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TABLE OF CONTENTS

GOING DIGITAL? HOW BLACK AND HISPANIC SENIORS ADAPTED DURING COVID

Mark A. Scanlan, Stephen F. Austin State University

ABSTRACT

The COVID-19 pandemic required isolation for many people at its peak. This isolation was especially prevalent and painful for seniors who became cut-off from friends and family. This study examines access to information and communication technologies by older adults and extends previous research by focusing on outcomes for racial and ethnic minorities within this population. Census data from 2017 and 2021 is used to compare online activities by older adults before and during the COVID-19 pandemic. Our results indicate that Black and Hispanic individuals aged 65 or older were less likely to own a computer or access the Internet than their White peers in both 2017 and 2021, but that the gap between these groups decreased during the pandemic. We also find that older Black Internet users were significantly less likely to engage in most activities online than their White peers. This deficiency, however, closed significantly between 2017 and 2021, especially in relation to social media use where no deficiency was found to exist. Hispanic Internet users who were 65 or older were found to be less likely to participate in half of the studied online activities in both years. Older Hispanic adults still lagged in online shopping and searching for health information online, while this group was equally as likely as their White peers to do activities such as use social media and engage in finances online. Our results indicate real progress for racial and ethnic minorities in the acceptance of information and communication technologies in their daily lives, but we also find that large benefits could still be achieved by targeting policy towards these groups.

INTRODUCTION

The sudden onset of the COVID-19 pandemic resulted in widespread uncertainty and panic as governments scrambled to understand the virus and control its spread. While the virus negatively impacted all demographics, it has been particularly dangerous for the elderly, who suffered significantly higher death rates than the general population. Early in the pandemic Americans over the age of 65 were at a 16- to 52-fold higher risk of dying from COVID-19 than their younger counterparts (Ioannidis et al., 2020). To date there have been over 1.1 million deaths in the U.S. from COVID-19 with adults aged 65 and older accounting for nearly 800,000 of these cases. In the month of September 2022 alone, the elderly represented 88% of COVID related deaths (Freed et al., 2022).

As it became apparent that the elderly were at an elevated risk from COVID-19 they began to self-isolate to avoid contracting the disease. At the same time, family members began to limit physical proximity with this group out of fear of unintentionally spreading the virus to them (Markowitz et al., 2022). This combination resulted in extended periods of isolation and increased loneliness among the elderly (Paulin, 2020). It had already been well documented before the pandemic that older adults who are socially isolated experience adverse health outcomes including higher rates of dementia, obesity, heart diseases, depression, and premature

death (NAS, 2020; Gerst-Emerson et al., 2015; Santini et al., 2020). The extended isolations that resulted from the spread of the COVID-19 virus magnified these effects, especially for those living in assisted care facilities, those who lived alone, and those who had socioeconomic disadvantages (Armitage et al., 2020; Kasara et al., 2021; Santini et al., 2020). One potential way to mitigate the feelings of isolation and loneliness is through the use of information and communication technologies (ICT's), specifically through online connections. Internet use can help, not only with shopping and receiving health related information during the pandemic, but it can also serve as a way to stay connected with friends, family, and society as a whole (Kasara et al., 2021; Berg-Weger et al., 2020).

Given the benefits of having access to technology, particularly during a pandemic, it becomes important to determine whether older adults lag behind the general population in adoption of ICT's. If a gap does exist, it is crucial to determine which groups of seniors are most at risk of lacking access to ICT's so that policies and programs can be better targeted to those groups. This study aims to fill this gap in the current literature by first examining the digital divide between the elderly and the young before and during the pandemic, then determining whether specific racial and ethnic groups among the older generations are at a greater risk of not being connected. We then answer the question of whether, once online, do Black and Hispanic seniors engage in online activities in the same way as their White peers? In the next section, we look at research that describes the digital divide in technology access and Internet use for older adults. Next, we describe the data in this study and outline the model and methodology that are employed to achieve our results. We then present our initial results on computer ownership, Internet access, and online activities. These activities include e-commerce, online banking, social media use, and finding health information online. The subsequent section extends these results by implementing interaction effects between race/ethnicity and age variables. We conclude by discussing the implications of our findings and recommending future research that should be conducted in this area.

LITERATURE

It was discovered early in the computer revolution that older adults are consistently slower to adopt computers and connect to the Internet. It follows, therefore, that the pandemic did not cause a shortage of computers for the elderly or limit their access to the Internet; instead it highlighted a problem that already existed. Studies by Lenhart et al. (2003), Goolsbee (2001), and Scanlan (2007) all noted that a person's age was inversely related to the likelihood that they would own a computer or connect to the Internet. Morris and Brading (2007) referred to this gap as the "Grey Divide". Anderson and Perrin (2017) find that Internet use among people 65 or older increased by 55% between 2000 and 2016, to a 67% overall usage rate. Even with this progress, they find older adults still significantly lag behind younger Americans who achieved a 90% usage rate. Therefore, while we observe the adoption rate of technology among older adults is increasing, it still falls short of the general population, even after controlling for income and educational differences using multivariant regression analysis (Friemel, 2016; Scanlan, 2022; Song et al., 2021).

As Internet usage among older adults has expanded, so has the literature on how this group consumes online content. One such area, eHealth, relates to searching for, receiving, and understanding health information found online (Hong et al., 2017). Opportunities for eHealth have broadened over time due to expansions in telehealth services, access to medicines online,

health intervention services, and health information being shared on social media. Taking advantage of these resources has been shown to bring about a variety of health benefits such as improved access to doctors and medicine, participation in support groups, and improved diets (McCully et al., 2013; Chou et al., 2011). In one such example, Muellmann et al. (2018) and Van Dyck et al. (2016) find that intentional web-based health interventions lead to improved physical activity among older adults. Given these quality-of-life benefits, eHealth literacy becomes acutely beneficial to older adults as they begin to face the health challenges that arise with age. However, even after controlling for access to computers and the Internet, older adults are still found to have low eHealth literacy and are less likely to use the Internet to search for health-related information online (Levy et al., 2015). Furthermore, older adults that are in good health are found to be more likely to use computers than those who were unhealthy, while Black and Hispanic seniors were less likely to use ICTs for health-related activities (Heart et al., 2013; Mitchell et al., 2019; Yoon et al., 2020; Walker et al., 2020). Our results confirm that older Black and Hispanic Internet users were less likely to engage in eHealth before the pandemic, we then extend this research by showing that this did not improve significantly after the pandemic began.

Beyond the health-related benefits of social media discussed above, the use of social networks during the pandemic became a way for friends and families to stay connected when direct contact became difficult. Historically older adults have been slow to adopt social media usage due to security and privacy concerns, uncertainty regarding social norms online, and an initial feeling that it lacked personal relevance for them (Leist, 2013). Yu et al. (2016a) find that older adults become less likely to use social media as they age but find older Black and Hispanic users are not significantly less likely to use social media than their White peers. Once older adults do become active on social media, they often fully incorporate it into their daily lives and view it as an effective resource in maintaining contact with friends and family (Quan-Haase et al., 2017; Yu et al., 2016b).

A final area of related literature for this study deals with the move by consumers towards shopping and banking online since the start of the pandemic. Anxiety over being exposed to COVID-19 while in public places convinced many consumers to move a large portion of their banking and consumer purchases online. According to the U.S. Census Bureau, e-commerce in the U.S. increased by 43% in 2020 alone, rising from $571.2 billion to $815.4 billion (Brewster, 2022). Truong and Truong (2022) explain that age was positively related to online shopping during the pandemic, indicating older adults were spending more than younger adults on e-commerce. They also find racial and ethnic minority shoppers were less likely to shop online than White consumers. Shaw et al. (2022) find that while older adults still lag in e-commerce, all age groups are expected to shop online significantly more in the coming years, relative to before the pandemic, due to the increased convenience.

STUDY OUTLINE AND FINDINGS

Our study builds from the broad concept in Friemel (2016) and Kampfen and Maurer (2018) who find that it is inappropriate to group all older adults into a single category when exploring technology use. Specifically, they find that activities such as having used a computer before retirement and exhibiting technical interest significantly increases the likelihood of technology use among older adults. They also find that key socio-economic variables such as income and years of schooling have significant effects on computer and Internet use among older adults. Related studies have focused on traits such as the difference between male versus female

Internet use among older adults. Van Deurson et al. (2015) find that Internet use is a male dominated activity among seniors with female seniors showing a greater propensity to avoid using the available Internet access at home. Hargittai, Piper, and Morris (2018) however, find that this difference disappears completely when they controlled for income, education, and level of autonomy.

This study extends the previous research by examining computer ownership, Internet access, and the online habits of Black and Hispanic seniors relative to their White counterparts both before and after the COVID-19 outbreak. We are the first to use a large, well respected, data set to study a wide range of connectivity issues and online activities for minority seniors over this timeframe. We are able to make unique observations regarding how habits may have changed for these older adults since the pandemic began by using data from both 2017 and 2021. Our research questions include whether Black and Hispanic seniors lagged behind their White peers in 2017 with respect to computer ownership, Internet access, social media use, eHealth activity, e-commerce, and online finances. We then address whether the incentives to increase Internet access created by the pandemic significantly changed the connectivity and online habits of this group of older adults. Our results indicate that Black and Hispanic seniors were less likely, in 2017, to own a computer and access the Internet than White seniors. Further, we find that the digital divide between minority and White users expands significantly in most areas for those over the age of 65, hitting Black seniors especially hard. Finally, we find that while there has been significant progress in closing the digital divide since 2017 large gaps still persist for Black and Hispanic seniors relative to their White peers.

DATA

The data for this study comes from the 2017 and the 2021 Current Population Surveys (CPS) conducted jointly by the U.S. Census Bureau and the Bureau of Labor Statistics. We take advantage of the Computer and Internet Use Supplement survey that was included in the November 2017 and 2021 surveys (NTIA). This supplement asks detailed questions about computer ownership, Internet access, and online activities for over 52,000 households and receives responses from over 123,000 individuals within those households. The breadth of questions asked in this survey allows us to address a wide variety of research questions, while the large sample size helps in the identification issues within the regression analysis. By using these data sets we can analyze how the spread of COVID-19 impacted online behavior among older adults.

The dependent variables of interest are only asked during the Computer and Internet Use Supplement survey and are described in the Table 1.

Table 1	
Dependent Variable	**Description**
Computer Ownership	Does anyone in the household own a desktop, laptop, or tablet?
Internet Access	Does anyone in the household use the Internet from home?
Shop Online	In the past 6 months have you used the Internet for online shopping, travel reservations, or other consumer services on the Internet?
Finance Online	Do you use the Internet for financial services such as banking, investing, or paying bills online?
Social Media	Do you use social networks such as Facebook, Twitter, or Instagram?
Health Search Online	Did you use the Internet to communicate with a doctor or health professional, access health records or health insurance records, or research health information online, such as with WebMD?

The explanatory variables of interest are presented in Table 2 and are separated into three categories. The first is the entire sample, the second compares computer owners to those that do not own computers, and the third compares Internet users with non-users. The household income and education questions ask the respondent to select a range in which their household income or education falls. These variables are therefore set up as categorical variables that correspond to the midpoints of each given range. The table shows that computer owners compared to those that do not own a computer are younger, have higher income and education levels, are married, and are more likely to live in a metropolitan area. It also indicates that Black, Hispanic and people with disabilities are less likely to own a computer. The same pattern for each of these variables holds true when comparing those who connect to the Internet from home to those who do not.

Table 2
Summary Statistics 2021

Variable	Entire Sample	Computer		Internet	
		Owners	Non Owners	Users	Non-Users
N	84,206	63,620	20,586	65,648	18,558
Age	48.55	47.144	52.889	47.263	53.096
	(19.61)	(19.138)	(20.831)	(19.02)	(20.923)
White	0.804	0.814	0.773	0.812	0.773
	(0.397)	(0.389)	(0.419)	(0.39)	(0.419)
Black	0.103	0.09	0.145	0.096	0.131
	(0.304)	(0.286)	(0.352)	(0.294)	(0.337)
Hispanic	0.136	0.125	0.17	0.128	0.165
	(0.343)	(0.33)	(0.376)	(0.334)	(0.371)
Native Am.	0.012	0.01	0.019	0.011	0.018
	(0.087)	(0.101)	(0.136)	(0.103)	(0.134)
Asian	0.058	0.064	0.041	0.059	0.057
	(0.235)	(0.245)	(0.199)	(0.235)	(0.231)
# People in HH	2.883	3.00	2.56	2.909	2.791

	(1.600)	(1.542)	(1.569)	(1.532)	(1.652)
HH Income	86,234	94,841	59,635	90,840	69,940
	(56,077)	(54,999)	(50,779)	(55,589)	(54,750)
Own Business	0.130	0.144	0.085	0.137	0.105
	(0.336)	(0.352)	(0.279)	(0.344)	(0.306)
Married	0.500	0.533	0.394	0.516	0.44
	(0.500)	(0.500)	(0.489)	(0.500)	(0.496)
Education	13.579	13.906	12.566	13.83	12.691
	(2.689)	(2.595)	(2.722)	(2.575)	(2.900)
Female	0.520	0.518	0.521	0.521	0.511
	(0.500)	(0.500)	(0.500)	(0.500)	(0.500)
Metro Area	0.812	0.826	0.768	0.819	0.785
	(0.391)	(0.379)	(0.422)	(0.385)	(0.411)
Disability	0.131	0.107	0.207	0.112	0.200
	(0.338)	(0.309)	(0.405)	(0.315)	(0.400)

METHODOLOGY

Each dependent variable of interest in this study, described in Table 1, is presented in the survey as a "Yes" or "No" question resulting in discrete dependent variables in each specification. To account for this restriction, we employ probit regression analyses and present the marginal effects in our findings. The explanatory variables will include age and race along with a variety of demographic and socioeconomic variables, as described in Table 2. Dummy variables for region are also included in each specification. The model will be defined as follows:

$$Y_i^* = X_i\beta + u_i \tag{1}$$

where X_i is a vector of explanatory variables, β is their corresponding coefficient estimates, and u_i is the error term. The observable outcome is defined as:

$$Y_i = \begin{array}{ll} 1 \; if \; X_i\beta + u_i > 0 \\ 0 \; if \; X_i\beta + u_i \leq 0 \end{array}$$

Questions on the survey relating to online activities are only asked to respondents who indicated they have access to the Internet. This allows for a better comparison of online activities based on race and ethnicity among those who are already online. This restriction on the data however can introduce selection bias into the results. To account for this structure of survey questions an inverse mills ratio is implemented in the regression analysis to avoid any bias in the results (Heckman 1979).

RESULTS ON COMPUTER OWNERSHIP AND INTERNET ACCESS

In this section we investigate whether older adults are still less likely than younger generations to own a computer or access the Internet in both 2017 and 2021. The independent variables of interest include age, race, and ethnicity variables. Other independent variables that are included in the probit regression, but not shown, are disability status, sex, marital status, the number of people living in the household, living in a metro area, whether they own their own business, household income (logged), highest education level, and regional dummies. The results of the multivariate regression analysis are included in Table 3 where columns (1) and (2) represent data from 2017 and columns (3) and (4) represent data from 2021.

Columns (1) and (3) of Table 3 relate to computer ownership based on age, race, and ethnicity for the entire sample in 2017 and 2021 respectively. We find that, similar to past studies, coefficients on age, Black, and Hispanic are all negative and highly significant for both years of study. This confirms the continued existence of digital divides in computer ownership based on age, race, and ethnicity, though it appears the divide has modestly shrunk between 2017 and 2021 for both Black and Hispanic individuals. Columns (2) and (4) of Table 3 examine the computer ownership of individuals who are 65 years of age or older in 2017 and 2021 respectively. Again, we find highly significant negative coefficients on both the Black and Hispanic variables. Like before we do find that the coefficients are less negative in 2021 suggesting the divide is shrinking.

Comparing column (1) to column (2) shows that in 2017 the negative coefficients on both the Black and Hispanic variables increased substantially (were more negative) for older adults relative to the entire sample. This indicates the racial divide in ICT's was larger for seniors than

Table 3
Probit Regressions for Computer Ownership in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		2021	
	Own a Computer	Own a Computer Age 65+	Own a Computer	Own a Computer Age 65+
Age	-0.004***	-0.011***	-0.004***	-0.009***
	(0.001)	(0.001)	(0.0001)	(0.001)
Black	-0.092***	-0.153***	-0.078***	-0.115***
	(0.006)	(0.013)	(0.006)	(0.014)
Hispanic	-0.117***	-0.159***	-0.093***	-0.138***
	(0.005)	(0.016)	(0.006)	(0.017)
N	105,596	22,189	83,051	20,479
LR chi(2)	19,431.29	5,121.39	12,449.59	3,809.24

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

for the general population in that year. A similar analysis can be done for 2021 by comparing columns (3) and (4). The results show that the coefficients on the Black and Hispanic

variables are again more negative for older adults than for the general population. There were some positive changes over this period, however, as older Black individuals closed the gap on their White peers between 2017 and 2021. In 2017 Black individuals overall were 9.2% less likely to own a computer than their White counterparts, while those aged 65 or older were 15.3% less likely to own a computer than their White peers. This translates to a 6.1% additional lag faced by older Black adults in 2017. This gap shrank in 3.7% in 2021 signifying progress in bridging this aspect of the Grey Divide, as older Black adults began catching up with their White peers more quickly than Black individuals in general. The gap for Hispanic individuals over this period actually increased slightly, changing from 4.2% in 2017 to 4.5% in 2021.

Table 4 presents results from the probit regressions on whether the respondent had Internet access at home in 2017 and 2021. We again verify previous research by finding that

Table 4
Probit Regressions for Internet Access in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		**2021**	
	Internet Access	Internet Access Age 65+	Internet Access	Internet Access Age 65+
Age	-0.005***	-0.013***	-0.003***	-0.010***
	(0.0001)	(0.001)	(0.0001)	(0.0001)
Black	-0.067***	-0.153***	-0.039***	-0.081***
	(0.005)	(0.013)	(0.005)	(0.013)
Hispanic	-0.046***	-0.098***	-0.035***	-0.073***
	(0.005)	(0.016)	(0.005)	(0.015)
N	105,596	22189	83,051	20,479
LR chi(2)	14,328.67	4,854.61	5,452.46	2,757.17

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

Black, Hispanic, and older individuals have lower Internet penetration rates than younger White individuals in both 2017 and 2021. Columns (2) and (4) extends this result by again focusing solely on computer owners who are aged 65 or older. Our results reiterate that the racial digital divide is magnified for those who are 65 or older in all instances. Interestingly, there are positive signs in the results for older adults as the gap between young and old Black users decreased from 8.6% down to 4.2%. Older Hispanic users also saw progress in this area as their gap shrank from 5.2% to 3.8%.

ONLINE HABITS

This section explores the online habits of Black and Hispanic seniors in areas related to social media use, online searches for health information, online shopping, and online finances. Since the CPS survey only asks about online activities for those who have access to the Internet, the results will directly measure the online habits of each group instead of capturing the underlying differences in access to technology. As before, independent variables that are included but not shown in each of the tables in this section are disability status, sex, marital status, the number of people living in the household, whether they live in a metro area, whether

they own their own business, household income (logged), highest education level, and regional dummies. Additionally, the Mills Ratio (Lambda) is included to account for selection bias, as discussed in the section on methodology.

Table 5
Probit Regressions for Social Media Use in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		**2021**	
	Social Media	Social Media Age 65+	Social Media	Social Media Age 65+
Age	-0.010***	-0.012***	-0.008***	-0.004
	(0.0004)	(0.002)	(0.001)	(0.002)
Black	-0.086***	-0.138***	-0.022*	-0.037
	(0.01)	(0.031)	(0.011)	(0.026)
Hispanic	-0.057***	-0.05	-0.009	-0.012
	(0.009)	(0.032)	(0.010)	(0.031)
N	43,902	8,989	36,097	9,563
LR chi(2)	5,271.06	273.86	4,004.79	371.24

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

Table 5 focuses on social media activity for the general population and those 65 and older in 2017 and 2021. The negative coefficients on the Black and Hispanic variables in Column (1) indicate that minorities overall were less likely to use social media than White users in 2017. Column (2) shows that Black Internet users who are 65 or older were significantly less likely than their White peers to use social media in that year. Contrary to this, in Column (2) we see that Hispanic Internet users who are 65 or older are just as likely to use social media as their White counterparts in 2017. Columns (3) and (4) of Table 5 show that during the pandemic the divide in social media use across race and ethnicity almost completely disappeared. Only Black Internet users overall were found to still lag behind White Internet users, but only by 2.2% and with only a 10% significance level.

Table 6 shifts the focus to whether individuals utilize the Internet to find health information of any type online. Column (1) of Table 6 shows Black and Hispanic Internet users were far less likely than White users to lookup up health information online in 2017. Column (2)

Table 6
Probit Regressions for Online Health Searches in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		**2021**	
	Health Search Online	Health Search Age 65+	Health Search Online	Health Search Age 65+
Age	-0.002***	-0.010***	-0.003***	-0.013***
	(0.0005)	(0.002)	(0.001)	(0.002)
Black	-0.126***	-0.202***	-0.138***	-0.202***
	(0.011)	(0.032)	(0.012)	(0.027)
Hispanic	-0.163***	-0.218***	-0.168***	-0.197***
	(0.009)	(0.031)	(0.012)	(0.032)
N	43,902	8,989	36,097	9,563
LR chi(2)	5,508.06	955.57	4,671.04	1,114.19

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

indicates that for seniors this gap not only persists, it expands, with each minority group lagging even further behind their White peers in that year. Unlike social media use, we find, in Columns (3) and (4), that Black and Hispanic users made very little progress bridging the gap in online health searches between 2017 and 2021. In fact, the results for the coefficients in 2021 are very similar to those in 2017. In both 2017 and 2021 Black Internet users who were age 65 or older were 20.2% less likely than their White counterparts to search for health information online. For Hispanic Internet users this changed from 21.8% in 2017 to 19.7% in 2021, showing a modest improvement over this period relative to White users.

