_1 + \beta_2 + \beta_3$is the mean outcome for the participants at t2. Finally, β_3 stands for the DID (our quantity of interest here).

To further estimate the impact of degree (intensity) of telehealth adoption on patients' perceived quality of healthcare, we apply OLS model to test our last hypothesis.

$$Rating_{its} = \beta_0 + \beta_1 VideoRatio_{it} + \delta X_{ijts} + Specialty_j + State_s + Week_t + \epsilon_{ijts} + beta0j \quad (4)$$

In Equation (4), $VideoRatio_{it}$ represents the proportion of video visits to all visits at week *t*. Same as in Equation (1) – (3), X_{ijts} is a vector of control variables that includes time-varying covariates known to impact the set of outcome measures we employ.

Results for Hypotheses 1 a, b, c, d Testing

Table 2 below presents the results of hypothesis 1 testing. We apply our model to the following time windows: pre-treatment period November 2019 – March 2020 and post-treatment period April 2020 – October 2020. We report White's robust standard errors to alleviate heteroskedasticity concerns. Additionally, we note the percent of explained variation is relatively small, as there could be other unobserved factors associated with quality of care, such as patient and physicians' socio-demographic characteristics, patient cooperation and illness implications, physician competency, physician motivation and satisfaction, providers' resources and facilities, collaborations and partnerships, among others.

Hypotheses 1a is supported. According to the results of model 1 in Table 2, we first find that patients' perceived quality of healthcare is significantly improved after the platform introduces the telehealth appointment function. We also find that the interaction term ($Treated_i \cdot Time_t$) are significantly positive. After the platform launch the features of telehealth, there is an increase in patients' perceived quality for

doctors who choose not to adopt telehealth. However, doctors who choose to use telehealth to meet patients have a much higher level of patients' perceived quality than before.

A possible reason for the increase in the level of patient recommendations for doctors who choose not to adopt telehealth and keep meeting patients in person is that the launch of the telehealth feature of the platform attracts more patients to use the online portal and they have appreciated those doctors who still willing to see patients during such dangerous pandemic time. Therefore, the introduction of the telehealth feature can increase the overall customer traffic of the online portal and benefit the listed doctors who choose not to use the function.

Model/ Variable	**(1) G3/G1 (H1a)**	**(2) G2/G1 (H1b)**	**(3) G3/G2 (H1c)**	**(4) G2 (H1d)**
Time	0.115* (0.040)	0.090** (0.029)	0.058* (0.042)	
Treated	-0.026 (0.032)	0.039*** (0.008)	-0.055 (0.032)	
Time*Treated	0.104* (0.037)	-0.016 (0.010)	0.130*** (0.037)	
Weekly online/offline visits ratio				0.015 (0.014)
Log(Word count)	-0.121*** (0.005)	-0.122*** (0.004)	-0.121*** (0.005)	-0.122*** (0.006)
N(Weekly COVID cases)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Gender	-0.006 (0.007)	-0.008 (0.006)	-0.011 (0.009)	-0.010 (0.009)
State dummies	*Yes*	*Yes*	*Yes*	
Specialty dummies	*Yes*	*Yes*	*Yes*	
Week dummies	*Yes*	*Yes*	*Yes*	
R-squared	*0.057*	*0.046*	*0.048*	*0.049*
N(doctors)	*6,888*	*10,427*	*4,103*	*3,821*
N(observations)	*40,967*	*67,910*	*30,335*	*28,639*

Table 2. Differences-in-differences regressions of telehealth effect on average rating (robust SE).

Note: These are models for November 2019 to August 2020 (assuming about 5 months in the pre and post and dummy_0403 as the start of intervention).

Hypotheses 1b is not supported. According to the results of model 2, patients' perceived quality of healthcare is not significant after the platform introduces the telehealth appointment function for doctors who adopt the hybrid model. We suggest the possible reason for this result may be that those doctors who adopt the hybrid model may be lack skills and preparation for telehealth adoptions. Without a clear understanding and strategy of telehealth but simply giving telehealth a try, the adoption of telehealth may not be as effective as they expected.

Hypotheses 1c is supported. We have model 3 to compare doctors who fully switch to video visits and doctors who adopt the hybrid model. The results show that telehealth adoption has a stronger impact on patient's perceived quality for doctors who adopt the video-only model than doctors who adopt the hybrid model. The interaction term ($Treated_i \cdot Time_t$) in model 5 is significantly negative.