Results from probit regressions related to the online shopping habits of the general population and seniors are presented in Table 7. Column (1) of the table provides evidence that Black and Hispanic Internet users were less likely to shop online than White users overall in both 2017 and 2021. These marginal effects are relatively large and highly significant. Given the mobility concerns and transportation limitations faced by many seniors, actively participating in

Table 7
Probit Regressions for Shopping Online in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		**2021**	
	Shop Online	Shop Online Age 65+	Shop Online	Shop Online Age 65+
Age	-0.006***	-0.014***	-0.005***	-0.010***
	(0.0005)	(0.002)	(0.001)	(0.002)
Black	-0.125***	-0.193***	-0.082***	-0.106***
	(0.011)	(0.034)	(0.011)	(0.027)
Hispanic	-0.109***	-0.121***	-0.102***	-0.114***
	(0.01)	(0.033)	(0.011)	(0.032)
N	43,902	8,989	36,097	9,563
LR chi(2)	7,602.94	1,038.46	5,376.03	1,111.37

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

online shopping could be very beneficial for their overall well-being. These potential benefits were magnified during the pandemic since e-commerce allowed people to avoid close contact in a public setting with people who may have been exposed to COVID-19. However, Column (2) of Table 7 shows that in 2017 Black and Hispanic Internet users that were aged 65 or older were 19.3% and 12.1% less likely to engage in e-commerce than their White peers respectively. Column (4) shows that while there was measurable progress in 2021, especially by older Black Internet users, there still existed a large and significant divide. In 2021 Black and Hispanic seniors were 10.6% and 11.4% less likely to shop online than their White peers.

The final area of online activity that we investigate relates to financial activities done over the Internet, such as online banking, investing, and bill payment. Similar to the benefits described for online shopping, completing financial services online helps seniors circumvent any transportation difficulties they may face and lets them avoid unneeded exposure during a pandemic. The results in Columns (1) and (3) of Table 8 show that in both 2017 and 2021 Black and Hispanic Internet users in general lagged behind White Internet users in online finance activities. In 2017 Black users in general were 13.7% less likely to engage in online finance while Black users who were 65 or older were 17% less likely. Older Black users showed incredible progress between 2017 and 2021 ending up only 10.7% less likely to participate in online finance than their White peers. This is important progress, but the gap is still large and significant. Older Hispanic Internet users fared much better in this online activity. In 2017 the coefficient for Hispanic Internet users who were 65 or older was almost identical to that for the Hispanic population in general, and only showed significance at the 10% level. By 2021, Column (4) of Table 8 indicates that older Hispanic users were just as likely to use online finances as their White peers.

Table 8
Probit Regressions for Finances Online in 2017 and 2021

	(1)	(2)	(3)	(4)
	2017		**2021**	
	Finance Online	Finance Online Age 65+	Finance Online	Finance Online Age 65+
Age	-0.009***	-0.017***	-0.008***	-0.012***
	(0.0005)	(0.002)	(0.001)	(0.002)
Black	-0.137***	-0.170***	-0.093***	-0.107***
	(0.011)	(0.032)	(0.012)	(0.027)
Hispanic	-0.086***	-0.083*	-0.084***	-0.050
	(0.01)	(0.032)	(0.011)	(0.031)
N	43,902	8,989	36,097	9,563
LR chi(2)	6,817.94	727.12	4,961.55	902.43

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

INTERACTION EFFECTS

To determine whether there is a persistent relationship between age and minority status across ICT usage we add interaction effects to each general specification. Table 9 presents the results from including an interaction effect between the age and Black variables. Columns (1) and (2) show that the racial divide relating to computer ownership and online access are persistent across age ranges. Columns (3) through (6) show that this connection disappears when focusing on online habits with the divide created by older individuals being offset by other age groups. Table 10 illustrates the results from including an interaction effect between the variables age and Hispanic. Again, there is a significant negative coefficient for computer ownership but no significant impact in relation to Internet access. Columns (3), (4) and (5) show positive and significant interaction effects for online shopping, online finances, and social media use. These results are driven heavily by younger users, but may be an indication of future progress in this area.

Table 9
Probit Regressions with Black and Age Interaction Term Included

	(1)	(2)	(3)	(4)	(5)	(6)
	Computer Ownership	Internet Access	Shop Online	Finances Online	Social Media	Health Online
Age	-0.004***	-0.005***	-0.006***	-0.009***	-0.01***	-0.002***
	(0.001)	(0.0001)	(0.0005)	(0.0005)	(0.0004)	(0.0005)
Black	-0.035***	0.007	-0.119***	-0.164***	-0.047*	-0.088***
	(0.013)	(0.011)	(0.023)	(0.024)	(0.023)	(0.023)
Black*Age	-0.001***	-0.002***	-0.0001	0.0005	-0.001	-0.001
	(0.0003)	(0.0002)	(0.0004)	(0.0004)	(0.0004)	(0.001)

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

Table 10
Probit Regressions with Hispanic and Age Interaction Term Included

	(1)	(2)	(3)	(4)	(5)	(6)
	Computer Ownership	Internet Access	Shop Online	Finances Online	Social Media	Health Online
Age	-0.004***	-0.01***	-0.01***	-0.009***	-0.010***	-0.002***
	(0.001)	(0.0001)	(0.0005)	(0.0005)	(0.0004)	(0.0005)
Hispanic	-0.055***	-0.031**	-0.18***	-0.219***	-0.113***	-0.191***
	(0.012)	(0.011)	(0.022)	(0.022)	(0.023)	(0.022)
Hispanic*Age	-0.001***	-0.0003	0.001***	0.003***	0.001**	0.001
	(0.0003)	(0.0002)	(0.0004)	(0.0005)	(0.0004)	(0.001)

Standard errors are in parentheses. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level or smaller.

DISCUSSION

In this study we find that older adults, along with those identifying as Black and Hispanic, still lag behind the general population in computer ownership, Internet access, and participation in many online activities. Our results go beyond updating the existence of the racial and Grey Divides by explicitly focusing on how age and race interact in these areas. By using Census data from before and during the pandemic, we investigate whether older adults were motivated to transition online as a way to maintain social distancing during the spread of COVID-19. We find that the racial divide does not only persist for those who are 65 or older relative to the general population, it is magnified in most cases. On a positive note, we do find the gap in technology use between Black and Hispanic older adults and the rest of the population shrank significantly in most areas between 2017 and 2021.

Older Black adults, in 2017, were 15.3% less likely to own a computer than their White peers, but this outcome decreased to 11.5% in 2021. This 3.8% improvement in computer ownership shows a step in the right direction, but also that deficiencies still exist. Positive changes in other activities experienced by Black seniors include a 7.2% improvement in Internet access, an 8.7% improvement in online shopping, and a 6.3% improvement in online finances. There were two surprising results for older Black Internet users. The first was a complete lack of improvement in searching for health care information online between 2017 and 2021. The second was the improvement in social media usage for this group who went from being 13.8% behind their White peers in 2017 to showing no statistical difference in this activity from their White peers in 2021.

Older Hispanic adults only made limited progress in computer ownership and Internet access, but were moderately more successful at bridging the divide in online activities with their White peers than were older Black adults. Between 2017 and 2021 Hispanic seniors experienced little change in their rates of online shopping and researching health information online. This group however was just as likely as their White peers to use social media and to engage in financial activities online in 2021. Surprisingly, we also found that in 2017 Hispanic Internet users in general were 5.7% less likely to use social media than their White counterparts, while in the same year Hispanic Internet users over the age of 65 were equally likely as their White peers to connect to social networks.

Results presented here are meaningful since they provide evidence that gaps still exist across race and ethnicity even after controlling for differences in income, education, and connectiveness to the Internet. These concepts have always been important to study but have taken on grave importance, especially for seniors, after experiencing a worldwide pandemic. The COVID-19 pandemic highlighted how isolated seniors can become during times of national or international emergencies. Without modern information and communication technologies in place, many older citizens can become effectively cut off from their friends, family, and society. Providing adequate access to computers and the Internet is crucial but is lacking for some groups. Racial and ethnic minorities still face a substantial digital divide. For minorities over the age of 65, this divide can seem more like a chasm that cannot be easily traversed. Effective policy moving forward must include increased access along with training aimed at this underrepresented group. This will ensure fewer people become isolated in the face of future pandemics or national emergencies.

Future research in this field needs to address two key issues: whether the positive trends in access and online activity continue after the pandemic has subsided, and what technology interventions are most meaningful for underrepresented seniors. This paper uses data from 2021 which is in the heart of the pandemic, and as of writing this study the country is still dealing with the very contagious Omicron variant of COVID-19. Once the pandemic has eased more substantially it will be important to determine if Black and Hispanic seniors persisted in their use of technology, or if the large divides re-emerged. One method of keeping technology use relevant for seniors is to provide targeted training in technical skills that promote safe and meaningful online engagement. Experimental research on different intervention techniques will provide invaluable insights on the most effective ways to get older adults comfortable with online activities. Documenting what types of trainings are successful for Black and Hispanic seniors in particular can help guide policy and resources to appropriate areas.

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MODELING COVID-19 EPIDEMIC TO GUIDE DECISION MAKING

Khalid Dubas, University of Mount Olive
Chiang-nan Chao, St. John's University

ABSTRACT

A coronavirus has many crown-like spikes on its surface. Two recent examples of these viruses are SARS-CoV-1 and SARS-CoV-2. The former caused the 2003 outbreak of severe acute respiratory syndrome (SARS), that according to the World Health Organization (WHO), as of July 5, 2013, infected a total of 8,439 people and 812 died worldwide. The latter caused the coronavirus disease 2019 (Covid-19), that the WHO declared a pandemic on March 11, 2020. Unlike the SARS-CoV-1, the SARS-CoV-2 is much more contagious and widespread, and it has adversely affected life in almost every country. The Centers for Disease Control and Prevention (CDC) reported that as of July 24, 2020, there were over 15 million confirmed cases of Covid-19 in the world, among them the US had 4,024,492 cases out of which 72,219 were new cases as of July 25, within a 24- hour period. It reported 143,868 total deaths in the US due to this disease that included 1,113 new deaths during this 24-hour period. Among the US cases, one million new cases were added during July 9-24, 2020, indicating an exponential growth of new Covid-19 cases relative to the timeline of SARS-CoV-1.

One way to understand and predict the impact of Covid-19 is to formulate a mathematical model to predict the spread of illness, hospitalization, death, recovery, etc. based on assumptions about the characteristics of the disease and behavior of individuals. Many institutions, universities, and organizations have formulated mathematical models for this purpose. Some notable organizations for this purpose include the Covid-19 Forecast Hub that hosts over 30 international research groups and their models, the CDC, and the FiveThirtyEight (Best & Boice, July 24, 2020; ABC News Internet Ventures, 2020).

The purpose of this research is to introduce basic terminology about the spread of infectious diseases and to formulate basic epidemic models to analyze Covid-19 to guide managerial decisions.

THE CHARACTERISTICS OF COVID-19 EPIDEMIC

Dr. Gro Harlem Brundtland, Director-General of the WHO (2003), said "We do not mark the end of SARS today, but we observe a milestone: the global SARS outbreak has been contained." He said "SARS is a warning, SARS pushed even the most advanced public health systems to the breaking point. Those protections held, but just barely. Next time, we may not be so lucky. We have an opportunity now, and we see the need clearly, to rebuild our public health

protections. They will be needed for the next global outbreak, if it is SARS or another new infection."

Thirteen years later, Dr. Brundtland's warning came true with the arrival of SARS-CoV-2 virus that causes Covid-19 disease and was first reported on December 31, 2019 (World Health Organization, 2021). Covid-19 has directly or indirectly affected most individuals, organizations, and countries. The economic and social life in most countries was severely affected. This study explores the parameters that govern the dynamics of this infectious disease and should be of interest to public healthcare policy planners, managerial decision makers, and individuals who want to minimize the chance of getting infected by Covid-19 disease.

The CDC reports that seven human coronaviruses have been identified since the mid-1960s and four of which (HKU1, NL63, 229E, and OC43) cause common illness in people while three coronaviruses, namely, MERS-CoV, SARS-CoV, and SARS-CoV-2, have evolved from animals to become human coronaviruses.

On January 21, 2020, the CDC confirmed the first US case of Covid-19 in Snohomish County, Washington, where a 35-year-old man, who had travelled to Wuhan, China, showed up at an urgent care clinic with Covid-19 symptoms (Holshue et al., 2020). The SARS-CoV-2 is a new virus for which people do not have a natural immunity and, at that time, there was no vaccine for it. The Covid-19, the **co**rona **vi**rus **d**isease that originated in 20**19**, caused a public health crisis that has resulted in an economic crisis. Almost every industry was adversely affected by the Covid-19 epidemic. In the US, the economy shrank 5% in the first quarter of 2020 followed by 9.5% in the second quarter.

The economic and business activity could not recover without controlling Covid-19. The government administrators, public health officials, business leaders, school administrators, employees, households, parents, and individuals tried to gain a better understanding of Covid-19 to control its spread so they could return to normal operations. The target audience of this study is everyone who is interested in how an infectious disease like Covid-19 spreads through a population and what measures are useful to minimize its impact and reduce and eliminate this disease.

Basic and Effective Reproductive Rates, R_0 and R_E

The reproductive rate or reproduction number measures the contagiousness of a disease. The spread of an infectious disease is controlled by its reproduction number. The basic reproductive rate, R_0, is the average number of secondary infections caused by an individual in a fully susceptible population. The effective reproductive rate, R_E, is the average number of secondary cases generated by an infected individual in a population where some individuals have been previously infected or immunized so not everyone is susceptible to the disease. R_0 plays a key role in the spread of a disease and in determining the population size that must be vaccinated to attain herd immunity. SARS-CoV-2 virus continues to mutate and spawn new variants and subvariants. WHO names coronaviruses using Greek alphabet. The following presents selected literature on reproduction number for different variants and subvariants of SARS-CoV-2 virus.

Esterman (2022) provides that the basic reproduction numbers, R_0, for various strains of SARS-CoV-2 virus. The ancestral strain in Wuhan, China: R_0 = 3.3. Delta strain that appeared in India: R_0 = 5.1. Omicron BA.1 in Botswana and South Africa: R_0 = 9.5. Omicron BA.2 has R_0 = 13.3. He summarizes the impact of these variants and subvariants as follows:

- *Three subvariants of Omicron (BA.1, BA.2, and BA.3) appeared in late November 2021 in South Africa. In early January 2022, BA.1 rapidly spread across Australia replacing Delta and causing more than 100,000 cases per day at the peak (early January 2021) of the first wave of Omicron. The second Omicron wave was caused by BA.2 and peaked in early April 2022 at more than 60,000 cases a day. Omicron BA.2 was even more transmissible than BA.1.*
- *Omicron BA.4 and BA.5 were detected in South Africa in January 2022 and February 2022 respectively. The third wave in Australia was caused by BA.4 and BA.5 started in July 2022, as BA.4 and BA.5 became the dominant Covid-19 strains. BA.4 and BA.5 are more infectious than previous variants and subvariants and are better able to evade immunity from vaccines and previous infections. BA.4 and BA.5, however, did not cause more sever disease compared with the previous subvariants of Omicron possibly due to previous infections or vaccinations.*

Katella (2022) notes the following characteristics for some variants and subvariants of SARS-CoV-2.

- *Alpha (B.1.1.7) first appeared in Great Britain in November 2020. It was 30%-50% more contagious than the original SARS-CoV-2 strain and created 66% of cases in the US by mid-April 2021. It also caused more severe disease than the original virus.*
- *Beta (B.1.351) appeared in South Africa at the end of 2020 and was 50% more contagious than the original virus. Beta may have caused more severe disease than the other variants, but it did not become the dominant variant in the US.*
- *Delta (B.1.617.2) first appeared in India in late 2020 and spread around the world to become the dominant variant. It was 80%-90% more contagious than the Alpha variant. Starting in June 2021, Delta spread across the US and caused some breakthrough infections among fully vaccinated individuals. More contagious variants of Delta later emerged and infected many people.*
- *Omicron (BA.1) appeared in Botswana and South Africa in late November 2021 and quickly spread across the world. BA.1 was more contagious than Delta but tended to cause less severe disease. In the US in December 2021, Omicron caused daily infections that exceed one million cases. Omicron generated many subvariants including BA.5, BQ.1, BQ.1.1.*

Liu and Rocklöv (2022) conduct extensive literature review of articles publications in Chinese and US journals and conclude that the reproduction number for Omicron is 5.08 which is higher than that of the Delta variants.

Selected Covid-19 Modelling Across the World

The following presents selected model building efforts by researchers to understand the dynamics of Covid-19 in different parts of the world.

Biswas, Khaleque, and Sen (2020), in a pre-print (not peer-reviewed) study use data from China and Italy in an SIR framework. They use a Euclidean network of interactions among

individuals to show that the new infections of Covid-19 are inversely proportional to Euclidean distance (raised to power ~1.85) from the epicenter of the disease. They calculate that the exponent of distance from the epicenter Wuhan is 0.268 for China and from the epicenter Bergamo is 0.383 for Italy. So generally, infections would be larger the closer the individuals are located to the epicenter of this disease and this spatial dependence follows an approximate power law with exponent ~1.85.

Cooper, Mondal, and Antonopoulos (2020) utilize a classical susceptible-infected-removed (SIR) model to study the spread of Covid-19 in China, South Korea, India, Australia, USA, Italy and the state of Texas in the USA. They consider data from January-June 2020. They make predictions regarding various parameters of disease dynamics and the numbers of individuals in S, I, R compartments of the populations until September 2020. They note: "This allowed us to estimate the development of Covid-19 spread in these communities by obtaining estimates for the number of deaths D, susceptible S, infected I and removed Rm populations in time." By comparing recorded data with the results of their predictions they claim that the spread of this disease can be controlled by early implementation of proper restrictions and strong control policies. They make a few statements that are incorrect. Here are our observations on this study.

- The authors utilize a typical closed SIR model where births and deaths (other than those due to COVID-19) can be neglected due to short duration of the study.
- They claim that their total population, N, is not specified or held constant. They specify three compartments of individuals in their three SIR equations so N in their model can be obtained by adding these three compartments. Thus, $N(t) = S(t) + I(t) + R(t)$. Adding their three SIR equations results in $\frac{dN}{dt} = N'(t) = 0$. So, their model requires a constant total population even though the authors do not acknowledge it.
- They claim that unlike in the classic SIR model, the susceptible population does not monotonically decrease in their modified SIR model but can increase to accommodate new surges in infections. Contrary to their claim, however, their equation (1) specifies the typical susceptibles function with a monotonically decreasing slope. $\frac{dS}{dt} = S'(t) = -aS(t)I(t) < 0$. So, the disease incidence, $aS(t)I(t)$, decreases monotonically in their model.
- They acknowledge that deaths and recoveries are not generated directly by their SIR model, so they estimate them separately. A better approach is to model them directly in and extended SIR model. For example, Ndaïrou, Faïçal, Iván Area, Juan J. Nieto, and Delfim Torres (2020) extend the SIR model to directly incorporate the number of deaths, recoveries, reinfections, hospitalizations, serious infections, etc.

- To estimate S, I, and R, they set initial values between 0-1 and scale their variables to fit the data. They set initial conditions of the SIR model as S(0) = 1, and I(0) = R(0) <= 1. This indicates that initially everyone is susceptible, and some people may be infected or removed (recovered or dead). However, although everyone is susceptible to the new pathogen, some people have to be infected at the start of the epidemic, thus S(0) < 1 and I(0) > 0 and R(0) = 0 since the infected individuals will be moved from the susceptible compartment to the infected compartment, while none will have recovered or died at the very beginning of the epidemic.
- They do not specify N(0), the initial population size in the SIR model. However, by definition, N(0) = S(0) + I(0) + R(0). The sum of the components (as fractions) will be one. They do not specify but their approach normalizes N to 1 (or 100%).
- They fit their model to the data by trial-and-error and visual inspection thus introducing bias in their estimates and predictions since the result are not produced automatically by applying the model itself but by active intervention by the researchers to fit the model to results. So different researchers will obtain different results from the same data set.
- They estimate and plot total infections, active infections (I), recoveries (R), deaths (D), and active susceptibles (S) over time for different countries and the state of Texas. Their plots show that the researchers have achieved good approximation in fitting their model to actual data. However, their SIR model does not extend to their data analyses.
- Their theoretical SIR model does not extend to their actual data analysis regarding deaths (D), recoveries (R), and surges based on increasing S and I. This is because their SIR model does not directly incorporate deaths and recovered individuals, nor does it accommodate surges due to increased numbers of usucaptible individuals.
- They state that during a surge, the number of susceptible individuals increases, and the number of infected individuals also increases. They conclude that in the absence of a vaccine, drastic actions should be taken to control the spread of disease in its early stages. So, the disease could be eliminated by reducing the susceptible population to zero.
- They recommend that in the absence of an effective vaccine the authorities should enforce strict measures to the spread of epidemic at its early stages.
- They do not share their code or data, so the readers are unable to replicate their results.

Ndaïrou, Area, Nieto, and Torres (2020) study transmission dynamics of Covid-19 in Wuhan (population about 11 million people) with a modified SIR model. This model utilizes a constant total population size N that is subdivided into eight epidemiological classes: susceptible, exposed, symptomatic and infectious, super-spreaders, infectious but asymptomatic hospitalized,

recovery, and fatality. This model allows for surges in susceptible class and does not require a monotonically decreasing susceptible class of individuals. These authors adjust the Wuhan population of 11 million by dividing by 250 to account for strict lock downs. They simulate results of the model and compare them with actual data and find good approximations of their model performance with actual data. They estimate the basic reproductive number for Wuhan as $R_0 = 0.945$. This is less than 1 indicating that the authorities quickly contained the spread of Covid-19 through strict Zero-Covid measures of quarantine and lock-down of communities with infected individuals. For a preprint (not peer-reviewed) of a study on the index case in Wuhan, China, please refer to Pekar, Worobey, Moshiri, Scheffler, and Wertheim (2020).

THE STUDY

This study takes a mathematical model building approach to generate insights to control Covid-19. This study addresses the following research questions:

- RQ #1. What types of mathematical models are useful in understanding Covid-19?
- RQ #2. What parameters determine the spread of an infectious disease like Covid-19 through the population?
- RQ #3. What proportion of the population will become infected with Covid-19 *if no preventive measures are taken* to stop the spread of this epidemic?
- RQ #4. What level of *vaccine-induced herd immunity* is required to control the disease?
- RQ #5. What steps should individuals and organizations take to control the spread of this disease?

THE SUSCEPTIBLE-INFECTIOUS-RECOVERED MODEL AND ITS VARIATIONS

The following two research questions are addressed here.

- RQ #1. What types of mathematical models are useful in understanding Covid-19?
- RQ #2. What parameters determine the spread of an infectious disease like Covid-19 through the population?

The SIR Model of Epidemics

The SIR model (Kermack & McKendrick, 1927) describes the diffusion of an infectious disease through a susceptible pupation by dividing the population into three different compartments of susceptibles (S), infectious (I), and recovered (R). The relationships among the number of S, I and R can be described as $S \rightarrow I \rightarrow R$. The SIR model may be closed or open where the closed model assumes that the overall population does not change while the open model allows new births and deaths (other than those due to the pathogen).

Closed SIR system

An SIR model can be represented with a deterministic ordinary differential equation (ODE) system given below:

$$\frac{dS}{dt} = -\beta I \frac{S}{N} \qquad equation\ (1)$$

$$\frac{dI}{dt} = \beta I \frac{S}{N} - \gamma I \qquad equation\ (2)$$

$$\frac{dR}{dt} = \gamma I \qquad equation\ (3)$$

- Equation (1) describes the dynamics of the susceptibles compartment in terms of outflow of individuals from the susceptibles compartment to the infectious compartment.
  - β is the probability of disease transmission times the contact rate between susceptible (S) and infectious (I) individuals that independently and randomly mix with one another.
  - $\frac{S}{N}$ is the fraction of encounters with susceptible individuals.
  - βIS is the *incidence rate*, the number of newly infected individuals per unit time.
  - $\beta I \frac{S}{N}$ is the *incidence fraction*. The negative sign in equation (1) represents removal of individuals from the susceptible compartment.
- Equation (2) describes the dynamics of the infected compartment in terms of inflow of individuals from the susceptibles compartment and outflow of individuals to the recovered compartment.
  - Equation (2) describes disease *prevalence*, which is the number of infected individuals at time t.
  - $\beta I \frac{S}{N}$ is the *incidence fraction*. The positive sign in equation (2) represents addition of individuals to the infected compartment.
  - γ represents *the recovery rate.* It is the rate of transition from infectious to recovered.
  - $\frac{1}{\gamma}$ is the average infectious period.

  - γI is the number of individuals who recover per unit of time. The negative sign indicates that these individuals are removed from the infected compartment.
- Equation (3) describes the dynamics of the recovered department.
  - γI is the number of individuals who recover per unit of time. The positive sign indicates that these individuals are added to the recovered compartment.
- N represents population size. N was operationalized by normalizing it to 1 indicating 100% of the population. So, $S + I + R$ would be expressed as fractions.
- $N = S + I + R$.
- N is constant in a closed SIR system, so $\frac{dN}{dt} = 0$. This can be confirmed by adding equations (1)-(3).
- The basic reproductive ratio, R_0, is the expected number of secondary infections from an index case in a randomly mixing pupation. For the SIR model, $R_0 = \frac{\beta}{\gamma}$.
- If $R_0 > 1$, each index susceptible case infects more than one other person so the infection spreads among susceptible population resulting in an expanding epidemic.
- If R_0<1, then each infected individual infects less than one other person on average and the epidemic dies out.

Open SIR System

In an open SIR model, there is "background" death rate (μ) that is balanced by per capita birth rate (μ). In this model, the relationships among the number of susceptibles (S), infectious (I) and recovered (R) can be described as follows:

$$\frac{dS}{dt} = \mu(N - S) - \beta I \frac{S}{N} \quad equation\ (4)$$

$$\frac{dI}{dt} = \beta I \frac{S}{N} - (\mu + \gamma)I \quad equation\ (5)$$

$$\frac{dR}{dt} = \gamma I - \mu R \quad equation\ (6)$$

In the open SIR system, the basic reproductive ratio, $R_0 = \frac{\beta}{\gamma + \mu}$.

ESTIMATING SIR MODEL WITH R SOFTWARE

The following two research questions are addressed here.

- RQ #3. What proportion of the population will become infected with Covid-19 *if no preventive measures are taken* to stop the spread of this epidemic?
- RQ #4. What level of *vaccine-induced herd immunity* is required to control the disease?

The SIR model has been extended to incorporate other aspects like exposed status, hospitalizations, deaths, etc. The model parameters can be estimated from published studies, discussed above, about the behavior of infectious pathogen, SARS-CoV-2.

This system of equations can be solved by numerical integration by using the *deSolve* package in R (R Development Core Team, 2022). *R is an open-source software and environment that can be utilized by the reader to reproduce the results of this study.* The appendix describes how the reader can utilize R to run programs.

The following annotated code is adapted from Bjornstad (2018) to estimate a closed SIR model. The main steps are described below.

1. In an R script, specify a gradient function (sir_mod) containing the following arguments: time t, a vector y representing the state variables (S, I, R, N) of the SIR model, and a variable *parms* containing parameter values (μ, β, and γ, and N).
2. Specify the time points in weeks, and time-increments per week, for example, 26 weeks with 10-increments per week.
3. S + I + R = N and N = 1. So, S, I, R are modeled here as fractions of N.
4. Specify *parms* values, for example, $\mu = 0$, $\beta = 2$ (so disease transmission rate is 2), and $\gamma = 1/2$ (so the infectious period is 2 weeks). For $\beta = 2$ and $\gamma = 1/2$, the basic reproductive rate, $R_0 = \frac{\beta}{\gamma} = 4$.
5. The starting values of the state variables S, R, R. Let 0.1% of the population be infected at the start of the epidemic so, I = 0.1%, S = 0.999, and R = 0.
6. The *ode()* function of the *deSolve* package in R is utilized to solve the system of differential equations. For this purpose the following arguments are entered into the *ode()* function: start (the starting state values of S, I, and R), times, the gradient function, and the parameters.
7. Plot the values of S, I, R, against time as shown in Figure 1(a).
8. Plot R_0 on the horizontal axis, and the corresponding proportion of the population that will ultimately become infected if no preventive measures are taken to stop the spread of the infectious disease. This is shown in Figure 1(b).
9. The following R script was utilized to obtain the results of this study.

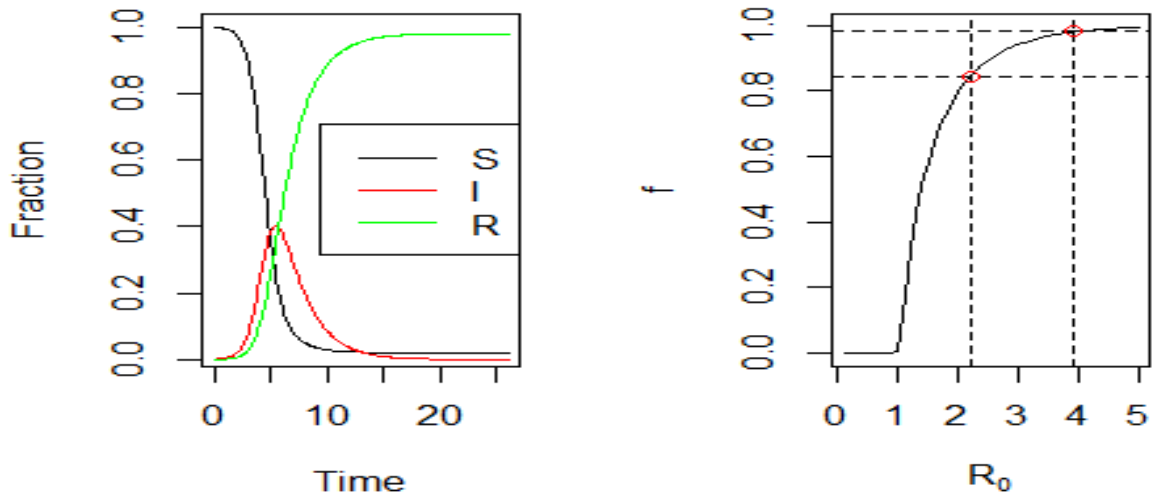
```
# Adapted from Bjornstand, O. N. (2018) Epidemics: Models and Data Using R, Springer.
# Here a # represents a comment and ## represents results generated by R code.

# Closed SIR model, mu = 0
```

```
# load the required package in R
require(deSolve)

## Loading required package: deSolve

# Define the gradient function
sir_mod <- function(t, y, parms){
  S = y[1]; I = y[2]; R = y[3]
  beta = parms["beta"]; mu = parms["mu"]; gamma = parms["gamma"]; N = parms["N"]

  dS = mu * (N-S) - beta * S * I/N
  dI = beta * S * I/N - (mu+gamma) * I
  dR = gamma * I - mu * R
  res = c(dS, dI, dR)
  list(res)
}

times = seq(0, 26, by = 1/10)
parms = c(mu=0, N=1, beta=2, gamma=1/2)
start = c(S=0.999, I=0.001, R=0)

out=ode(y=start, times=times, func=sir_mod, parms=parms)
out=as.data.frame(out)

par(mfrow=c(1,2))
plot(x=out$time, y=out$S, ylab="Fraction", xlab = "Time", type="l")
lines(x=out$time, y=out$I, col="red")
lines(x=out$time, y=out$R, col="green")
legend("right", legend = c("S", "I", "R"), lty = c(1,1,1), col = c("black", "red",
"green"))

# Calculate R0
(R0 <- parms["beta"]/(parms["gamma"] + parms["mu"])) # So R0 = 4.

## beta
##    4

# Calculate the threshold for vaccine-induced herd immunity.
(pc <- 1 - 1/R0) # So 0.75% vaccine cover is required to eliminate the disease.

## beta
## 0.75

# Final epidemic size. Load the rootSolve pacakge in R.
require(rootSolve)

## Loading required package: rootSolve

equil=runsteady(y=c(S= 1-1E-5, I=1E-5, R=0),
                times=c(0, 1E5), func=sir_mod, parms=parms)

# Final epidemic size - rough method
(f <- exp(-R0))
```

```
##     beta
## 0.018316

# For R0 = 4, what fraction of S escape infection?
round(equil$y, 3)

##    S    I    R
## 0.02 0.00 0.98

# The fraction of S that escape infection = 1-f
R0 = seq(0.1, 5, length=50)
betas = R0 * 1/2
f=rep(NA, 50)
for(i in seq(from=1, to=50, by=1)){
  equil=runsteady(y=c(S=1-1E-5, I=1E-5,R=0), times=c(0,1E5), func=sir_mod,
                  parms=c(mu=0, N=1, beta=betas[i], gamma=1/2))
  f[i]=equil$y["R"]
}

# Plot f, the fraction of S that become infected.
plot(R0, f, type="l", xlab = expression(R[0]))
abline(v=2.2, lty=2); abline(v=3.9, lty=2);
abline(h=.845, lty=2); abline(h=.98, lty=2)
points(x=2.2, y = .845, pch = 21, col = "red")
points(x=3.9, y = .98, pch = 21, col = "red")
```

RESULTS AND CONCLUSION

Figure 1 (a): The S, I, and R over time. Figure 1(b): The fraction infected (f) versus R_0



- Figure 1 displays the fraction of susceptibles, infected, and recovered individuals over time in the left panel, and the relationship between the proportion of the pupation that becomes infected with the disease and the basic reproductive rate. It is apparent that a higher proportion of the pupation will become infected as R_0 increases. So, the basic message here is to reduce R_e as much as possible to bring the spread of disease under control. So, every effort must be made to reduce the effective R_e to reduce the fraction of infected individuals in the population.

Esterman (2022) provides R_0 = 3.3 (for the ancestral strain in Wuhan, China); R_0 = 5.1 for Delta that appeared in India; R_0 = 9.5 for Omicron BA.1 in Botswana and South Africa; and R_0 = 13.3 Omicron BA.2. For this study we set the range of $R_0 = 2.2 - 3.9$. Figure 1(b) displays these R_0 values on the horizontal axis and the corresponding proportion of the population that would become infected if no measures are taken to reduce the spread of Covid-19 disease:

1. If $R_0 = 2.2$, at equilibrium only 15.50% of the population escapes infection while 84.50% of the population becomes infected and recovers that includes individual who are impaired health or those who die due to this disease.
2. If $R_0 = 3.9$, at equilibrium only 2% of the population escapes infection while 98% of the population becomes infected and recovers that includes individual who are impaired health or those who die due to this disease.

Clearly these infection numbers are very high and intolerable and call for taking steps to reduce the effect reproductive rate, R_E, that will bring this epidemic under control. Traditional methods of disease surveillance often do not measure cases that are asymptomatic, not diagnosed, or not reported. So, the traditional methods should be supplemented by studies of population-level incidence of Covid-19 based on a national blood sample containing infection-induced SARS-CoV-2 antibodies. One such recent study, published by the CDC, shows that by December 2021, 33.5% (95% CI = 33.1–34.0) of the US population was infected with Covid-19 and by February 2022, 57.7% (95% CI = 57.1–58.3) of the US adults, and about 75% of the US children, were infected by Covid-19 (Clarke, et al., 2022).

Vaccine-Induced Herd Immunity

The threshold for vaccine-induced herd immunity, p_c, can be calculated by p_c = 1 - 1/R_0. So, if $R_0 = 2.2 - 3.9$ then p_c = 54.55% - 74.36% vaccine cover is required to eliminate the disease. This percentage will need to be adjusted for the effectiveness of a vaccine (say it is 50% - 90% effective) and what proportion of the population will take the vaccine.

Taking Steps to Control the Spread of Covid-19

The final research question is addressed here.

- RQ #5. What steps should individuals and organizations take to control the spread of this disease?

The Covid-19 has had a very severally negative impact on the lives of many Americans as they have had to adapt to the new reality of this epidemic. Both non-pharmaceutical and pharmaceutical measurers should be undertaken to control the spread of Covid-19. WHO, CDC, Federal and state governments, The Association of American Medical Colleges, the Center for Health Security, and organizational administrators issues guidelines to guide the behavior of individuals. Table 1 presents some guidelines that were issued in early 2020 and most of them are still valid as a reference for future.

Table 1: Guideline to Reset the US Response to Covid-19

A Road Map to Reset the Nation's Approach to the Pandemic	Resetting Our Response: Changes Needed in the US Approach to Covid-19
Source: Association of American Medical Colleges. Retrieved from https://www.aamc.org/Covidroadmap/roadmap	Source: The Center for Health Security. Retrieved from https://www.centerforhealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2020/200729-resetting-our-response.pdf
Immediate Actions 1. Remedy critical supply and drug shortages. 2. Increase availability and accessibility of testing. 3. Establish national standards on face coverings. 4. Establish and enforce national criteria for local stay-at-home orders and reopening protocols. 5. Establish national criteria for K-12 school reopenings and convene a working group to study different approaches by mid-August. 6. Immediately expand health insurance through COBRA. 7. Begin planning now to prioritize distribution of the SARS-CoV-2 vaccine. 8. Address and resolve health care inequities. 9. Inform, educate, and engage the public. Longer-Term Actions 1. Broaden health insurance. 2. Strengthen the nation’s public health infrastructure.	1. Encourage and, where appropriate, mandate nonpharmaceutical interventions. 2. Close higher risk activities and settings in jurisdictions where the epidemic is worsening and reinstitute stay-at-home orders where healthcare systems are in crisis. 3. Bolster PPE supply chains and stockpiles and make information about the PPE manufacturing base and supply chain publicly available, with the goal of expanding PPE availability. 4. Bolster test supply chains, plan for shortages, and collaborate with states and commercial laboratories to expand capacity and improve test turnaround times. 5. Conduct and make public detailed analyses of epidemiologic data collected during case investigations and contact tracing. 6. Curate and fund a rapid research agenda to cope with major challenges that have arisen. 7. Scale up contact tracing and continue to improve performance. 8. Identify and disseminate best practices for improving the public health response. 9. Plan for a vaccine, including production, allocation, distribution, and community engagement, to ensure a successful rollout. 10. Develop policies and best practices to better protect group institutions.

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APPENDIX: A BREIF INTRODUCTION TO R LANGUAGE AND ENVIRONMENT

R is an open-source and free software language and environment for statistical analysis, model building, and visualization. R can produce elegant graphs with ease. Ross Ihaka and Robert Gentleman, University of Auckland, developed R in 1991 by utilizing two programming languages -- Scheme and S. Scheme emphasizes simplicity and elegance, and it is a dialect of Lisp language. S language was developed at Bell Telephone Laboratories (Bell Labs) during 1970s and 1980s; it focused on data analysis and emphasized ease of use (Peng, 2022).

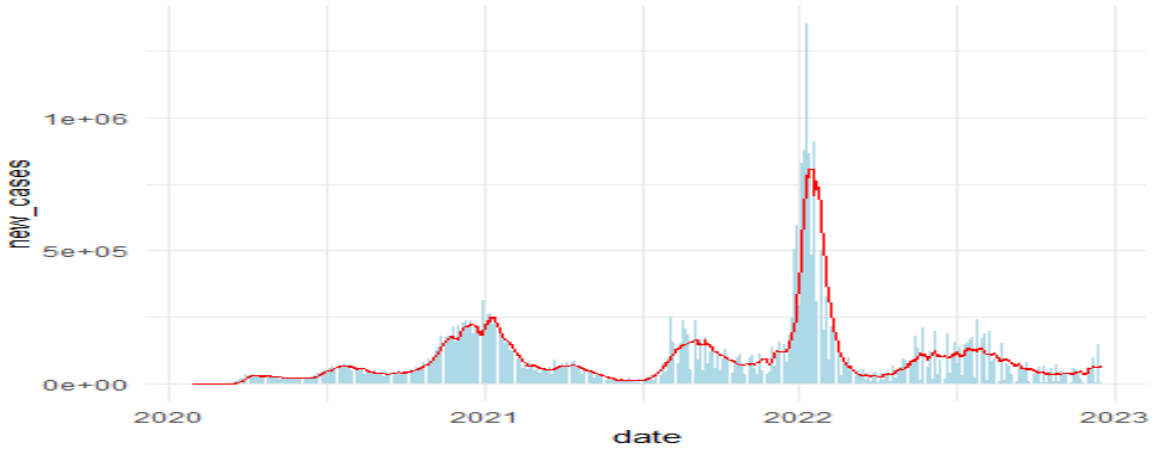
Managers and policy makers interested in exploring and understanding the dynamics of an infectious disease like Covid-19 can do so by using R that they can download and install from https://cran.r-project.org/. Posit (or RStudio) is a popular Integrated Development Environment (IDE) that makes it easier to utilize R and produce high quality output in various formats

(DOCX, HTML, PDF, etc.). Posit is also free and can be download and installed from https://posit.co/. Both R and Posit run on a variety of operating systems including most Unix platforms, Mac OS, and Windows. Many YouTube videos guide beginners to download and install R and Posit (or RStudio) and run R programs (for example, R Programming 101, 2018).