Hypotheses 1d is conditionally supported. The result of model 1 in Table 2 tests the hypothesis by comparing 5 months in the pretreatment period and 5 months in the post-treatment period and shows that, for hybrid adopters, the degree of their telehealth adoption and patient's perceived quality of care has no significant relationship.

To further test our hypothesis, we take the phase of pandemic into consideration. According to a recent physician's report[9], people's psychological conditions during the pandemic have three stages: Emergency,

[9] https://hbr.org/2020/08/leading-into-the-post-covid-recovery

regression, and recovery. The first weeks of managing any crisis (emergency phase) can feel both meaningful and energizing. As time goes by, people will then move to the second phase—regression. While focus and performance can be enhanced during the emergency phase, people become tired and distracted during the regression phase. Finally, we will come to the third and final recovery phase.

We hypothesize that doctors who invest more time and effort in telehealth during the pandemic can acquire more benefits in terms of patient's perceived quality only happened during COVID-19 emergency phase. The reason is that both doctors and patients may be more open to try and learn telehealth. Those doctors who are willing to invest more time during this emergence phase can have more experience in integrating two channels, which in turn get better patients' perceived quality. In contrast, during the regressions stage, doctors' learning passion will decrease, so such an effect will disappear or even have a negative effect.

Here, we set the first four months after the release of telehealth as the emergency phase (Apr 20 – Jul 20), while the following four months as the regression phase (Aug 20 – Nov 20). We apply equation (4) on two different time windows: (1) 5 months in pretreatment period (Nov 2019 – Mar 2020) and emergency phase for post-treatment period (Apr 2020 – Jul 2020). (2) 5 months in pretreatment period (Nov 2019 – Mar 2020) and regression phase for post-treatment period (Aug 2020 – Nov 2020). The results are shown in Table 3. We can identify the positive relationship between the degree of their telehealth adoption and patient's perceived quality of care for hybrid adopters through the first-time window, while there is a negative relationship in the second time window. These results infer those doctors who invest more time and effort in telehealth during the pandemic can acquire more benefits in terms of patient's perceived quality, while such effect only happened during COVID-19 hospital surge phase.

	Pre: Nov 19 - Mar 20 Post: Apr 20 – Aug 20	Pre: Nov 19 - Mar 20 Post: Apr 20 – Jul 20 (Pre-pandemic phase vs emergence phase)	Pre: Nov 19 - Mar 20 Post: Aug 20 – Nov 20 (Pre-pandemic phase vs regression phase)
Model/ Variable	**(4) G2 (H1d)**	**(4) G2 (H1d)**	**(4) G2 (H1d)**
Weekly online/offline visits ratio	0.015 (0.014)	0.033* (0.015)	-0.056** (0.018)
Log(Word count)	-0.122*** (0.006)	-0.121*** (0.006)	-0.146*** (0.006)
N(Weekly COVID cases)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Gender	-0.010 (0.009)	-0.006 (0.009)	-0.005 (0.009)
State dummies	*Yes*	*Yes*	*Yes*
Specialty dummies	*Yes*	*Yes*	*Yes*
Week dummies	*Yes*	*Yes*	*Yes*
R-squared	*0.049*	*0.050*	*0.055*
N(doctors)	*3,821*	*3,706*	*3,977*
N(observations)	*28,639*	*25,477*	*30,457*

Table 3. Regressions of weekly online/offline visits ratio effect on average rating (robust SE).

Models and Results of Hypothesis 2 Testing for Moderation

Models for Hypothesis 2 Testing

In this section, we examine how doctor specialty risk moderates the impact of doctors' telehealth adoption. In regression Equation (5), we look at the moderating role of specialty:

$$Rating_{ijts} = \beta_0 + \beta_i Treated_i + \beta_t Time_t + \beta_j Risk_j + \beta_{2x2} Treated_i \cdot Time_t + \beta_{2x2} Treated_i \cdot Risk_j + \beta_{2x2} Time_t \cdot Risk_j + \beta_{3x3} Treated_i \cdot Time_t \cdot HighRisk_j + \delta X_{its} + Specialty_j + State_s + Week_t + \epsilon_{its} + beta0j \quad (5)$$

where $Risk_j$ is a variable indicating whether a doctor's specialty faces the high risk of exposure to COVID-19.