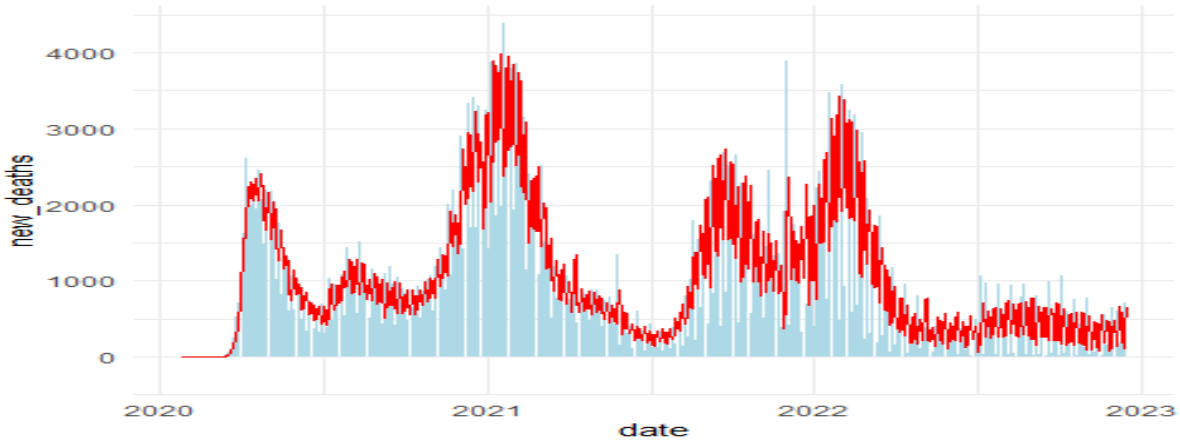
While R is an impressive language and environment for modeling, data analysis, and visualization, its capabilities have been extended by thousands of packages. There are over a hundred R packages for Covid-19 modeling and data analysis (Soetewey, 2020). The following illustrates how to utilize tidycovid19 package in R along with other R packages, to collect and analyze Covid-19 data. The tidycovid19 package provides many functions for downloading, analyzing, and displaying Covid-19 information (Gassen, n.d., Gassen, 2022). Readers can work in the R console or in Posit (or RStudio) to create an R script containing the following R code. China and the US took two different approaches to Covid-19 control, so the following code highlights infections and deaths in these two countries along with analyses about geographic spread of this disease in different regions. The reader will appreciate the ease with which latest Covid-19 data can be accessed, analyzed, and displayed.

```
# R code to obtain, analyze, and display the latest Covid-19 data
# Here a # represents a comment and ## represents results generated by R code.

# set RStudio as the CRAN mirror to download and install R packages
options(repos = c(CRAN = "http://cran.rstudio.com"))

# install an R package called remotes
# install tidycovid19 package: remotes::install_github("joachim-gassen/tidycovid19")

# install an R package called pacman
# load several packages with p_load() function in pacman package
pacman::p_load(tidyverse, tidycovid19, zoo)

# download data with download_merged_data() function in tidycovid19
df <- download_merged_data(cached = TRUE, silent = TRUE)

str(df) # look at the structure of df data file

# print regions
unique(df$region)

## [1] "Latin America & Caribbean " "South Asia"
## [3] "Sub-Saharan Africa "        NA
## [5] "Europe & Central Asia"      "Middle East & North Africa"
## [7] "East Asia & Pacific"        "North America"

# print 3-letter country code
unique(df$iso3c)

# print country names
unique(df$country)

#------------ USA -----------
# new cases aveaged weekly
```

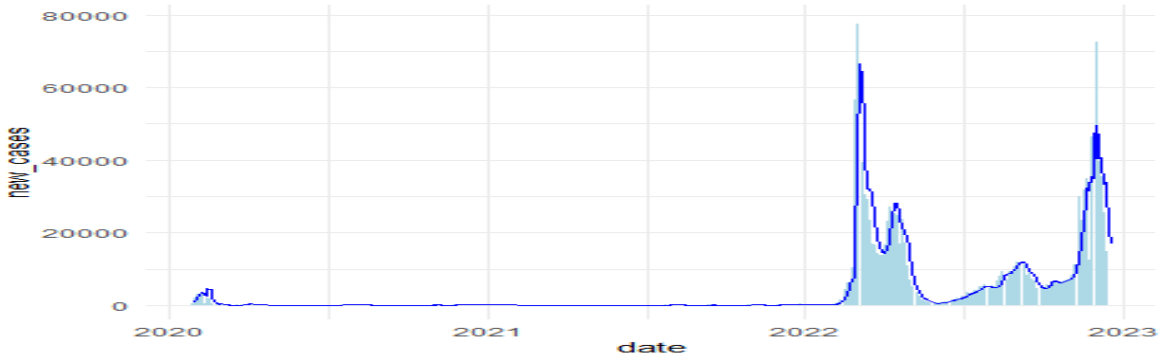
```
df %>% filter(iso3c == "USA") %>%
  mutate(
    new_cases = confirmed - lag(confirmed),
    ave_new_cases = rollmean(new_cases, 7, na.pad=TRUE, align="right")
  ) %>%
  filter(!is.na(new_cases), !is.na(ave_new_cases)) %>%
  ggplot(aes(x = date)) +
  geom_bar(aes(y = new_cases), stat = "identity", fill = "lightblue") +
  geom_line(aes(y = ave_new_cases), color ="red") +
  theme_minimal()
```




```
# new weekly deaths averaged over a month
df %>% filter(iso3c == "USA") %>%
  mutate(
    new_deaths = deaths - lag(deaths),
    ave_new_deaths = rollmean(new_deaths, 4, na.pad=TRUE, align="right")
  ) %>%
  filter(!is.na(new_deaths), !is.na(ave_new_deaths)) %>%
  ggplot(aes(x = date)) +
  geom_bar(aes(y = new_deaths), stat = "identity", fill = "lightblue") +
  geom_line(aes(y = ave_new_deaths), color ="red") +
  theme_minimal()
```

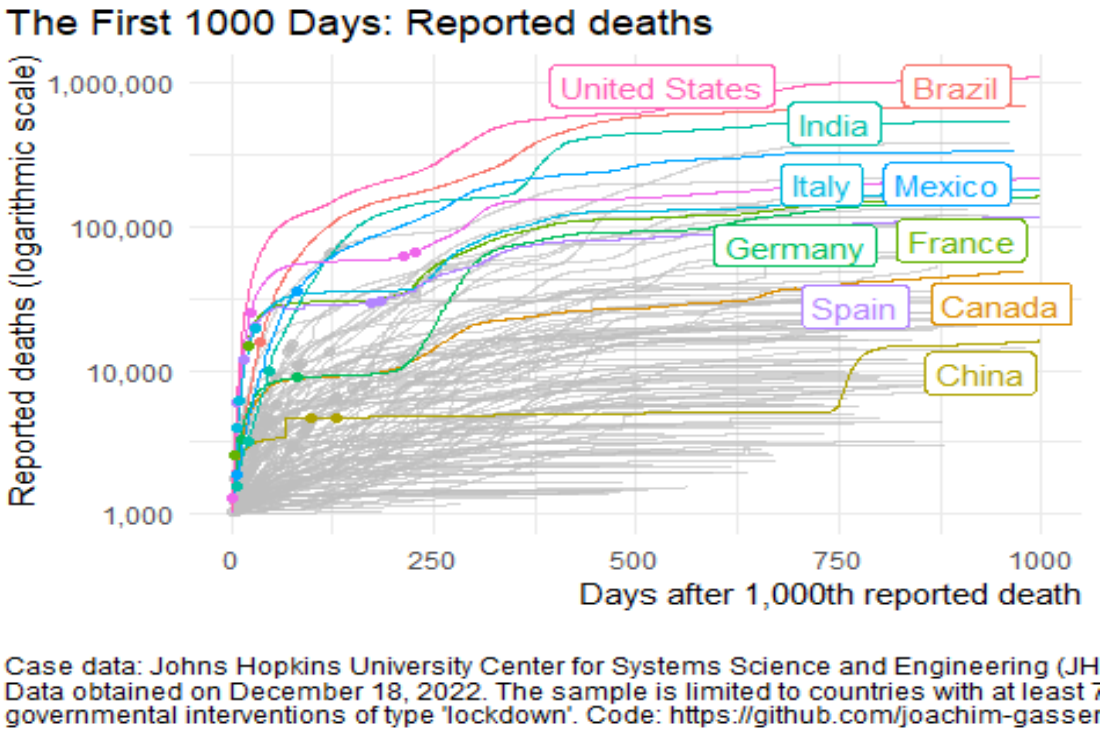


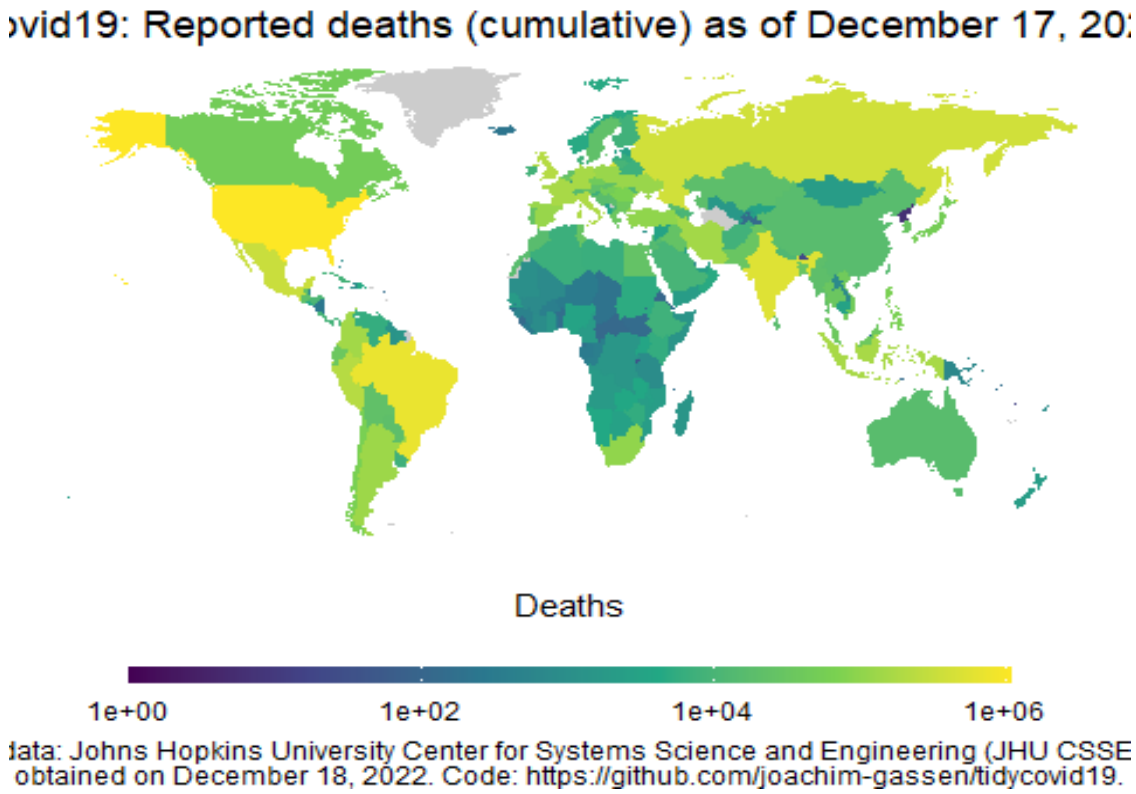

```
#--------- China -----------------
df %>%
  filter(iso3c == "CHN") %>%
  mutate(
    new_cases = confirmed - lag(confirmed),
    ave_new_cases = rollmean(new_cases, 7, na.pad=TRUE, align="right")
  ) %>%
  filter(!is.na(new_cases), !is.na(ave_new_cases)) %>%
  ggplot(aes(x = date)) +
  geom_bar(aes(y = new_cases), stat = "identity", fill = "lightblue") +
  geom_line(aes(y = ave_new_cases), color = "blue") +
  theme_minimal()
```




```
# new weekly deaths averaged over a month
df %>% filter(iso3c == "CHN") %>%
  mutate(
    new_deaths = deaths - lag(deaths),
    ave_new_deaths = rollmean(new_deaths, 4, na.pad=TRUE, align="right")
  ) %>%
  filter(!is.na(new_deaths), !is.na(ave_new_deaths)) %>%
  ggplot(aes(x = date)) +
  geom_bar(aes(y = new_deaths), stat = "identity", fill = "lightblue") +
  geom_line(aes(y = ave_new_deaths), color ="red") +
  theme_minimal()
```

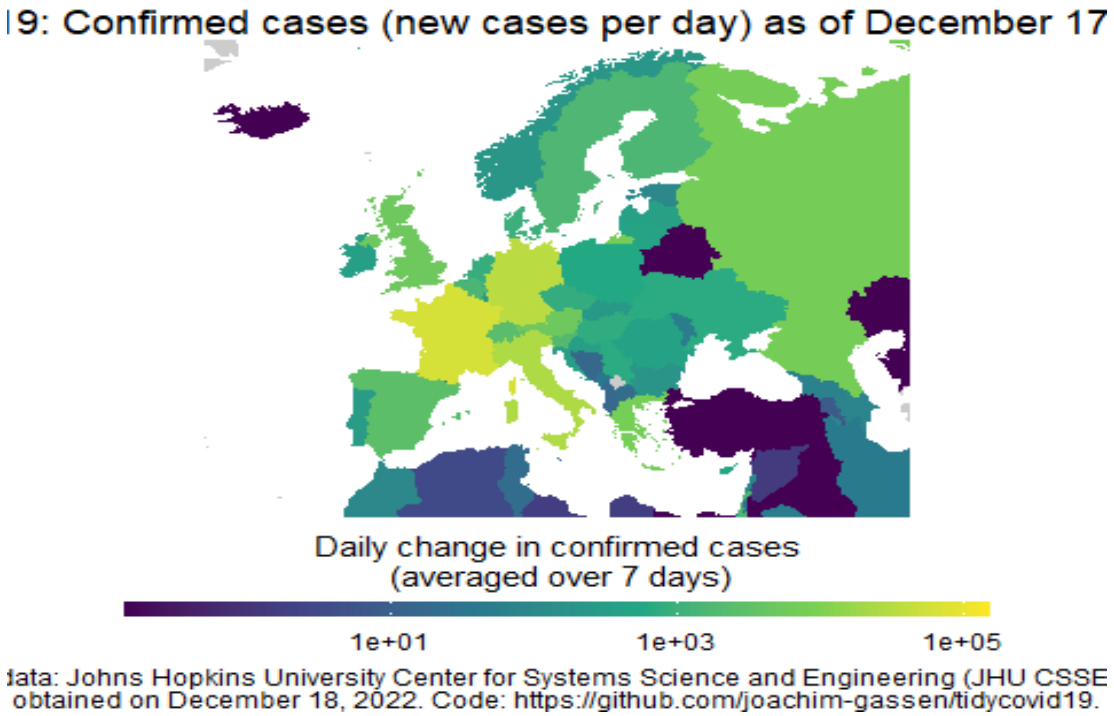

```
#------ many countries ------------------
merged <- download_merged_data(cached = TRUE, silent = TRUE)
plot_covid19_spread(
  merged, highlight = c("BRA", "CAN", "CHN", "DEU", "ESP", "FRA", "GBR", "IND",
"ITA", "MEX", "USA"),
  intervention = "lockdown", edate_cutoff = 1000
)

## Warning: ggrepel: 1 unlabeled data points (too many overlaps). Consider
## increasing max.overlaps
```



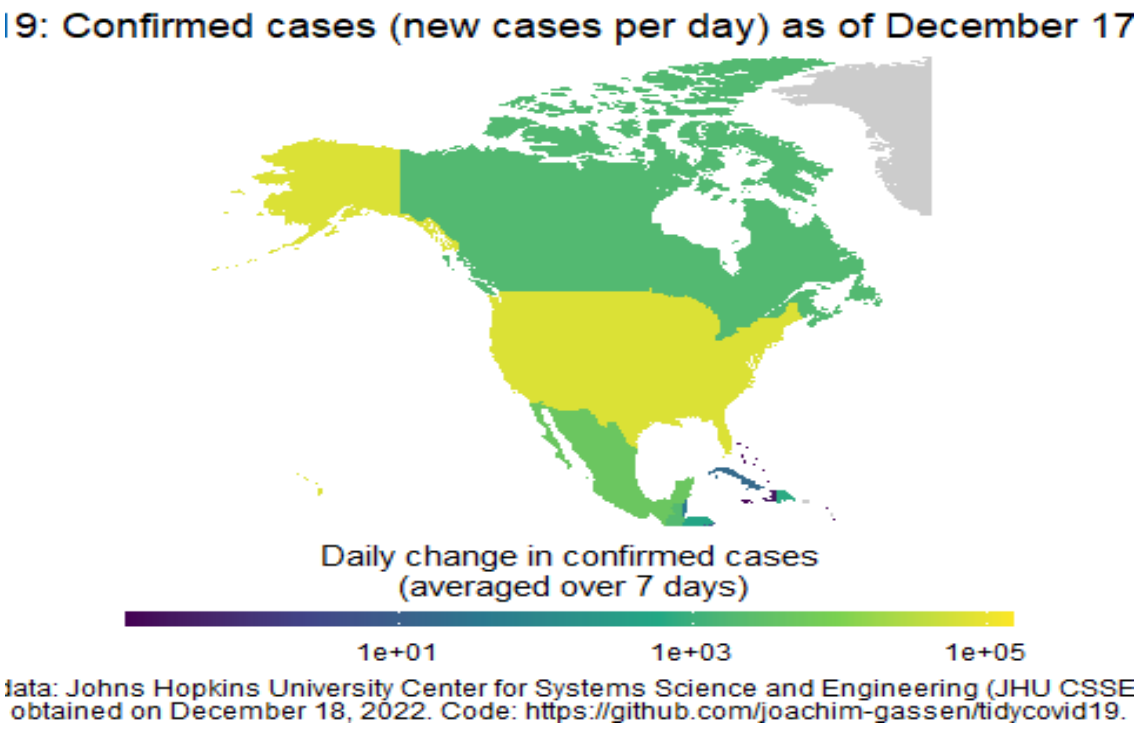


Covid19: Confirmed cases (new cases per day) as of December 17, 2022

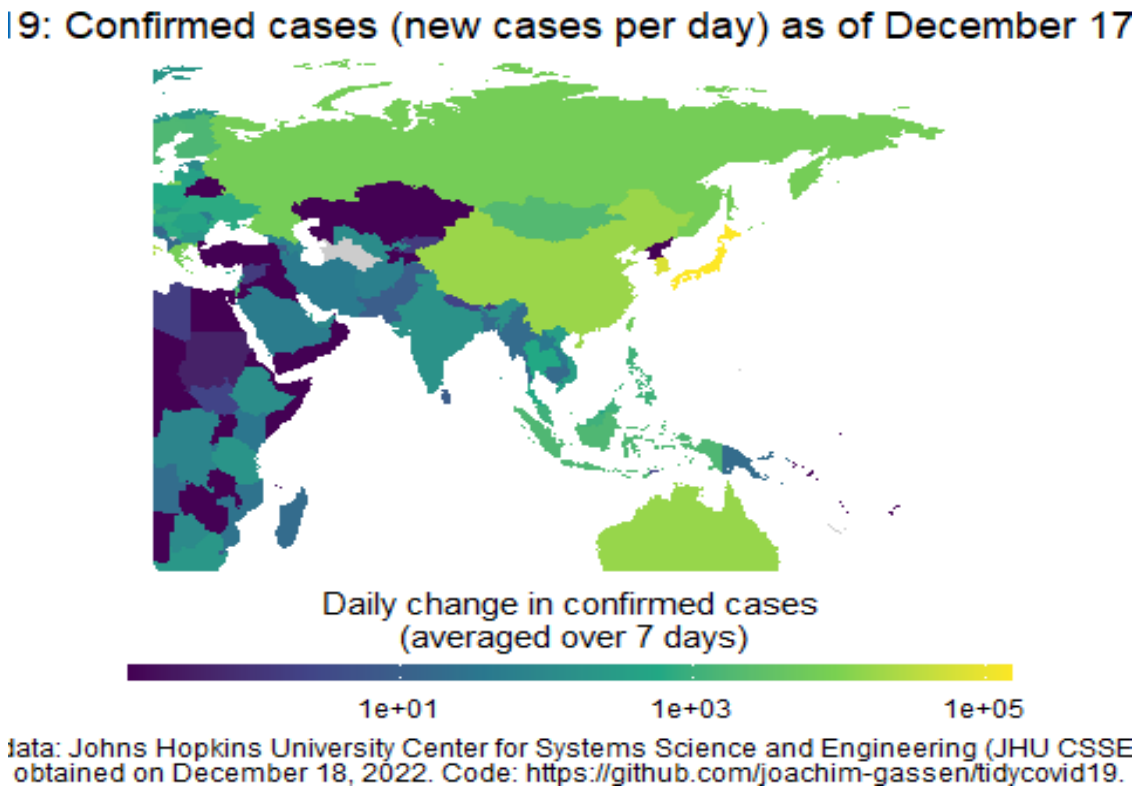
```
# Covid19: Confirmed cases (new cases per day) as of December 17, 2022
map_covid19(merged, type = "confirmed", region = "Europe")
```




```
# Covid19: Confirmed cases (new cases per day) as of December 17, 2022
map_covid19(merged, type = "confirmed", region = "North America")
```




```
# Covid19: Confirmed cases (new cases per day) as of December 17, 2022
map_covid19(merged, type = "confirmed", region = "Asia")
```


9: Confirmed cases (new cases per day) as of December 17
Daily change in confirmed cases
(averaged over 7 days)
1e+01
1e+03
1e+05
lata: Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE
obtained on December 18, 2022. Code: https://github.com/joachim-gassen/tidycovid19.

UNDERGRADUATE BUSINESS STUDENT ONLINE ATTITUDE AND BEHAVIOR: AN EMPIRICAL EXAMINATION OF THE COVID-19 PANDEMIC EFFECTS

Carl J. Case, St. Bonaventure University
Darwin L. King, St. Bonaventure University

ABSTRACT

Phishing has been an ongoing challenge for both individuals and organizations. Of particular concern to information systems educators are the attitudes and online behavior of the next corporate users, our current business students. This study was therefore conducted to empirically examine the aspects of spyware, phishing, and identity theft and, in particular, if there are COVID-19 pandemic effects. Results suggest that online minutes have greatly increased, concern about spyware has decreased, and concern about identity theft has increased since the beginning of the pandemic. However, no statistically significant correlation between online minutes and behavior was found.

Keywords*: phishing, identity theft, undergraduate students, empirical study*

INTRODUCTION

Spyware is one of the oldest and most widespread online threats in which the computer is secretly infected to initiate a variety of illegal activities including identity theft or a data breach (Malwarebytes.com, 2022). Techniques include phishing, spoofing, using Trojan horses, exploiting security vulnerabilities such as back doors, and so on.

In terms of identity theft, the Aite-Novarica Group found that 47% of Americans experienced financial identity theft in 2020. And, the Federal Trade Commission's (FTC) Consumer Sentinel Network analysis of over 5.7 million complaints in 2021 found that 25% were for identity theft (Insurance Information Institute, 2022). The most common types of identity theft were for government benefits applied for/received (31%) and credit card fraud for new accounts (29%).

Data threats can be manifested in several forms such as ransomware, targeted hacking, vendor or customer impersonation, IP address hacking, extortion, and so on (Neustar, 2018). The most recent noteworthy data breaches include: the 2021 LinkedIn data breach exposing the personal information of 700 million users (93% of all LinkedIn members), the March 2021 attack on Microsoft that affected more than 30,000 U.S. businesses and government agencies, the 2021 infiltration of the Colonial Pipeline Company with ransomware that caused fuel shortages across the U.S., and the ransomware attack of the meat processing company JBS that shut down beef and poultry processing plants on four different continents (Sobers, 2022).

The IBM Security (2021) Data Breach Report estimates the average cost of a data breach is $4.24 million. Data breaches that take longer than 200 days to identify and contain cost on average $4.87 million as compared to $3.61 million for breaches that take less than 200 days. Overall, the report found it takes an average of 287 days to identify and contain a data breach. Ransomware attacks, for example, cost an average of $4.62 million which includes escalation, notification, lost business, and response costs, not including the cost of the ransom.

According to Verizon's Data Breach Investigative Report 2022 analysis of over 23,000 cybersecurity incidents and 5,200 confirmed breaches from around the world, 25% of all data breaches involve phishing and 85% of data breaches involve a human element (Verizon.com 2022). Moreover, the FBI's Internet Crime Complaint Center (IC3) found that phishing, including vishing, SMiShing and pharming, was the most prevalent threat in the U.S. in 2020, with 241,342 victims (Jones, 2022). This was followed by non-payment/non-delivery (108,869 victims), extortion (76,741 victims), personal data breach (45,330 victims) and identity theft (43,330 victims). This is problematic given that Terranova Security's 2020 Gone Phishing Tournament found nearly 20% of all employees are likely to click on phishing email links and, of those, 67.5% go on to enter their credentials on a phishing website.