Results for Hypothesis 2 Testing

In the regressions on moderating factors, we examine the impact of doctors' specialty risk of exposure to COVID-19 on patients' perceived quality of care. The estimation results are reported in Table 4. We also tested our hypothesis 2 mainly on two different time windows: (1) pre-treatment period Sep 2019 – Mar 2020 and post-treatment period: Apr 2020 – Aug 2020 (full post-treatment period) and (1) pre-treatment period Sep 2019 – Mar 2020 and post-treatment period: Apr 2020 – Jun 2020 (short post-treatment period).

Model/ Variable	**(5) G3/G1 (H2)**	**(5) G3/G1 (H2)**
Time	0.075*** (0.019)	0.117* (0.043)
Treated	0.075 (0.054)	0.074 (0.054)
Risk	-0.003 (0.039)	-0.005 (0.039)
Time*Treated	-0.050 (0.065)	-0.054 (0.065)
Time*Risk	-0.003 (0.020)	-0.002 (0.020)
Treated*Risk	-0.138* (0.066)	-0.139* (0.066)
Time*Treated*Risk	0.209* (0.078)	0.212* (0.078)
Log(Word count)	-0.122*** (0.005)	-0.121*** (0.005)
N(Weekly COVID cases)	0.000 (0.000)	0.000 (0.000)
Gender	-0.006 (0.007)	-0.006 (0.007)
State dummies	*Yes*	*Yes*
Specialty dummies	*Yes*	*Yes*
Week dummies		*Yes*
R-squared	*0.055*	*0.057*
N(doctors)	*6,888*	*6,888*
N(observations)	*40,967*	*40,967*

Table 4. Differences-in-differences regressions of telehealth effect on average rating: moderating effect of doctors' specialty risk of exposure to COVID-19 (robust SE)

Note: These are models for November 2019 to August 2020 (assuming about 5 months in the pre and post and dummy_0403 as the start of intervention).

The results show that the coefficients on the triple interaction term are significantly positive for time window 2, but not significantly for time window 1. These results point to the fact that the adoption of telehealth is more beneficial for a doctor with high-risk specialties than in low-risk specialties during the early stage of the pandemic outbreak.

It is plausible that specialties with a high risk of infection generally need closer interaction between doctors and patients. At the early and severe stage of the pandemic, patients may believe that they benefit from telehealth since the technology can reduce the risk of infection of both parties. However, those high-risk specialties might have some features that cannot be replaced by telehealth. For example, OB-GYN needs to use an ultrasound machine to produce pictures of a baby. That's why the interaction term in time window 1, shown in columns (1), is not significant.

Discussion

In this study, we investigate the impact of telehealth adoption by practicing physicians on patients' perceptions of service quality. The results lend support to our predictions. First, we found that the adoption of telehealth will lead to an increase in patients' perceived quality of care for doctors that switch fully from in-person to online visits. These results suggest that doctors can benefit from the adoption of telehealth from the perspective that patients perceived health care quality during the pandemic period.

To elaborate, during the pandemic, patients' perception of healthcare can be improved via the use of telehealth. This finding highlights the critical importance of interactions and communications between doctors and patients. The patients' perception is displayed and embedded in their rating of the visits (online or offline). We believe this positive effect of telehealth points to two possibilities that future research may further explore. First, a direct effect on doctors, that is, the adoption of telehealth and visit patients via video conference will change doctors' behavior by leading the doctors to improve their healthcare delivery, such as spending more time to answer patients' questions. Second, an indirect effect on patients, that is, although the doctors do not change their behavior, the patients' perceived quality of doctors improved because of the hyperpersonal effect. For example, through in-person visits, patients may observe that the doctors are reviewing their medical records while they are expressing their symptoms to the doctors, which may make them feel uncomfortable since the lack of eye contact. The video window and medical records may be shown on the same screen through telehealth. Although the doctors are reviewing patients' records, patients may still believe the doctors are looking into their eyes.

The first direct effect can be explained by various virtual team behavioral research in which video conferencing is shown to improve engagement, discussions, and decision-making among virtual team members comparing to face-to-face meetings. The second indirect effect can be explained by hyperpersonal theory in computer-mediated communication literature, which posits that an information receiver (i.e., patients in or case) tend to idealize perception of the sender (i.e., doctors).

We further look into whether different strategies of telehealth adoption (i.e., doctors who accept video visits only and doctors who adopt the hybrid model) have different impacts on patients' perceived quality of healthcare. We have observed that the positive impact of telehealth is stronger for those doctors who fully switch from in-person to video visits. This interesting finding tells us that although telehealth is a useful alternative to such external shocks, it is still very important to resume face-to-face medical care as soon as possible. We also have observed that for the hybrid adoption strategy adopters, the degree (or intensity) of doctors' telehealth adoption is positively associated with patients' perceived quality of care, during the emergence phase only. We can infer from this result that although doctors are more likely to have a better integration of online and offline channels if they perform telehealth to a greater extent, but the necessity of offline visits is still irreplaceable. After the emergence phase, doctors may still put more effort into their offline visits.

Finally, our research shows that doctors specialties with high risks of disease infection get higher patients' perceived quality of care. Doctor specialties with high risks of infection are expected to work closely with patients, compared with a doctor with specialties with low risk of infection. One of the main purposes to adopt telehealth is to reduce the risk of exposure to coronavirus by increasing social distancing. This discovery can reduce people's suspicion that telemedicine may only be useful to those specialties that do not need close contact with patients. Those doctors with high-risk specialties can be benefits from telehealth to maintain continuity of care to the extent possible can avoid additional negative consequences from delayed preventive, chronic, or routine care.

Practical Implications

Our study has several practical implications. First, our findings are of interest to healthcare providers in areas affected by the coronavirus disease 2019 (COVID-19) pandemic. In order to adopt social distancing practices, health care facilities and providers offer clinical services through virtual means such as telehealth. For consumers of healthcare services, telehealth provides a way to stay at home and communicate with physicians through virtual channels. The results of our study suggest the adoption of telehealth can improve patients' perceived quality of care. In other words, we have shown that the technology is proven to be useful from the viewpoints of patients. For healthcare providers and managers of healthcare portals, with the

emphasis on patients' perceived quality, it is in their interests to improve patients' perceived service quality. The results give both doctors and platforms an overall understating that what factors are patients focus on more while using video conference.

Second, our study provides guidance for healthcare providers that what kind of telehealth adoption model should they use during the pandemic, either the video-visit-only model or the hybrid model. Our results show that both models can significantly improve patients' perceived quality during the pandemic. However, the effectiveness is stronger for those who adopt video only model. This infers that the hybrid model might be an effective way to deal with external shock, but not a long-term solution. Therefore, for those who have confidence and resources to reopen shortly, such as big hospitals, the hybrid model might be a good option. Those hybrid model adopters might need to pay attention to the proportion of video visits carefully and try to give more patients the opportunities to visit in person as time goes by. For those who may not be able to provide in-person visits shortly, video visits only might be a better option. Practically, provides can try to split the examinations and visits. In this way, patients can still do in-hospital examinations but still visit their doctors online.

Finally, a key managerial implication is that those doctors with specialties with high risks of infection are the group of doctors that can benefit most from telehealth adoption. Our research shows increased patients' perceived quality for specialties of high risk gets higher patients' perceived quality. This finding enhances the benefits of telemedicine, which can reduce the spread of the virus to frontline medical workers during this critical moment, and further emphasizes that telemedicine services can promote public health mitigation strategies during this pandemic by increasing social distance.

Conclusion

Our study makes several contributions. First, we extended the existing literature on healthcare information technology adoption. Specifically, we investigated the impact of telehealth adoption by practicing physicians on patients' perceptions of service quality.

Secondly, we drew upon and extended the hyperpersonal model by investigating the differences in patients' perceived quality before and after the telehealth adoption. We disclosed the mechanism of the positive influence of telehealth adoption by showing that different strategies of telehealth adoption (i.e., doctors who adopt telehealth and only accept video visits, doctors who adopt telehealth and accept both video visits and in-person visits, and doctors who do not adopt telehealth) is the driving force for the improvement of patient's perception quality. We also demonstrated the extended theory by showing that the connection between the degree of doctors' telehealth adoption and patients' perceived healthcare quality is operating through the pandemic phases. Finally, our study can serve as a foundation to tell that telehealth is effective to reduce the spread of the virus to frontline medical workers since those specialties who need a lot of physical contacts can especially benefit from telehealth adoption.

At the current stage, we are primarily focused on validating the current empirical results. To do so, we must ensure the reliability and validity of several of our outcome variables (i.e., topic frequencies and associated sentiment), which were mined from the unstructured text data. Our first immediate objective is to use the Grounded Theory approach to qualitatively determine the topics that are most commonly mentioned in the reviews and create a questionnaire for the human classifiers. Our next objective implies using the developed questionnaire to conduct an extensive classification of training data using human workers. To this end, following the best practices in research and business, we aim to rely on the high-quality data classification workforce available through Amazon MTurk.

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