Phishing mechanisms continue to evolve. A new form is through the use of Quick Response (QR) codes (Bergal, 2022). In January of 2022, the FBI issued an alert about cybercriminals tampering with posted QR codes to steal login and financial information. Pay-to-park kiosks, for example, have been targeted with criminals slapping stickers with fake QR codes on pay stations. Fake codes are then used to redirect payments and embed malware in the unsuspecting victim's mobile device.

According to Check Point, in the fourth quarter of 2020, Microsoft was the most impersonated brand globally when it comes to brand phishing attempts, accounting for 43% of the attempts (checkpoint.com, 2020). Attackers are likely exploiting Microsoft's name given the increase in organizations relying on Microsoft's suite of cloud applications since the start of the pandemic. Other brands impersonated include DHL (18% of attempts), LinkedIn (6% of attempts), and Amazon (5% of attempts). Unfortunately, email security provider Ironscales' State of Cybersecurity Survey poll of more than 400 U.S. IT professionals found that 81% of respondents experienced an increase in email phishing attacks since the start of the pandemic, from March 2020 to September 2021 (Thomas, 2021). And, only 19% of organizations provide cybersecurity awareness training on an annual basis.

Given the increasing incidences of phishing, data breaches, and identity theft, the study was conducted to examine the attitude, incidence, and trends relative to undergraduate business students. This empirical study examines several questions. Are students concerned about spyware and identity theft? What are student online activity minutes? Are students protected with a second firewall? Have students responded to phishing email and/or have been a victim of identity theft? And, has the March 11, 2020 World Health Organization declaration of the novel coronavirus (COVID-19) as a global pandemic changed attitudes and activity (Cucinotta & Vanelli, 2020)? Results are important in better understanding the state of student online behavior and if modifications to student education are needed to minimize vulnerability.

PREVIOUS RESEARCH

An initial study by the authors conducted in 2006-2007 found that only 26% of undergraduate students indicated receiving phishing email with 16 phishes received per month per student (Case and King, 2008). A subsequent study conducted 2007-2010 examined email quantity (King & Case, 2012). Results demonstrated that students received 212 emails per month with the largest category, 35%, being unsolicited or spam emails. Class-related (26%), personal/non-class (13%), and other email (26%) were less common. A third study by the authors conducted 2011-2015 examined types of phishing (Case & King, 2016). Responses illustrate that for every year of the study, credit card phishing emails were the most common type of attack with 18-23% of students per year indicating receiving them. Amazon.com (14-19%), eBay (8-12%), Nigerian Scam (6-10%), and other (4-5%) phishes were also received.

To predict user susceptibility to phishing websites, Abbasi, et.al (2021) proposed and tested the phishing funnel model (PFM). PFM incorporates user, threat, and tool-related factors to predict actions during four key stages of the phishing process: visit, browse, consider legitimate, and intention to transact. Experiments demonstrated PFM significantly outperformed competing models/methods by correctly predicting visits to high-severity threats 96% of the time. In addition, a follow-up field study revealed that employees using PFM were significantly less likely to interact with phishing threats relative to comparison models and baseline warnings.

Furthermore, because scammers may use a step by step approach to gain a potential victim's trust, Abroshan, et.al (2021) investigated the extent risk-taking and decision-making styles influence the likelihood of phishing victimization in such instances. Results suggest that the attitude to risk-taking and gender can predict users' phishability in the different steps selected.

In terms of spyware, Sideri et al. (2019) used a case study to investigate the privacy literacy of university students in relation to the usage of social media. Researchers held a thirteen-week course on social media with the goal of strengthening privacy literacy. Although the students at the outset did not have the necessary knowledge in this field, after completing the course participants exercised more caution with regard to their profile visibility, paid more attention to the privacy settings of Facebook, and had increased awareness of the usefulness of anti-spyware software.

Relative to identity theft, Ogbanufe & Pavur (2022) explored why and how individuals adaptively and maladaptively respond to the threat. The researches provided empirical evidence of conditions under which fear and regret motivate personal security protection measures, thus enabling practitioners to promote identity theft protection more efficiently. Results suggest that fear is only effective when the threat is high and anticipated regret is effective in both high and low threat conditions. Also, anticipated regret has the most potent effect on increasing adaptive coping responses in a low threat model. Thus, anticipated regret rather than fear could be used in situations where the threat is low.

Finally, Salam, et.al (2021) proposed an empirical assessment of the construct of user control over identity theft. Findings suggest that when users have the perception of more control over the identity theft threat, they are likely to find solutions, feel it is their responsibility, and have more intentions for identity theft prevention actions to prevent identity theft.

RESEARCH DESIGN

This study employs a survey research design. The research was conducted at a private, northeastern U.S. university. A Student Phishing instrument was developed by the authors and administered each semester during a five-year period (from spring 2018 through spring 2022) to undergraduate students enrolled in a School of Business course. However, because of the university unanticipated face-to-face instruction discontinuance midway through the spring of 2020, no data were collected during that semester. The courses included a variety of subjects such as Business Information Systems, Introduction to Financial Accounting, Introduction to Managerial Accounting, Macroeconomics, and Business Policy. A convenience sample of class sections and faculty members was selected to minimize the probability of a student receiving the survey in more than one class and to ensure consistency, the same questions were asked during each of the semesters. Because of the sensitivity of the subject and to encourage honesty, no personally-identifiable data were collected and respondents were informed that surveys were anonymous, participation was voluntary, and responses would have no effect on his/her course grade. In addition, students were asked to complete the survey only one time per semester. Prior to the pandemic, the surveys were completed via paper in an academic classroom. Subsequent to the beginning of the pandemic, the surveys were completed via an online link.

The survey instrument was utilized to collect student demographic data such as gender and academic class. In addition, the survey examined student Internet behavior regarding shopping, non-school related surfing, phishing, spyware, firewalls, and identity theft. Results were summarized by activity and correlations were calculated to determine potential relationships between online minutes and behaviors. To examine potential trends, the data was segmented by calendar year. However, because of the anonymity of respondents, it could not be determined if a given student participated during multiple semesters so repeated measures were not examined.

RESULTS

A sample of 952 usable surveys was obtained. As indicated in Table 1, 60% of the respondents were male and 40 were female. These percentages were fairly consistent with the study university's School of Business student population.

Table 1
Gender Response Rate by Year

	2018	2019	2020	2021	2022	Total
Male	59%	60%	67%	58%	65%	60%
Female	41%	40%	33%	42%	35%	40%
Count	311	344	80	155	62	952

The response rate by academic class was relatively equally distributed. As indicated in Table 2, 18% of respondents were freshmen, 36% were sophomores, 30% were juniors, and 16% were seniors.

Table 2
Academic Class Response Rate by Year

	2018	2019	2020	2021	2022	Total
Freshmen	21%	28%	0%	4%	10%	18%
Sophomore	36%	32%	23%	41%	55%	36%
Junior	28%	17%	70%	46%	26%	30%
Senior	15%	8%	8%	9%	10%	16%

Responses were first examined with regard to the student's level of concern about spyware. As indicated in Table 3, in 2018, 16% strongly disagreed, 22% disagreed, 28% were neutral, 20% agreed, and 10% strongly agreed with respect to being concerned about spyware. At the onset of the pandemic in 2020, 24% strongly disagreed, 33% disagreed, 19% were neutral, 23% agreed, and 6% strongly agreed about his/her concern. By 2022, 19% strongly disagreed, 31% disagreed, 21% were neutral, 21% agreed, and 8% strongly agreed about his/her concern. Results demonstrate that the percent of students concerned about spyware was relatively consistent from 2018 to 2022 with 30%, 28%, 29%, 30%, and 29%, respectively, of students indicating concern. On the other hand, the percentage not concerned varied from 2018 to 2022 to 38%, 37%, 57%, 39%, and 50%, respectively, of students.

Table 3
Concerned About Spyware by Year

Level of Agreement	2018	2019	2020	2021	2022
Strongly Disagree	16%	13%	24%	14%	19%
Disagree	22%	24%	33%	25%	31%
Neutral	28%	30%	19%	32%	21%
Agree	20%	19%	23%	21%	21%
Strongly Agree	10%	9%	6%	9%	8%

Next, responses were examined with regard to the student's level of concern about identity theft. As indicated in Table 4, in 2018, 8% strongly disagreed, 31% disagreed, 47% were neutral, 13% agreed, and 3% strongly agreed with respect to being concerned about identity

theft. At the onset of the pandemic in 2020, 18% strongly disagreed, 34% disagreed, 20% were neutral, 28% agreed, and 5% strongly agreed about his/her concern. In terms of identity theft, from 2018 to 2022, 16%, 15%, 33%, 34%, and 26%, respectively, of students indicated concern. The percentage not concerned varied from 2018 to 2022 to 39%, 27%, 52%, 39%, and 46%, respectively, of students.

Table 4
Concerned About Identity Theft by Year

Level of Agreement	2018	2019	2020	2021	2022
Strongly Disagree	8%	3%	18%	16%	15%
Disagree	31%	24%	34%	23%	31%
Neutral	47%	58%	20%	30%	29%
Agree	13%	15%	28%	21%	21%
Strongly Agree	3%	0%	5%	13%	5%

Activity minutes per day are presented in Table 5. Results illustrate that in 2018, respondents indicated spending 1 minute per day shopping online while spending 112 minutes per day engaged in non-school surfing. At the onset of the pandemic in 2020, respondents spent 3 minutes shopping and 221 minutes engaged in non-school surfing per day. By 2022, respondents spent 1 minutes shopping and 177 minutes engaged in non-school surfing per day. While shopping online minutes per day remained consistent at one minute per day from 2018 to 2022, non-school surfing varied from 112 minutes, 110 minutes, 221 minutes, 157 minutes, and 177 minutes per day, respectively, during the study years. Overall, total minutes per student increased from 107 minutes (1.8 hours) in 2018 to 165 minutes (2.8 hours) in 2022.

Table 5
Activity Minutes Per Day by Year

Activity	2018	2019	2020	2021	2022
Shopping Online	1	1	3	1	1
Non-School Surfing	112	110	221	157	177
Total	107	105	219	154	165

Respondent behavior was further examined and presented in Table 6. In 2018, 6% indicated responding to a phishing email in the past year, 27% indicated using a second firewall, 4% indicated being a victim of identity theft, and 26% indicated personally knowing a victim of identity theft. At the onset of the pandemic in 2020, 7% indicated responding to a phishing email in the past year, 17% indicated using a second firewall, 7% indicated being a victim of identity theft, and 37% indicated personally knowing a victim of identity theft. By 2022, 2% indicated responding to a phishing email in the past year, 11% indicated using a second firewall, 5%

indicated being a victim of identity theft, and 53% indicated personally knowing a victim of identity theft. With respect to behavior, in general, the majority of students did not exhibit any of the behaviors during each of the five years. For example, from 2018 to 2022, only 6%, 6%, 7%, 8%, and 2%, respectively per year, of students responded to a phishing email during the past year. Moreover, only 4%, 11%, 7%, 7%, and 5%, respectively per year, of students have been a victim of identity theft. Second firewall usage was more common each year, respectively, with 27%, 35%, 17%, 14%, and 11%, respectively per year, of students indicating this behavior. Personal knowledge of an ID theft victim was also more common with 26%, 24%, 37%, 38%, and 53%, respectively per year, of students indicating this knowledge.

Table 6
Behaviors by Year

Behavior	2018	2019	2020	2021	2022
Responded to Phishing Email in Past Year	6%	6%	7%	8%	2%
Use a Second Firewall	27%	35%	17%	14%	11%
Have Been Victim of Identity Theft	4%	11%	7%	7%	5%
Personally Know an ID Theft Victim	26%	24%	37%	38%	53%

Finally, potential correlations between the quantity of surfing minutes and various behaviors were examined in Table 7. Statistically significant Spearman Rho correlations were not found with respect to any behavior including responding to a phishing email in the past year, using a second firewall, or being a victim of identity theft.

Table 7
Spearman Rho Correlations between Surfing Minutes and Behavior

Behavior	Correlation Coefficient
Responded to Phishing Email in Past Year	-.188
Use a Second Firewall	.132
Have Been Victim of Identity Theft	.082

* Correlation is significant at .05 level (2-tailed).
** Correlation is significant at .01 level (2-tailed).

The limitations of these results are primarily a function of the sample, sample distribution, and type of research. The use of additional universities, a more equal distribution among gender, and increased freshman participation would increase the robustness of results. Another limitation relates to the self-reported nature of the survey.

IMPLICATIONS

There are three important implications from the study. One implication relates to student attitude. Prior to the pandemic, a minority, 36-37%, of students per year were not concerned about spyware. However, at the onset of the pandemic, the majority, 57%, of students indicated a lack of concern. This lack of concern remained at 50% of students by the end of the pandemic. It is possible the social isolation and life traumas associated with the pandemic resulted in an increased sense that online privacy is not as important as the other life and death challenges associated with a pandemic. Another aspect of the pandemic relates to concerns about identity theft. Prior to the pandemic, 15-16% of students indicated concern. However, at the onset of the pandemic, this percentage more than doubled to 33%. At the end of the pandemic, the percentage decreased to 26%, but remains much larger than the pre-pandemic years. It is possible that the increased dependence on and use of the Internet because of face-to-face COVID-19 exposure concerns and/or travel lock-downs during the pandemic has triggered the identity theft concern. These changes suggest that the pandemic has affected attitude related to both personal privacy and security threats.

A second implication is evident when examining behavior. While two behaviors, responding to a phishing email and being a victim of identity theft, have remained relatively small and consistent in occurrence during each of the five years, other behaviors have changed since the onset of the pandemic. Non-school surfing increased by 100% to 221 minutes per day during the first year of the pandemic and remained 54% higher at the end of the pandemic as compared to four years earlier. It likely that surfing increased because of the social isolation and/or increased discretionary time as a result of unemployment and tele-commuting. Another behavior, using a second firewall for intrusion detection/prevention, decreased by 50% to 17% at the onset of the pandemic and continued to decrease through the study years. This may also be a result of the feeling of social isolation and perception that one is not being spied upon.

Finally, the third implication relates to the difference in the level of identity theft victimization between students and others. While respondents indicated a dramatic increase in the knowledge of others being victimized (24% prior to pandemic, 37% at the onset, and 53% at the end of the pandemic), student victimization has varied slightly, from 4% to 11% per year, during the study. It is possible that either students are more aware of other's victimization or are more vigilant because of education. This suggests that continued proactive education has been and may continue to be helpful in combating the scourge of identity theft. Future research will need to determine if the pandemic effects have permanently changed undergraduate student attitudes and behavior.

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WHAT IS THE GLOBAL FUTURE ROLE OF DIGITALIZATION FOR SMALL AND MEDIUM-SIZED ENTERPRISES? LESSONS LEARNED FROM COVID 19

Ron G. Cheek, University of Louisiana Lafayette
David Stevens, University of Louisiana Lafayette
Angel Littlejohn, University of Louisiana Lafayette
Robert D. Hatfield, Western Kentucky University

ABSTRACT

The economic shock from COVID-19 was unprecedented for organizations all over the world regardless of their sizes. The pandemic's most severe implications were for Small and Medium-sized Enterprises (SMEs). SMEs lacked the resources, sources of financing, and other means to survive until conditions stabilized from the pandemic. But for many SMEs, digital technologies (DTs) offered the timely and most cost-effective method to survive the COVID-19 pandemic. In many instances the primary DTs utilized by the SMEs were nothing more than social media sites such as Facebook, Instagram, LinkedIn, and other similar sites. Now post pandemic, digitalization continues to play a major role in the success of many SMEs. In this paper we examine the impact of DTs on SMEs during the COVID-19 pandemic. We will also examine how these enterprises have dramatically changed the manner in which they now operate, and how DTs will drive their innovation in the future. For academic researchers, DTs and their impact on SMEs are underexamined, demand numerous new and novel theories, and will offer a rich research stream for academicians across all disciplines for years to come.

Keywords: digital technologies, SMEs, social media, COVID-19, global economy, Web 3.0

INTRODUCTION

Digital Technologies (DTs) provided a lifeline for many Small and Medium-sized Enterprises (SMEs) during the COVID-19. But the lessons learned by SMEs using DTs for survival have now become key components of their business strategies and operations. In this paper we will also examine how these enterprises have dramatically changed the manner in which they now operate, and how DTs will drive their innovation in the future.

The importance of DTs for SMEs was amplified during the COVID-19 pandemic. But for SMEs, DTs were life-lines during the COVID-19 pandemic. It was a new way of conducting business that they had used only sparingly prior to the pandemic. In this paper we examine the impact of DTs on SMEs during the COVID-19 pandemic and how these enterprises have

dramatically changed the manner in which they now operate, and how these technologies will drive their innovation in the future.

For SMEs, in many instances the primary digitalization tools utilized were nothing more than social media sites such as Facebook, Instagram, LinkedIn, and other similar sites. But especially important to SMEs, these DTs did not have a steep learning curve, and most of their employees were already literate in their uses, functions and operations. Therefore, they could be seamlessly and quickly implemented and used for communications, supply chain challenges, and direct interaction with customers. The lessons learned from the utilization of digital tools during COVID-19 have dramatically changed the manner in which SMEs now operate and how they will drive business and innovation in the future.

We define DTs as electronic tools, devices and resources that generate, store or process data. The definition of DTs includes social media, videos, mobile phones, and many other internet-based tools such as Facebook, Instagram, LinkedIn, and Twitter. These are the DTs that can be used for buying, selling, and acquiring or sharing information. DTs offer 24/7/365 access and can be used by customers and organizations of all sizes (El Sawy, et al. 2010; Lyytinen and Yoo 2002; Yoo et al. 2012). The digitalization of data in print, emails, blogs, tweets, and other forms has made a wealth of data available for researchers. For example, it is estimated that 85% - 95% of all business data is unstructured and most of that is text. DTs have challenged and exceeded the ability of academic press to catch up (Gandomi & Haider 2015).

The purpose of this paper is to examine the role of digitalization for SMEs during the COVID 19 pandemic and to identify lessons SMEs learned from their use during the pandemic. But it is also important to examine how post COVID-19 SMEs are use DTs' distinct competitive advantages to successfully compete against even larger, global organizations. Finally, we discuss the future directions and implications for digitalization for SMEs in the future.

Role of SMEs in the Global Economy

The economic shock from COVID-19 is unprecedented for all organizations of all sizes. However, it's impact has been most severe for SMEs. SMEs lack in the resources, availability of financing, and other means to survive until conditions stabilize from the pandemic over the last few years. The fear was that many of these SMEs would not be able to survive (Kalemli-Ozcan et al, 2020). Researchers (Bartik et al. 2020) in March 2020 surveyed 5,800 U.S. SMEs exploring the impact of COVID-19 on their organizations. Their results highlighted the financial fragility of many of the businesses. In fact, 2/3 of those surveyed had only enough cash to last 2 months. The researchers estimated that if the crisis would last 4 months, 32.7 million jobs would be lost. And if the crisis extended to 6 months, the job losses would climb to 35.1 million. In Canada the impact of COVID-19 on unemployment was dramatic. Seasonally adjusted unemployment as of May 2019 was 5.4%, as of May 2020 the unemployment rate was 13.7% (Statistics Canada, 2022).

SMEs represent a primary component of the global economy. In the U. S., the Small Business Administration (SBA) explains "Small firms (500 or less) accounted for 9.3 million net new private-sector jobs from 2005 to 2019, or 64 percent of the total jobs created" (U.S. Small Business 2020). The SBA Office of Advocacy's latest report explains in the U.S. SMEs employ

58.9 million people or 47.5% of the private workforce, create the greatest number of new jobs annually, and account for over 44% of the U.S. total economic activity (U.S. Small Business 2018). The European markets were one of the first to acknowledge that SMEs were in crisis as a result of the COVID-19 pandemic. In Europe 24 million SMEs represent 99.8% of total enterprises (250 or less employees), and employ 95 million people. These European SMEs contribute 60% of the overall economy (SMEunited2024 2019). In Canada, the seasonally adjusted unemployment was 5.4% in May 2019, after the COVID-19 crisis, the unemployment in May 2020 rose to 13.7%. SMEunited in 2019 published for the European Commission for SMEs a long-term EU SME Strategy with a clear vision for 2030 (SME2024 2019). But although this was report was timely, everything changed with the outbreak of the COVID-19 pandemic. The timetable for implementation was dramatically fast forwarded. As a result, SMEunited (2020) submitted a revised proposal to the European Commission for SMEs explaining that the COVID-19 had an "unprecedented impact on SMEs" across Europe. These SMEs are fighting "for their survival and fear the future of their company and their employees". One of the major program priorities related to DTs and its need for immediate consideration.

Globally short-term financial packages, subsidies, or even grants have rolled out focused as "stop gap" measures for SMEs to weather the COVID-19 crisis. The U. S. Congress provided life support with the Coronavirus Aid, Relief, and Economic Security (CARES) Act, a $2.2 trillion spending program in March 2020. SMEs ultimately received $649 billion to cover payroll, rent, utilities, and other obligations (De Rugy, 2020). The Canadian government offered a Canada Emergency Wage Subsidy (CEWS) to qualified small businesses, at a no-interest, and also a deferral of income tax payments (Canada, 2020). The European Commission has acknowledged that the SMEs need security, financial support, and practical support. Their plan is to do this through loans, guarantees, support for private capital investment, and government advisory assistance. The financial instruments offered by the European Commission for SMEs are focused on recovery and growth from COVID-19 and require a commitment to "digital transition".

The SMEunited Social Affairs and Training Policy Director Liliane Volozinskis in their address to the European Alliance for Apprenticeships in July 2020 explained that post COVID-19 embedded digital skills for apprenticeships "now become the rule and not the exception". Volozinskis further offered that SMEunited's apprenticeship's curricula thanks to the European Alliance's financial support was prepared to provide apprentices those unique skills for digital technologies. Days later SMEunited urged genuine partnerships between membership countries, SMEunited, and the impacted SMEs. These partnerships would contribute to overcoming communication problems, promote the exchange of good practices at all levels including European, national, and regional levels (Porganyi 2020). By October, the European SME Business climate continues an unprecedented drop caused by the COVID-19 crisis. Gerhard Huemer, EU SME Economic Policy Director in his presentation explained that for recovery support measures should focus on innovation and the transition to a digital and greener economy (SMEunited2020). Working together was a vital strategy for a recovery by EU SMEs.

Impact of DTs post COVID-19 on SMEs

Bernd Schmitt (2019) explains that just as the Industrial Revolution resulted in technology-driven economic transformation; we are now seeing another major transformation to DTs. These DTs are dramatically changing and adding value to the consumers buying experiences. Schmitt states that DTs offer a rich new research agenda for the future as the next phase of the digital transformation occurs. He further states that DTs require new methodologies for analyzing digital content. The methodology he proposes is "sentiment analysis" which refers to the use of text mining including natural language processing "to extract consumer attitudes and affective states from digital content".

DTs are expected to continue to drive dramatic innovation in the future. Baskerville et. al. (2020) suggests that "digital technologies are now creating and shaping physical reality". They feel there is an ontological reversal where first the digital version is created and then the physical version is created, if needed at all. Research also proposes using both unstructured text and visual data for new deep learning methods (Donghyuk Shin et al. 2020).

In fact, DTs continue to "revolutionize the delivery and consumption of information" across businesses and industries (Shivendu & Zhang 2020). For example, a publisher can now offer content in digital media versus physical products, reducing costs and offering digital-savvy consumers their preferred medium of information. Fernandes et al. (2022) explain that DTs have an enormous impact on entrepreneurs across the world. Just as social media sites such as Google, Facebook, Apple, and others have changed the business world, DTs are expected to have the same impact on future entrepreneurs.

The International Institute of Management Development (IMD) released its 2022 World Digital Competitiveness Ranking (World Digital Competitiveness 2022). IMD feels that digital technologies will be key economic drivers for businesses, governments, and society as a whole, regardless of location. Their rankings help businesses and governments to understand where they can strategically allocate resources are most needed.

But just as DTs offer methods of innovation and cost savings, they too have their challenges. As SMEs offer new DTs based products and services, they must be careful to ensure that the digital technology components create value (Lehmann et. al. 2022). Each venture operates using its own unique business model and just using DTs without added value will not be well-received by their consumers. SMEs function in a global economy. But digital infrastructures are often country specific and do not always work well from country to country. Successful SMEs will carefully review and understand the moderating effects of their DTs as they move from country to country (Shade & Schuhmacher 2021).

George et al. (2021) sees digital entrepreneurship as transforming organizations approach to sustainable development. Traditionally, innovation for sustainable development was done by the State, "now, entrepreneurial start-ups, nonprofit ventures, and incumbent organizations engaging in digital sustainability activities are tackling problems" normally done by governments, NGOs and international agencies. They feel SMEs, through the use of DTs, will develop business models and theories to address problems in sustainable development. SMEs are providing sociological value, but they are doing this with a focus on developing an economic proposition.

In addition to the large-scale social media sites such as Google, Facebook, Instagram, and others, many SMEs are creating self-developed applications (apps). Fan et. al. (2021) suggests this has created dynamic entrepreneurial ecosystems. These "apps" offer great opportunities for cognitive knowledge, although its value may be temporal. The impact of DTs has been destructive across industries. Those SMEs that have embraced DTs in their overall activities have increased their intangible values verses those firms that haven't embraced DTs (Rahmati et. al. 2021).

Straková et al. (2022) concluded while there were great DTs opportunities for SMEs in the future, there were challenges to maintain the balance "between main value-creating processes and supporting processes". Where many SMEs used DTs post COVID-19 for survival, supporting DTs business models must be developed to ensure profitability and competitiveness. The DTs process has certainly had a dramatic impact on SMEs, but in the short-term there may be a period of slow advancement until DTs business models are developed.

Vavura (2022) is concerned about the existing gap in the digitalization of SMEs between the European Union and the United States. From their perspective, SMEs in the United States were more prepared for the digital economy. In March 2021 the committee on Industry, Research and Energy (ITRE) commissioned a study (Codagnone et al. 2021) on "Europe's digital decade and autonomy". The purpose of this study was to establish a successful digital transformation of Europe by 2030. Based on the conclusions and recommendations from this study, the European Commission will begin legislation and other initiatives to provide educational and financial support for the advancement of digital technologies in SMEs in Europe.

There has been a dramatic growth in the use of DTs (social networking platforms Facebook, Instagram, etc.) among buyers and sellers across international markets (He Huang et al. 2022). He Huang et al. (2021) reflect that "sales from products sold through social networks are projected to reach $36.09 billion in 2021, up roughly 35% from 2020, and the number of U.S. consumers buying through social networks will grow by 12.9% to 90.4 million in 2021 from 80.1 million in 2020". With the acceptance of doing business online, SMEs are now using social media and search engines to drive down their costs for advertising and promotion. But some major social retailers such as Amazon have opened their platforms to 3rd party sellers (Chen & Guo, 2022). The 3rd party sellers get exposure to Amazon's 208 million unique monthly visitors while Amazon gets a commission on each product sold. In some cases, Amazon offered the same products as the 3rd party sellers. But sometimes Amazon and the 3rd party seller are selling the same products and Amazon is both selling and getting commissions on both. Future trends show many SMEs using social media platforms will sell directly to their customers, by passing traditional advertising and arrangements with others like Amazon (Barnhart 2022).

Concluding Thoughts

Others too have questioned the direction of strategic management research. Drnevich et al. (2020) suggest a refocusing of management research "based on the logic of discovery of real-world phenomena and strategic problems". The question becomes whether longitudinal research studies will produce the seminal works and business models necessary to deal with a digital

technology driven world. Can SMEs take advantage of the opportunities available in DTs, while waiting for academic researchers to create models and theories to support their efforts?

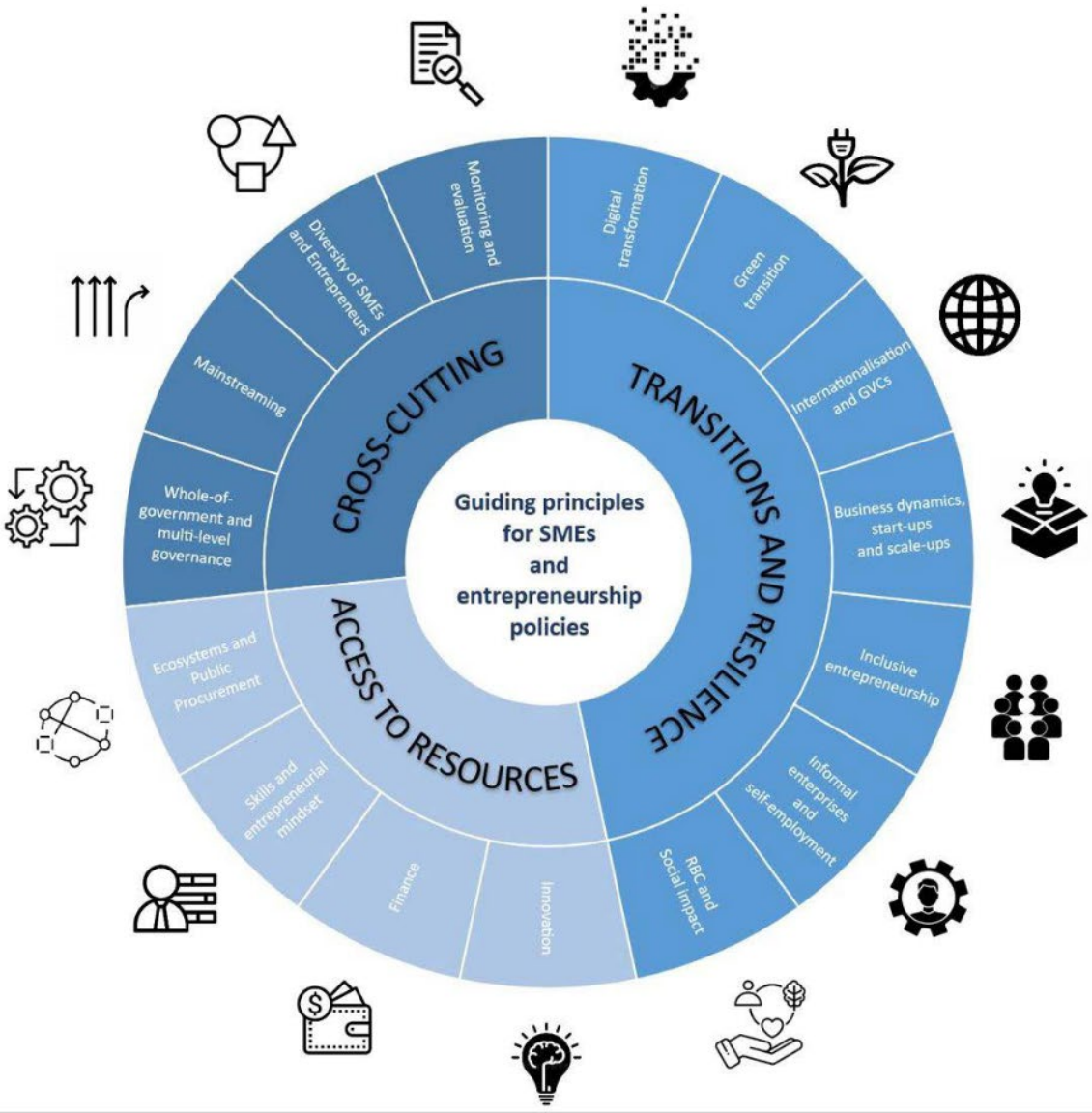
It is expected that DT driven business models for SMEs will become pervasive and can be expected to drive disruption of existing legacy and operational models. They will continue to spur innovation and disconcert existing business models (Khurana et al. 2022, Silva et al. 2022). Empirical research by others (Rupeika-Apoga et al. 2022) recognize that in the digital transformation for some SMEs there is a "knowledge gap" that exists and offers great opportunities for research. This lack of focus by academic researchers offers a great opportunity for the development of new digital technology theories (Xin et al. 2022).

In June 2022, the Organization for Economic Co-operation and Development (OECD) outlined principles for effective, efficient and coherent SME and entrepreneurship policies (OECD 2022). The OECD is an international organization that offers advice on public polices to SMEs to "better prepare the world of tomorrow". From their perspective, "SMEs and entrepreneurs constitute the backbone of economies in OECD countries and beyond". Recognizing the challenges that SMEs and entrepreneurships face post COVID-19, they have released the "OECD SME and Entrepreneurship Strategy" (See Table 1). A core component of this report is the need for Digital Transformation by SMEs and entrepreneurs. In their opinion, this digital transformation is necessary to ensuring open and well-functioning markets across global economies. The OECD's latest offering highlights their acknowledgement of the role of SMEs in the global economy and digitalization's place in it.

In dire straits during and after the COVID-19 pandemic, DTs offered a lifeline to SMEs. The lessons they learned using DTs to survive will continue to drive their organizations into the future. The traditional business models for every SME, regardless of industry, have been transformed by the COVID-19 pandemic. Whether it is for marketing, operations, manufacturing, or any other activity, new technology innovations continue to offer alternate ways of doing business. For those SMEs operating in the global environment, they will use DTs to sell, produce, and collaborate with others worldwide.

For academic researchers, DTs and their impact on SMEs are underexamined, demand numerous new and novel theories, and will offer a rich research stream for academicians across all disciplines for years to come.

Table 1
OECD SME and Entrepreneurship Strategy



Source: https://www.oecd.org/cfe/smes/Guiding-principles--SMEs.pdf

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USING PHENOMENOLOGICAL INQUIRY TO UNDERSTAND STAKEHOLDER MANAGEMENT SUCCESS CRITERIA ON PROJECTS

Valerie P. Denney, Embry-Riddle Aeronautical University
Daryl V. Watkins, Embry-Riddle Aeronautical University

ABSTRACT

This study employs phenomenological inquiry to investigate success criteria for stakeholder management on projects and explores the gaps in the characteristics of stakeholder relationship management success between literature, practice standards, and practitioners. The literature review highlights the importance of stakeholder value, successful stakeholder management dimensions, project manager competencies, and the business case for managing stakeholders. The methodology employed open-ended questions to experienced project managers with a minimum of five years of experience. Phenomenology principles were applied to ensure a deeper understanding of the state of the practice in project management. Two research questions were examined: (1) What constitutes successful stakeholder management? and (2) What is the cost (or Return on Investment [ROI]) of managing stakeholders?

Data were collected through a survey, with responses analyzed to identify key themes. For research question 1, three themes emerged: (1) simultaneous focus on the present and future, (2) effective communication, and (3) being on the same page, resulting in delivering expectations. The first theme highlighted the need for continuous review of success from the customer's perspective, while the second emphasized the importance of regular, consistent, and proactive communication. The third theme underscored the importance of efficiency in decision-making to meet stakeholder expectations. A notable definition of success was "a sale at a mutually satisfactory price, delivery of the promised service/product, and satisfied stakeholders who offer positive feedback."

For research question 2, a single theme was identified: quantifying management costs. Respondents acknowledged that the cost of not managing stakeholders could lead to various negative outcomes, and some provided methods for quantifying the cost of stakeholder management. However, others believed that the costs were difficult or impossible to quantify.

The findings contribute to understanding the gaps between stakeholder management success in practice and the literature. This research provides practical insights to enhance stakeholder management success criteria and improve project outcomes for project, program, and portfolio managers. This study contributes to the literature on stakeholder management by highlighting the importance of simultaneously focusing on the present and future, effective communication, and efficient decision-making. Further research is needed to explore the practical implications of these findings and to develop robust methods for quantifying

stakeholder management costs and understanding the relationship between these costs and the success of stakeholder management efforts.

Keywords: stakeholder management, success, business case, project management, program management, expectation management

INTRODUCTION

The current business environment is characterized by a complex web of stakeholders, whose interests, needs, and expectations significantly impact the success of projects. Stakeholder management has therefore emerged as a critical aspect of project management. This study employs phenomenological inquiry to understand the success criteria for stakeholder management on projects, bridging the gap between the theoretical literature and the practical experiences of project managers.

The original concept of stakeholder theory, credited to Freeman (1984, 2015), broadened the perspective of corporate responsibilities beyond the maximization of shareholder value (Friedman, 1970), to encompass a wider range of participants, including shareholders, customers, suppliers, and employees. Despite the extensive literature on stakeholder management, a gap exists in understanding the characteristics of successful stakeholder relationship management from the practitioners' perspective. This study aims to address this gap by exploring two primary research questions: What constitutes successful stakeholder management, and what is the cost or Return on Investment (ROI) of managing stakeholders?

A review of the existing literature highlights that there is no single, universally accepted method of measuring stakeholder management success. The success dimensions identified include effective communication, time management, the identification and agreement on objectives and mission, project manager competencies, the delivery of strategic benefits, and stakeholder satisfaction. The business case for stakeholder management extends beyond project outcomes, with improved decision-making, increased efficiency, better risk management, and enhanced relationships identified as key benefits. However, the practical implementation of these dimensions and benefits often faces challenges, particularly in balancing conflicting needs and expectations.

Drawing from the lived experiences of seasoned project managers, this study identifies key themes for successful stakeholder management. These include a simultaneous focus on the present and future, effective communication, and efficiency in decision-making. The study also acknowledges the challenge of quantifying stakeholder management costs, with some practitioners asserting that such costs are difficult or impossible to quantify.

This study contributes to the existing literature by providing practical insights that can enhance stakeholder management success criteria and improve project outcomes. Furthermore, it underscores the need for further research to develop robust methods for quantifying stakeholder management costs and understanding their relationship with the success of stakeholder management efforts.

This paper continues with a description of the methodology employed in the study, followed by the presentation of findings, discussion, and conclusions. Through this, it aims to provide a comprehensive understanding of stakeholder management success criteria, bridging the gap between theory and practice.

LITERATURE REVIEW

Overview

The Project Management Institute (PMI) reported that projects with effective stakeholder management are more likely to be completed on time, within budget, and with higher levels of customer satisfaction (PMI, 2017). Berman et al. (2019) identified four seminal works written between 1984 and 1997 (Donaldson & Preston, 1995; Freeman, 1984, 2015; Jones, 1995; Mitchell et al., 1997), which provide the foundational concepts of stakeholder theory. The key concept of stakeholder value is central to stakeholder theory, with organizations creating value through net gains or losses experienced by stakeholders. This value encompasses tangible elements such as financial returns and overall performance (Donaldson & Preston, 1995), as well as intangible aspects like reputation (Kowalczyk & Kuckarska, 2020), quality (Waters & Ahmed, 2020), and social and environmental impact (Gurmu, et al, 2022; Uribe, et al, 2018).

The Measures of Successful Stakeholder Management

There is no universally accepted method of measuring the success of stakeholder management (Davis, 2016; 2017). Rather, there are numerous means of gauging successful stakeholder management, or its opposite, stakeholder mismanagement. The dimensions of stakeholder management success include communication, time, identifying and agreeing on objectives and mission, project manager competencies and focus, delivery of strategic benefits, top management support, stakeholder satisfaction, acceptance of the product, and adherence to cost and budget (Davis, 2016; 2017). Successful projects are those that are completed on time and within budget, engage diverse groups of stakeholders throughout the project lifecycle, and ultimately deliver high levels of satisfaction to stakeholders.

The Business Case for Managing Stakeholders

The business case for stakeholder management is closely tied to achieving project outcomes and business goals. This is accomplished by ensuring that project managers consider and address the needs and expectations of all stakeholders. By engaging stakeholders early and regularly, project managers can better understand their needs and expectations, and make changes to the project plan to address stakeholder considerations. Those actions can lead to improved project outcomes, such as increased buy-in, reduced resistance, and increased likelihood of project success (PMI, 2017).

In addition to project outcomes, several other benefits arise from effective stakeholder management. Involving stakeholders in the decision-making process leads to better-informed choices that consider the needs and perspectives of all parties (Martunnen et al., 2015). Clear communication of project goals, timelines, and expectations reduces misunderstandings and minimizes the need for rework, thus increasing operational efficiency (Alqaisi et al., 2018). Further, the quality of relationships with stakeholders is enhanced, resulting in improved trust

and greater collaboration in future projects (Cleland & Gareis, 2006). Lastly, comprehensive stakeholder engagement improves risk management by enabling project managers to identify and mitigate potential risks early on (PMI, 2017).

Balancing Conflicting Needs and Expectations

Orts and Strudler (2002) emphasized the importance of taking a holistic and ethical approach to management. They suggested that organizations can benefit from considering the needs and interests of a wide range of stakeholders to create long-term value. This framework was further developed by Orts and Strudler (2009) to provide practical applications for organizations to balance stakeholder needs, especially around ethical and environmental concerns. The authors argued that overly broad definitions of stakeholder extend the range of moral and ethical considerations to the point of limiting the usefulness of stakeholder theory.

Eisenhardt and Martin (2000) argued that, to remain competitive and achieve long-term success, organizations must identify and respond to changes in the business environment such as shifting stakeholder interests and expectations. Developing such a dynamic capability enables organizations to sense environmental changes and manage conflicts more effectively.

The Role of Interpersonal Skills in Stakeholder Management

Bourne (2016) contended that the success of a project is intricately linked to the quality of stakeholder relationships, which are often shaped by planned and ad hoc communication. Stakeholder mapping helps leaders identify and categorize stakeholders based on their influence, interest, and impact, allowing for more targeted engagement strategies. They further identified a range of competencies that project leaders should possess, such as active listening, adaptability, empathy, and clear communication. These competencies facilitate collaboration, influence, and transparency, all of which are critical for project success.

The literature elaborates on these competencies in depth. Active listening allows leaders to understand stakeholder needs and preempt issues by asking relevant questions (Pinto & Slevin, 2017). Adaptability and flexibility are essential for adjusting to changing stakeholder expectations (Baugh, 2015). Empathy aids in relationship building and conflict management (Nartey et al., 2023), while engagement fosters participation and commitment to the project (Achterkamp & Vos, 2008). Clear channels of communication ensure mutual understanding of project goals and facilitate information exchange (PMI, 2017). A collaborative environment encourages stakeholders to interact and solve problems together (Baugh, 2015). Leaders also need to develop the ability to influence stakeholders across all levels (PMI, 2017). Transparency in communication cultivates trust (Mantel et al., 2011).

Addressing Conflicts and Risks in Stakeholder Management

Conflicting interests, risks, and problems need to be addressed in complex projects. Project leaders must establish clear roles, responsibilities, and expectations for stakeholders; set up systems for tracking and reporting progress; and expeditiously address issues (Baugh, 2015; Beam et al., 2023). Project leaders can use facilitated decision-making processes, such as consensus-building or multi-voting, to resolve conflicts transparently.

Frame (2003) recommended that project leaders methodically analyze key factors such as the nature of the conflict, the interests and priorities of the parties involved, power dynamics, time constraints, and available resources before selecting an appropriate conflict resolution strategy (e.g., competing, collaborating, compromising, avoiding, and accommodating). Elements such as the root cause and type of conflict may help determine the most suitable approach. For example, misunderstandings can sometimes be resolved through communication and collaboration, while conflicting goals might resolve using a competitive strategy. An understanding of stakeholder interests, priorities, and power differentials can inform the selection of a strategy that is most likely to meet all parties' needs and reflects the reality of power dynamics. Conflicts involving unequal power dynamics may be better resolved through accommodation or compromise, while conflicts between parties with more balanced power dynamics may lend themselves to collaboration or competition. Time constraints might force quicker resolution strategies such as compromise or avoidance. Finally, the availability of resources, including time, money, and personnel, might force project leaders to select a specific strategy. More recent articles on stakeholder conflict provide additional guidance (Yu et al, 2019; Zarewa, 2019).

In conclusion, the literature review suggests that successful stakeholder management is a complex process that requires a balance of technical and interpersonal skills. It is also clear that there is a need for more research to develop practical tools and frameworks to support project leaders in managing stakeholders effectively.

Critical Analysis of the Literature

The literature on stakeholder management provides valuable insights into the importance of stakeholder management in project success. However, it also reveals some gaps and limitations. The literature strongly emphasizes the importance of effective stakeholder management for project success, providing a strong theoretical foundation for the field. The focus on both tangible and intangible values is a significant strength, as it acknowledges the multi-dimensional nature of stakeholder value. The literature also provides a comprehensive list of skills necessary for effective stakeholder management, which can be useful for project managers.

Despite the strengths, the literature also has several weaknesses. One major weakness is the lack of a universally accepted method for measuring stakeholder management success. This lack of consensus can lead to confusion and inconsistency in practice. The literature also seems to lack practical tools and frameworks that project managers can use to manage stakeholders effectively. While the literature provides a list of necessary skills, it does not provide clear guidance on how to develop these skills or apply them in practice. So, while the literature on stakeholder management provides valuable insights, there is a need for more research to address its limitations.

METHODOLOGY

Research Design

This study deploys qualitative inquiry (Creswell & Creswell, 2018) to investigate stakeholder management in project management settings. Specifically, it gathers insights through open-ended questions from seasoned project managers and compares these with current literature.

Conceptual Framework

Guided by interpretivism, this study captures subjective experiences in stakeholder management. We chose phenomenology as our qualitative approach given its recurring use in project management literature (Denney, 2020; Hlalele, 2019; Kadangwe & Emuze, 2017, Müller, & Jedličková, 2020; Prakash & Ambekar, 2020; Rolfe, et al, 2017). and its suitability for this research (Butler-Kisber, 2018). This methodology allows us to dive into the lived experiences of project managers, offering a real-world lens on the topic.

Variables Explored

In conventional quantitative studies, variables are pre-defined and quantified. However, in the phenomenological paradigm in qualitative research, themes and patterns naturally arise from the data, instead of the constraints of predefined variables. This study identifies emergent themes:

1. Successful Stakeholder Management: Key elements as defined by professionals in the field.
2. Stakeholder Management Cost & Value: A focus on resource allocation and return on investment.
3. Stakeholder Engagement Challenges: Identification of barriers in stakeholder interactions.
4. Balancing Conflicting Needs: Strategies used by project managers to handle conflicting stakeholder expectations.

Sampling and Sampling Method

We employed purposive sampling (Creswell & Creswell, 2018) to select experienced project managers with at least five years in the field, aligning with criteria used in existing research (Denney, 2020; International Project Management Association (n.d.), PMI, 2022); Wai & Rindermann, 2017). Two phases of participant selection yielded 71 qualified respondents. Data were collected in two cycles, 2017-2018 and 2021-2022, to provide a more comprehensive view.

Scope and Delimitations

The research is U.S.-focused, given the recruitment methods used. A majority of respondents work in government contracting, IT, construction, or manufacturing, although the study was not industry specific. 42% of the respondents identified as female and 58% as male. The average number of years of experience is as follows: for program managers (17 years),

project management (14), other project management functions (12) and project management support (8 years).

Data Collection

Open-ended electronic questionnaires facilitated in-depth responses from participants, allowing us to better understand their perspectives.

The questionnaire was submitted electronically, which allowed the respondents adequate time to craft and answer instead of being pressured during a face-to-face interview (Kvale & Brinkmann, 2015). Each respondent was asked to write approximately 500-700 words per question to enable the researchers to understand their context and perspective.

A copy of the questionnaire is shown in table 1.

Table 1
RESEARCH QUESTIONAIRE

Welcome to our Study on Stakeholder Management in Project and Program Management
Instructions: (described below)
Q1. SUCCESSFUL STAKEHOLDER MANAGEMENT- Describe what is necessary to achieve successful stakeholder relationship management on a project? Use as many adjectives or descriptive phrases as you like.
Q2. STAKEHOLDER MANAGEMENT COST- How do you quantify the cost of stakeholder relationship management? Essentially, what is the business case for spending time and money on stakeholder management? As part of the business case, describe how quantified (or propose to quantity) the value or impact to the project of spending money on stakeholder management? How do you think it can be measured?
Q3. STAKEHOLDER ENGAGEMENT ISSUES- There are two parts to this question: …(a) What barriers to communication have you seen with specific stakeholders? Examples are extremely helpful with sufficient context to help with interpretation of meaning. …(b) To what extent have you dealt with difficult stakeholders including ambivalent, unreceptive, or unsupportive? Please provide as many examples as you can describing the situation, and how it was resolved.
Q4. BALANCING CONFLICTING NEEDS AND EXPECTATIONS- Think of at least one situation where there were conflicting needs and expectations among the stakeholders. Describe each situation and the thought process for resolution.

Participant instructions included the following:

> *For these questions, the term stakeholder relationship management (or stakeholder management, for short) includes the entire process of identifying, prioritizing, engaging, and monitoring stakeholders.*
>
> *There are no set or standard or expected answers. This is not a "check the box" or "select the best answer" exercise. The more you write and provide context, the more it will help us in understanding your thought process as an experienced professional and add a practical dimension to the myriad of theoretical research. We are looking for your experience-- including what has worked and what hasn't related to stakeholder engagement and why you perceive it that way….*

Data Analysis

Inductive coding was employed to analyze the text for emerging themes and patterns, in line with the qualitative nature of this research (Emerson, et al., 2011).

Validity and Reliability

The study achieves validity and reliability by acknowledging and embracing subjectivity. Phenomenology, as an approach, ensures consistency, credibility, and authenticity in capturing human experiences. Validity was achieved by rigorously capturing participants' lived experiences and perspectives by directly capturing participant reflections. The reliability of the study is enhanced by the detailed documentation of the research process, allowing for replicability and consistency in data analysis.

Ethical Considerations

Ethical approval was obtained from our university's IRB, ensuring compliance with federal regulations. Participants signed We secured informed consent from participants, safeguarded their privacy, and upheld strict confidentiality measures. Our transparent communication about the study's purpose and potential impact ensured the participants' well-being and rights were respected throughout the research process.

FINDINGS

The research question is what are the gaps in the characteristics of stakeholder relationship management success between what is reported in the literature, practice standards, and practitioners? As previously described, this contains two specific research questions. The findings are organized along the research questions. Verbatim (in vivo) phrases are shown by quotations.

Research question 1 (RQ1): What constitutes successful stakeholder management?

This question was answered using the responses to survey question 1 (Successful Stakeholder Management) , question 3 (Stakeholder Engagement Issues), and question 4 (Balancing Conflicting Needs and Expectations) described on table 1. In this research question, respondents were asked to identify elements which are necessary for success. Three themes emerged including a simultaneous focus on present as well as the future, regular/ consistent communication and being on the same page results in delivering to expectations. A summary of the findings for RQ1 is found on table 2.

To summarize, one of the best definitions is that success is…*"a sale at a mutually satisfactory price, delivery of the promised service/product and satisfied stakeholders who offer positive feedback."*

Research question 2 (RQ2): What is the cost (or Return on Investment [ROI]) of managing stakeholders?

This question was answered using the responses to survey question 2 (Stakeholder Management Cost). In this research question, respondents were asked to address the cost of

not managing stakeholders which can lead to dissatisfied customers, late deliveries, and lack of return business to name a few. Respondents were asked how they quantify the cost of stakeholder relationship management. Essentially, this question is about the business case for spending time and money on stakeholder management. Only a single theme emerged: quantifying management costs. A summary of the findings for RQ2 is found on table 3.

Table 2
SUMMARY OF RQ1 (SUCCESSFUL STAKEHOLDER MANAGEMENT) FINDINGS

Theme	**Summary [n=96]**	**Key Responses [in vivo in italics]**
Simultaneous focus on present as well as the future	Continuous	*Success means meeting customer expectations on time and budget, and continuation of customer business and relationship*
		At every stage gate (milestone), the next phase needs to be reviewed and deliverables highlighted
	Future Benefits	*Continuation of customer business and relationship*
		Ability to *build your credibility*
		Ability to *build your brand*
Communication	Regular	*...to ensure stakeholders are engaged and support your project*
		Results in efficiencies to i*dentify... stakeholder needs/wants; adapt services/products to the need; assess the value/price relationship; market/promote/sell the service; deliver the promised service; evaluate the entire effort; follow-up with stakeholders.*
		Need socialization and engagement to gain support, buy-in and approval of the project
		Failure in regular communication will result in need for critical communication, often one-on-one in order to resolve misunderstandings and to placate upset stakeholders.
	Consistent	*Providing a brief, succinct status in a consistent agenda style ... helps to keep everyone focused*
	Proactive	*Solicit thoughts and expertise on the move forward plan*
		Allow the rest of the organization to read the comments to provide perspective for their stakeholder engagement.
		Client lets you know of a coming project.
		Client calls you out of the blue for advice
		Requires anticipation and knowledge of the customer's buying habits and needs
	Appreciation	*Verbalizing and showing appreciation for their involvement.*
	Barriers are Multi-Dimensional	*Barriers are distance ---geographical and cultural.*
		Time including limited availability or accessibility
		Priority of other projects or stakeholders, special interest groups or gatekeepers who block your access
		Experience levels
		Legal or regulatory barriers including cut-off direct communication except through contracts negotiators.
		Jaded customers [because] *we only talked to them when there was a competition.*

		Difficult people, strained relationships; egotistic or headstrong people.
		Personal bias or negative attitude toward contractors; egotistic or headstrong people.
Being on the same page results in delivering to expectations	Efficient Decisions and Problem Resolution	*Key resource might not be assigned or could be taken away [because they] do not have an accurate idea of true status and the plans for closure.*
		Decisions made do not have to keep being re-made
		Efficient testing and the acceptance into the field.
		Improved risk identification, requirements definition, and schedule management...which will have direct impact on quality deliverables.
		Enhancing "one team" approach and attitude working toward the common goal.
		Should exploit common grounds, if any, setting aside differences.
		Will avoid ... deviation from set goals and standards.
	Intangibles	*You basically win their hearts and minds*
		Become a "value-added" resource for the stakeholder

Table 3
SUMMARY OF RQ2 (RETURN ON INVESTMENT) FINDINGS

Theme	**Summary [n=61]**	**Key Responses [in vivo in italics]**
Quantifying management costs	Obvious and self-evident	*Business case for stakeholder management writes itself.*
		Easier to quantify during the pursuit of a new business opportunity; more difficult to quantify during project execution -
	Yes-quantifiable	*Difference between the P(win) of doing it - P(win) of not doing it*
		Ratio of dollars won to dollars at stake.
		Value of meeting the needs of the organization and expectations of stakeholders
		Value of meeting the delivery deadline within budget
		Collect data on what was learned and used via the Stakeholder Meetings
		Measured by soft ROI of saving resources (cost avoidance)
		Measured from zero defects
	Only when not working well	*Easier to measure when it* [stakeholder management] *is not working well since not managing stakeholder can be costly.*
		Only quantifiable if lessons learned concludes that a major factor in the loss or win was poor stakeholder management
		Measured from quality delivery non-conformance
		Measurable if you have penalty clauses.
		Regulatory fines
		Only quantifiable if the project is abandoned and the project is implemented and paid for in phases meaning that future phases are halted
		Project hours and wage earnings can be calculated for rework and for projects that exceed the established timelines.
		Quantify in terms of business loss for the down time ... due to stakeholder mismanagement
	Not quantifiable	*Substantially difficult; not quantifiable*
		[Lesson learned approach used to] *interview key participants in the program pursuit/renewal process ...with the intent of determining: Why Did We Win/Lose?*

		Risks of not meeting stakeholder expectations should be logged and monitored through the risk management process of each project.
		Bad reputation costs how much? ---- this is a significant factor
		Money which is spent on stakeholder management is already an element of the project funding and can't be separated out.

DISCUSSION

As previously described, this research contains two specific research questions. The discussion is organized along with the research questions.

RQ1: What constitutes successful stakeholder management?

Findings for this research question resulted in three themes: (1) simultaneous focus on now and the future, (2) effective communication, and (3) being on the same page resulting in delivering the expectations. Consistently, respondents said that the key to success is a repeatable process, training for the stakeholder management team, holding the team accountable for a consistent application, and performing a post decision analysis of the effectiveness and needed improvement of the plan.

Theme 1: Simultaneous Focus on Now and the Future. Respondents described the need to not only focus on success with the current project or operations, but also into the future. The emphasis was on a continuous review of the meaning of success from the perspective of the customer. It is noted that the emphasis here was on the customer, rather than on the myriad of other stakeholders. Respondents noted a variety of future benefits including intangible elements of trust, credibility, reputation, and brand recognition. The key was an emphasis on continuous data gathering and action.

One of the best responses to what constitutes success was expressed as *"success means meeting customer expectations on time and budget, and continuation of customer business and relationship".* While this is rather broad, it explains this simultaneously focus quite well.

This theme does not appear in the literature to any great extent. As in the literature review, Cleland and Gareis (2006) discussed how effective stakeholder management can help build trust and improve relationships with stakeholders, leading to increased collaboration and support for future projects. More recently, Gemünden, et al. (2018) conceptualized project entities as entrepreneurial and future stakeholder-oriented innovating organizations. However, neither source emphasizes the simultaneous focus on now and the future, making this finding a possible gap in the literature.

Theme 2: Communication. Respondents described the importance of effective communication as the primary element of stakeholder success. This included having regular, consistent, and proactive communication. Of particular interest is how respondents gave specific examples of proactive customer/client behavior including soliciting input before moving on and requiring anticipation and knowledge of the customer buying behavior. Respondents also

provided specific ways to measure this success. This includes documenting that a "*client lets you know of a coming project* and when a *client calls you out of the blue for advice".* Those statements capture the essence of measurable proactive engagement.

Only one respondent commented on the need to express appreciation, however, there are several recent academic sources which discuss this concept (Morency et al, 2020; Pucher et al., 2017; Zhou, 2014).

It is noteworthy of the specific multi-dimensional barriers to communication which were identified. These included geographical, cultural, time, priority, experience levels, legal, personal biases, and personal conflicts. This finding is consistent with the broad array of literature on this topic (for example, Bourne & Walker, 2005; Davis, 2016, 2017; Mantel & Meredith, 2011; Pinto & Slevin, 2017).

Theme 3: Being on the Same Page Resulting in Delivering the Expectations. Respondents primarily focused on efficiency in decision-making so that "*decisions do not have to keep being re-made."* From the respondents, it is unclear if this economic focus is a result of the effective communications, or a factor in achieving effective communications. However, none of the respondents provided tangible ways to measure the financial results of efficient decision making with intangibles noted include "*win*[ning] *their hearts and minds* and *becom*[ing] *a "value-added" resource*". Efficient decision making in stakeholder engagement is well covered by several recent sources (Alqaisi et al., 2018; Lin et al, 2017; and Tarode & Shrivastava, 2022).

RQ2: What is the cost (or Return on Investment [ROI]) of managing stakeholders?

This question is narrowly focused and only has one theme: the degree to which one can quantify management costs. A few respondents commented that the answer is obvious and self-evident, such as the *"business case for stakeholder management writes itself"*, but without any specifics on how to do this or why it is self-evident.

A small number of the respondents attempted to quantify the cost by measuring the cost of the value proposition to include dollars won vs. dollars at stake, cost avoidance by not having to rework products, and zero defects. Others identified necessary data collection to include lessons learned during stakeholder meetings, but the precise calculation is unclear.

Most respondents focused only on quantifiable costs only when the project or program was cancelled, at risk or generally not going well. This includes a variety of "unsuccessful" costs, including the cost of not being on the ground floor, penalties, fines, project abandonment, loss of sales, and defect analysis. For example, the cost is measured as the "*relationship between failure to win new or follow-on business as a result of poor stakeholder management*," and the cost of "*poor or no stakeholder management is the value of reputation*." This focus on quantifying the negative impact is similar to that found in measurement of the value an ethics program (Denney, 2018). Clearly, most respondents agree that it is easier to measure the cost of stakeholder management when it is not working well. There are only a few recent articles with a goal of measuring successful stakeholder management on a healthy (such as Davis, 2017 and Li et al, 2013) there is little evidence of how to specifically measure the value. Additionally, a few,

such as Arafat, (2020) and Robu and Lazar (2021) discuss ROI, but with focus only on time savings, not the broader topic of investments vs. return.

Although the cost of stakeholder management was identified as challenging to quantify, the ROI of stakeholder management presents an area for more extensive exploration. ROI could be measured not only in terms of financial gains but also in the context of improved project outcomes, enhanced stakeholder relationships, and better risk management. For instance, effective stakeholder management could lead to a more streamlined decision-making process, resulting in cost savings. Further, enhanced stakeholder relationships can lead to increased opportunities for collaboration, potentially leading to new projects and revenue streams. Similarly, better risk management as a result of effective stakeholder management could prevent costly project delays or failures. Therefore, it is imperative to develop a multi-dimensional approach to measure the ROI of stakeholder management, which considers both tangible and intangible returns.

CONCLUSIONS

In conclusion, this phenomenological study investigated the success criteria for stakeholder management on projects and explored the gaps in the characteristics of stakeholder relationship management success between literature, practice standards, and practitioners. The research identified three themes for successful stakeholder management: (1) simultaneous focus on the present and future, (2) effective communication, and (3) being on the same page, resulting in delivering expectations. These themes emphasize the importance of continuous review of success from the customer's perspective, regular and consistent communication, and efficient decision-making.

In terms of quantifying the cost (or ROI) of managing stakeholders, the study found that respondents could more readily measure the cost of stakeholder management when it was not working well, rather than when it was successful. This indicates a need for further research to develop robust methods for quantifying stakeholder management costs and understanding the relationship between these costs and the success of stakeholder management efforts.

The findings of this study contribute to the literature by identifying a possible gap regarding the simultaneous focus on the present and future in stakeholder management. Additionally, the research provides practical insights for project, program, and portfolio managers to enhance stakeholder management success criteria and improve project outcomes.

Further research is necessary to explore the practical implications of these findings and develop robust methods for quantifying stakeholder management costs. Moreover, future research could investigate how to measure the value of successful stakeholder management and delve deeper into the ROI of stakeholder management efforts, considering not only time savings but also the broader topic of investments vs. return.

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WORK DISTRACTION: EMPLOYER COSTS OF PREVENTABLE JOINT DISORDERS AND IMPLICATIONS FOR BUSINESS

Murat Arik, Middle Tennessee State University
Bronwyn G Graves, Linfield University

ABSTRACT

Presenteeism (or lost productivity due to work distraction) represents a major cost to businesses. One set of painful conditions that leads to presenteeism is temporomandibular joint disorders (TMDs), and this paper measures the per-person six-month cost of work distraction due to TMD symptoms. This study determined that per person over a six-month period, it costs employers an average of $2,649 for women and $2,342 for men for TMD-related work distraction. Findings reveal the effect of painful symptoms greatly outweighs the effect of non-painful symptoms in influencing work distraction. This study finds that the intervention of an effective novel method of treating TMD has important implications for businesses and employers through cost savings due to a reduction in painful TMD symptoms, with per-person savings of $1,775 for women and $1,748 for men. This paper contributes to the literature on pain and work by quantifying productivity costs for those with painful TMD symptoms.

Keywords*: Presenteeism, work distraction, the cost to employers, temporomandibular joint disorders, pain*

INTRODUCTION

Absenteeism and presenteeism are significant problems for businesses incurring high costs, ranging from 20.9 to 22.1% of total employer payroll costs (SHRM, 2014). Effects of illness-based absenteeism and presenteeism can be varied by the type of firm and the type of illness (i.e., acute or chronic) (Pauly et al., 2008), and firms are seeking ways to incorporate appropriate interventions to reduce illness-based absenteeism and presenteeism (Ammendolia et al., 2016).

As chronic conditions of the jaw joint, temporomandibular joint disorders (TMDs) are one set of illnesses causing absenteeism and presenteeism for firms in the United States. Those with a TMD could experience painful symptoms (such as headaches or jaw and neck pain) and non-painful symptoms (such as jaw locking or popping). Women are more likely to report having a TMD, with a U.K. estimate of 81% (Durham et al., 2016b), and an estimated 4.8 percent of adults in the United States (or 11.2 to 12.4 million people) reported pain around the TMJ in 2018 (NASEM, 2020).

Pain and chronic orofacial pain (COFP) as general categories have workplace impacts through absence and work distraction. Much less research exists on the impact of TMD pain or,

even more specifically, TMD symptoms. The impact of pain on work is important as estimates put productivity costs for pain at $61.2 billion a year for common pain categories (Stewart et al., 2003) and about $1 billion a year (Canadian) for dental-related absenteeism (Hayes et al., 2013). A recent study puts the per-worker cost of persistent orofacial pain (POFP) at £1,575 ($2,059 in 2019 U.S. dollars) every six months (Breckons et al., 2018).

This study contributes to the literature on pain and work by creating estimates of work productivity loss specifically for individuals with TMDs, using measures of work distraction and American Community Survey income data. In this study, we answer three main research questions: (1) how are painful or non-painful TMD symptoms driving workplace distraction, (2) what is the cost of productivity (measured by workplace distraction) of having a TMD, and (3) what is the reduction in productivity cost due to TMD intervention? Though TMDs are generally included in studies dealing with work and orofacial pain (e.g., de Magalhães Barros et al., 2009; Lacerda, Traebert, and Zambenedetti, 2008), not all TMD symptoms are painful. This study uses novel survey data to measure how the severities of painful and non-painful TMD symptoms affect work distraction. To the authors' knowledge, this is the first study to measure the work distraction caused by TMDs specifically. Additionally, this study shows that intervention with the novel treatment for TMDs can reduce the lost productivity for employers.

The remainder of the paper presents the following: the literature surrounding the effect of chronic pain, orofacial pain, and dental pain on work; the data and the methodology in this study; and the results and conclusion.

LITERATURE REVIEW

Estimates of the effect of absenteeism and presenteeism can vary across research and by type (e.g., illness-based or family-based) (Shultz et al., 2009). Presenteeism is a more significant portion of the costs of illness than absenteeism (Pauly et al., 2008); therefore, employers and managers should be aware both of the costs of presenteeism for their firms and of the interventions available to reduce pain- and illness-based presenteeism (Ammendolia et al., 2016).

Research on pain and work primarily examines how the most common pain types (such as arthritis, back pain, and headache) affect work performance and absenteeism (Stewart et al., 2003). Stewart et al. (2003) estimate that working with painful conditions cost around $61.2 billion in 2003 (or $90.6 billion in 2021 dollars). Like this paper, prior research distinguishes between work absences due to pain and work distraction due to pain, also known as "presenteeism" (Stewart et al., 2008; Stewart et al., 2003). Other nationally representative studies similarly point to the necessity of measuring the costs of presenteeism for those with painful conditions (chronic pain: Barreto & Sá, 2019; Gaskin and Richard, 2012; van Leeuwen et al., 2006), as those with painful conditions are less likely to miss work and more likely to work while in pain.

Chronic or persistent orofacial pain (COFP or POFP) represents an umbrella term for four painful conditions: "temporomandibular disorder, atypical odontalgia, burning mouth syndrome, and atypical facial pain" (Peters et al., 2015, p. 778). COFP disorders are primarily studied together in terms of costs of treatments and costs to employers (Breckons et al., 2018).

Specific research on TMDs shows that the severity of an individual's TMD is positively correlated with her quality-of-life impact, and the effect on the quality of life for those with TMD pain is comparable to headaches and back pain in terms of affecting life and social costs (de Magalhães Barros et al., 2009). Additionally, individuals with TMDs use 10 to 20 percent more dental services than those without TMDs, accounting for an additional dental procedure a year (Hobson, Huang, and Covell, 2008). Though characterized by painful symptoms, temporomandibular disorders (TMDs) are also associated with mechanical jaw issues and other non-painful symptoms (such as trouble sleeping or earaches) (NASEM, 2020). This paper identifies the impact of painful versus non-painful TMD symptoms and measures the amount of lost productivity for those with TMDs.

A body of literature on orofacial and dental pain shows that pain of those types leads to work absences and presenteeism. Estimates for the effect of dental or orofacial pain on absenteeism range from nine to 27 percent (Lima and Buarque, 2019; Miotto et al., 2014; Lacerda, Traebert, and Zambenedetti, 2008), while estimates for work presenteeism range from 20 to 50 percent (Lima and Buarque, 2019; Miotto et al., 2014). Breckons et al. (2018) confirm using UK DEEP study survey data that the cost to employers of POFP of presenteeism is about four times as high as the cost of absenteeism. These studies reveal that while dental and orofacial health issues do impact employers through workers' absences, individuals with orofacial pain are less likely to miss work than they are to work while distracted by their pain. It is concluded that presenteeism, not absenteeism, makes up the majority of costs for employers of individuals with dental or orofacial pain. The distraction of pain leads to productivity losses and increases the chance of workplace injury (Lacerda, Traebert, and Zambenedetti, 2008).

This study follows the human capital method used in Breckons et al. (2018) to create the measures of indirect employer costs due to presenteeism. Breckons et al. also found that the intensity of POFP, measured by a dichotomized Graded Chronic Pain Scale, could predict both direct and indirect costs.

Table 1 presents the results of the literature dealing with the direct and indirect costs of painful conditions. The research in Table 1 points to the need to quantify productivity losses on an individual and national scale for specific types of painful conditions. While the studies in Table 1 provide point estimates for common painful conditions, dental-related conditions, and orofacial pain, our study focuses more narrowly on the effects of two types of TMD symptoms (painful and non-painful) on work distraction and productivity. Filling this gap in the literature on painful conditions and work is critical for advancing the knowledge in this area of research. To the authors' knowledge, this is the first study to quantify productivity losses due to TMDs. (See Najeddine et al. [2007] for correlates of work productivity losses for those with TMDs.) This study adds to the literature by determining the impacts on work distraction of painful and non-painful TMD symptoms and by providing estimates of the costs of work distraction for those with TMDs. Our results help inform firms' health and productivity management decisions (Shultz et al., 2009).

DATA

Survey

This study uses data attained through surveying a sample of TMD patients who had used a new medical device to relieve TMD symptoms (the Urbanek splint, hereafter U.S.). The Institutional Review Board (IRB) approved the survey of Middle Tennessee State University (request I.D. 21-10122q, approved 8/31/2020, expires 12/31/2021). Of the 844 potential respondents, 359 took the survey (response rate of 44%). After data cleaning and excluding those not employed and those with missing data, 128 (or 15%) remain for use in this study.

Table 1
SELECTED LITERATURE

Authors (Year)	Estimate of Lost Productivity Cost due to Pain	2019 USD[1,2]	Sample	Nationally-Representative	Condition	Other findings
Stewart et al. (2003)	$61.2 billion per year	$84.78 billion per year	American Productivity Audit, n = 28,902	Yes	Common pain conditions (e.g. headache, back pain, arthitis pain, musculoskeletal pain)	76.6% of cost is due to work distraction.
Gaskin and Richard (2012)	$299 to $334 billion in lost productivity	$332 to $371 billion in lost productivity	Medical Expenditure Panel Survey (2008), n = 15,945	Yes	Any type of pain	
Stewart et al. (2008)	1.8 hours a week per person of lost work time (lost productivity)		American Migraine Prevalence and Prevention Study, n = 5,997	Yes	Migraine	
Edmeads and Mackell (2002)	$710 per person per six months	$1,010 per person per six months	National Health and Wellness Study (1998), n = 1,087	Yes	Migraine	Two-thirds of costs of having migraines are due to lost productivity.
Hayes et al. (2013)	$1 billion (Canadian)	$807 million	Canadian Health Measures Survey (2007/2009), n = 5,586	Yes	Dental problems and treatment	
Barreto and Sa (2019)	$6.2 million per year		Brazilian sample of education workers, n = 54	No	Chronic pain	
van Leeuwen et al. (2006)	$5.1 billion (Austrailian)	$4.8 billion	New South Wales Health Survey (1997), n = 17,543 Northern Sydney Area Pain Study, n = 2,092	Yes	Chronic pain	
Breckons et al. (2018)	£1,575 per person per six months	$2059 per person per six months	U.K. Sample, (n = 198)	No	Persistent Orofacial Pain (POFP)	78.9% of cost is due to indirect costs (quality of work) and intensity of pain leads to greater indirect costs.

Note: Author's review of selected literature on pain and lost productivity.

[1]Calculations using BLS CPI Inflation Calculator https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=334&year1=201201&year2=201901

[2]Canadian, Australian, and United Kingdom inflation calculations: https://www.in2013dollars.com/canada/inflation/2013?endYear=2019&amount=1 and https://www.exchangerates.org.uk/

Work Productivity Losses Costs due to Pain

The survey's focus was on the effect of the new medical device, the costs of previous treatments, the reported ease of use, and the reported patient satisfaction with the device. In order to measure the effectiveness of the device, the study used a before-and-after framework, where patients were asked to rate the severity of a list of 19 TMD symptoms in the six months prior to treatment with the device and after using the device. The averages for the painful and non-

painful symptoms were taken separately for the two measures of symptom severity. Respondents were also asked to rate their level of work distraction in the six months prior to treatment with the device on a scale from 0 to 5, where 0 indicates no distraction and 5 indicates severe distraction. The measures of symptom severity and work distraction prior to treatment were used, along with demographic information collected in the survey, to measure the effect of painful and non-painful TMD symptom severity on work distraction. Then, work distraction measures (both before and after) were used to quantify the cost to employers for work distraction for individuals with TMDs.

Table 2 shows that the percentage of women in the data is consistent with the gender composition of those with a TMD found by Durham et al. (2016b). It is also acknowledged that those in the sample may have more severe TMD symptoms than others with TMDs, as the severity of their TMD had prompted them to search to find an orofacial surgery specialist. However, this is tempered by the fact that a continuing search for TMD symptom relief has been common in other studies (Seo et al., 2020).

Descriptive Statistics

Table 2 presents the descriptive statistics for the data used in this study. The individuals in the sample had moderate levels of work distraction (an average of 2.13 on a scale from 0 to 4 and 2.15 on a scale from 0 to 5), consistent with findings for those with common pain conditions (Stewart et al., 2003), dental pain (Lima & Buarque, 2019), chronic headache pain (Stewart et al., 2010), and COFP (Breckons et al., 2018). This confirms that those in the sample are not outliers in terms of work presenteeism. The range of ages in the sample is large (from 20 to 73), and the average age is 44. The average number of medical, dental, or other practitioners from which the individuals in the sample sought treatment (both before and after TMD diagnosis) is about three. The maximum number of practitioners reported in this sample is 15, which is in line with Breckons et al. (2018), who report that those with COFP had seen nine practitioners in the past six months alone. The average length of treatment for TMD symptoms (both before and after diagnosis) is about four years. Furthermore, the average number of TMD treatments to relieve TMD symptoms (before or after TMD diagnosis) for those surveyed is about 1.5.

Length of time with TMD diagnosis and length of time with TMD symptoms measures were recoded from range categories to years using the midpoint (e.g., “1 to 3 years” was recoded to 2 years). For the category “20 years or more,” the lower bound of 20 years was used. (See Table A4 in the Appendix for a complete list of range categories, the midpoints used, and the distribution of the sample among them.) The average length of time that an individual in the sample has had a TMD diagnosis is about seven and a half years. The average length of time an individual has had TMD symptoms before diagnosis is about eight years.

Raw work distraction (WD) data was collected on a scale from 0 to 5, where 0 is no work distraction, and 5 is complete work distraction before treatment with the U.S. For the sake of this paper, categories 4 and 5 of WD have been merged due to low reporting of category 5 (n = 2). The measure of high work distraction (HWD) contains the highest WD category: WD = 4. The measure of any work distraction (AWD) contains all WD categories that are greater than zero.

Table 2
DESCRIPTIVE STATISTICS

Gender	Women	79.41%		
	Men	20.59%		
	Average	St. Dev	Min	Max
Age	44.31	12.90	20.00	73.00
Practictioners	3.04	2.41	0.00	15.00
Length of Treatment for TMD symptoms	4.16	6.51	0.00	30.00
Number of TMD Treatments	1.48	1.44	0.00	5.00
Number of Comorbidities	3.48	2.52	0.00	10.00
Length of TMD Diagnosis	7.51	6.74	0.50	20.00
Length of TMD Symptoms Pre-Diagnosis	7.93	6.79	0.50	20.00
Raw Work Distraction (WD) Data	2.15	1.39	0.00	5.00
Work Distraction (WD)	2.13	1.36	0.00	4.00
WD = 0	19.53%			
WD = 1	11.72%			
WD = 2	20.31%			
WD = 3	32.81%			
WD = 4	15.63%			
High WD	15.63%			
Any WD	80.47%			
Work Distraction After Treatment (WDA)	0.70	1.04	0.00	4.00
Painful Symptom Severity	2.97	1.05	0.00	4.89
Non-Painful Symptom Severity	2.60	1.00	0.60	4.83
Painful Symptom Count	7.71	1.92	0.00	9.00
Non-Painful Symptom Count	7.75	2.48	1.00	10.00
Painful Symptoms / Total Symptoms	0.50	0.09	0.00	0.80

	Average Severity	Count	Percent of Total
Painful TMD Symptoms			
Jaw pain or jaw tension	3.85	127	96.95%
Neck and shoulder pain or tension	3.44	121	92.37%
Headache	3.31	120	91.60%
Pain with chewing	3.12	114	87.02%
Headache, jaw, or neck pain while sitting	3.27	111	84.73%
Ear pain	2.62	110	83.97%
Waking at night due to headache, jaw, or neck pain	2.88	104	79.39%
Shoulder pain	2.44	99	75.57%
Upper arm pain	1.65	81	61.83%
Non-Painful TMD Symptoms			
Clenching or grinding of teeth	3.93	123	93.89%
Jaw popping	3.23	120	91.60%
Limited mouth opening	2.99	114	87.02%
Ear ringing/tinnitus	2.71	109	83.21%
Jaw locking	2.49	100	76.34%
Dizziness	1.99	91	69.47%
Arm/hand/finger tingling or numbness	1.99	88	67.18%
Subjective hearing loss/fullness	1.91	86	65.65%
Vertigo	1.57	84	64.12%
Visual disturbances	1.21	77	58.78%

Source: Author's Calculations
Note: "Percent of Total" refers to those in the sample with the symptom.

METHODOLOGY

Effect on Work Distraction: Painful versus Non-painful Symptoms

This study uses OLS and logit models to measure the severity of painful and non-painful TMD symptoms on work distraction (WD). The general formula for the ordinary least squares (OLS) models is presented below:

$$y_i = \alpha + \beta_1 PAIN_i + \beta_2 NPAIN_i + \sum_j \beta_j X_i + \in_i, \quad (1)$$

where the subscript i represents the individual, PAIN represents the effects of an individual's painful TMD symptoms, and NPAIN represents the effects of an individual's non-painful TMD symptoms for either the severity or the count variables. X_i is a vector of demographic variables for each person that include age, gender, number of comorbidities, number of practitioners seen, length of time with TMD symptoms, length of time with TMD diagnosis, number of previous TMD treatments, and length of TMD symptom treatment. It should be noted that socioeconomic variables present in other studies (Miller et al., 2019) are not included in the model because those questions were not present in the original survey.

Our four variables of interest are the severity of painful symptoms, the severity of non-painful symptoms, the number of painful symptoms, and the number of non-painful symptoms. Due to strong correlations, the effects of severity measures and count measures cannot be determined in the same model. The primary model involves symptom severity, and robustness checks are conducted using the count variables for both the OLS models and the ordered logit models outlined in the next paragraph.

Our next set of models uses a proportional odds ordered logit regression function, as shown below:

$$P(y_i > j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1 + \exp(\alpha_j + X_i\beta_j)}, j = 0, \dots, J-1, i = 1, \dots, n \quad (2)$$

where y_i is the category of work distraction for person i, j is the reference work distraction category, the subscript i represents the individual, and J is the number of work distraction categories. One difference between the two models is the intercept, where the ordered logit model intercepts are calculated separately for the distinct categories. The independent variables (including variables of interest and the vector of demographic variables) are the same in the ordered logit models as in the OLS model. The dependent variables for the ordered logit models are high work distraction (HWD) and any work distraction (AWD). For HWD, the ordered logit reference category is WD = 4, meaning the model measures what influences an individual to report category 4 of work distraction in the six months prior to treatment versus categories 0-3. For AWD, the reference category is WD = 0, meaning the model measures what influences an individual to report category 0 versus categories 1-4. The ordered logit uses separate intercepts for each category to calculate the odds ratio that the dependent variable is greater than the category of interest.

Costs of Work Distraction

To find the cost of work distraction for the sample and estimates for other U.S. cities, the human capital method (Hayes et al., 2013; van den Hout, 2010) is used, which values work distraction using individuals' income. The human capital approach assumes that an individual's income represents their contribution to an employer; thus, the value of the distracted hours represents the value of lost productivity. The formula used by Breckons et al. (2018) is as follows:

$$Productivity\ loss\ (hrs) = \left(1 - \frac{WD}{5}\right) \times H\,, \tag{3}$$

where WD is the rating of work distraction from 0 to 5, where 5 is no work distraction due to TMD symptoms and 0 is complete work distraction due to TMD symptoms. Full data (keeping category 5 of WD) is used in calculations of productivity losses. H represents the average number of hours in a typical workday. The productivity loss, thus, represents the number of hours in an affected day that are "lost" due to work distraction due to TMD symptoms for an individual per day. The productivity loss formula was revised to fit the data as shown below:

$$Productivity\ loss\ (hrs) = \frac{WD}{5} \times H\,. \tag{3.1}$$

To find the wages lost from the loss of productive hours, the productivity loss is multiplied by the average hourly wage (AHW), as shown below:

$$Productivity\ cost\ (\$) = Productivity\ loss\ (hrs) \times AHW. \tag{4}$$

The data collected by the survey has no measures of typical hours worked or average wages. However, this study imputes these measures using Integrated Public Use Microdata Survey (IPUMS) data from 2019. As the year falls between Census years, the sample of IPUMS data used is from the American Community Survey (ACS) 1% sample. Hayes et al. (2013) use occupation codes to match the average wages of individuals in their study. This study matches the average wages of individuals in the sample by these identifying factors: area (e.g., Atlanta, GA), age, full-time status, and gender. The same methodology is followed (matching by age, full-time status, and gender) to find the income estimates for the selected cities.

Income in ACS is reported by year, so the yearly income is divided by 48 to represent weekly income. The usual hours of work in a week variable reported in ACS were used to create a variable representing hourly wage. The usual hours of work a week variable were divided by five to get the usual hours of work per day. All these measures are the averages by age, full-time status, and gender. Full-time status is considered 40 hours or more a week. These calculated variables are reported in the Appendix.

The data has no measure of the number of days an individual worked with pain, so the estimate found by Breckons et al. (2018) is used for those with COFP of 34.6 days in a six-month period (or about 30% of workdays).

The measures of per person average cost per six months of work distraction (using the methods outlined above) was used to find the point estimates for the potential cost to employers due to TMD-related work distraction. Using non-seasonally-adjusted Bureau of Labor Statistics data for the sample MSAs in this paper, the number of those employed in an MSA is multiplied by the estimated percent of those in the United States reporting pain around the TMJ (4.8%, NASEM 2020). It is assumed that women make up 50% of those employed in an MSA. BLS estimates of national full-time work proportions for women and men for 2019 (74.9% and 86.2%, respectively, Bureau of Labor Statistics 2020) are used, and multiply 4.8% by the likelihood that someone with a TMD will be a woman (81%) (Durham et al., 2016b) to measure the costs separately for women and men.

RESULTS

Contributions of Painful and Non-painful Symptoms to Work Distraction

Table 3 reports the results for the OLS model measuring the effects that the severities of painful and non-painful symptoms have on work distraction (WD). The first model shows that painful symptom severity is positively related to WD. Using the sample average WD of 2.13 implies that a one-unit increase in the average severity of painful symptoms increases WD by about 38%. In the first model, non-painful symptoms are negatively related to work distraction. The coefficient implies a 12% decrease in WD for every one-unit increase in the average severity of non-painful symptoms. Both results are significant at the five percent level.

Table 3
WORK DISTRACTION (WD) OLS MODEL RESULTS
Symptom Severity

	(1)			(2)		
		95% CI			95% CI	
	Coefficient	Lower	Upper	Coefficient	Lower	Upper
Average of Painful Symptoms (0-5)	0.8124 *** *0.1126*	0.6186	1.0062	0.7620 *** *0.1326*	0.4914	1.0325
Average of Non-Painful Symptoms (0-5)	-0.2630 * *0.1195*	-0.5492	0.0231	-0.2514 . *0.1273*	-0.5689	0.0661
Gender				-0.5096 *0.3119*	-1.1783	0.1591
Age (years)				-0.0105 *0.0085*	-0.0300	0.0090
Length of diagnosis with TMD (years)				0.0176 *0.0176*	-0.0213	0.0566
Length of TMD symptoms before treatment (years)				0.0093 *0.0165*	-0.0250	0.0436
Number of practictioners				0.0453 *0.0507*	-0.0631	0.1538
Number of previous TMD Treatments				-0.0202 *0.0909*	-0.1666	0.1262
Total cost of TMD symptom treatment ($100s US dollars)				0.0006 *0.0007*	-0.0006	0.0019
Number of comorbidities				0.0321 *0.0495*	-0.0622	0.1264

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 4
HIGH WORK DISTRACTION (HWD) ORDERED LOGIT MODEL RESULTS
Symptom Severity

	(1)				(2)				(3)			
			95% CI				95% CI				95% CI	
	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper
Average of Painful Symptoms (0-5)	-1.2435 *** *0.2142*	**0.2884**	0.1863	0.4325	-1.2370 *** *0.2430*	**0.2903**	0.1774	0.4610	-1.0129 *** *0.1968*	**0.3632**	0.2443	0.5294
Average of Non-Painful Symptoms (0-5)	0.3989 * *0.2030*	**1.4902**	1.0042	2.2310	0.4488 * *0.2192*	**1.5665**	1.0232	2.4232				
Gender					0.7459 *0.5227*	**2.1084**	0.7592	5.9391	0.8895 . *0.5100*	**2.4339**	0.8990	6.6914
Age (years)					0.0230 *0.0145*	**1.0232**	0.9947	1.0532	0.0244 . *0.0142*	**1.0247**	0.9969	1.0540
Length of diagnosis with TMD (years)					-0.0303 *0.0290*	**0.9701**	0.9163	1.0268	-0.0212 *0.0280*	**0.9790**	0.9266	1.0344
Length of TMD symptoms before treatment (years)					-0.0161 *0.0271*	**0.9840**	0.9330	1.0378	-0.0266 *0.0253*	**0.9738**	0.9263	1.0232
Number of practictioners					-0.0864 *0.0854*	**0.9172**	0.7714	1.0849				
Number of previous TMD Treatments					0.0766 *0.1439*	**1.0796**	0.8151	1.4353	-0.0714 *0.1310*	**0.9311**	0.7202	1.2056
Total cost of TMD symptom treatment ($100s US dollars)					-0.0016 *0.0013*	**0.9984**	0.9952	1.0008				
Number of comorbidities					-0.0405 *0.0794*	**0.9603**	0.8212	1.1222	-0.0486 *0.0784*	**0.9525**	0.8160	1.1108

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1" 1. OR is Odds Ratio.

Table 5
ANY WORK DISTRACTION (AWD) ORDERED LOGIT MODEL RESULTS
Symptom Severity

	(1)				(2)				(3)			
			95% CI				95% CI				95% CI	
	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper
Average of Painful Symptoms (0-5)	1.2435 *** *0.2142*	**3.4679**	2.3121	5.3687	1.2370 *** *0.2430*	**3.4453**	2.1692	5.6381	1.0129 *** *0.1968*	**2.7535**	1.8888	4.0939
Average of Non-Painful Symptoms (0-5)	-0.3989 * *0.2030*	**0.6710**	0.4482	0.9958	-0.4489 * *0.2192*	**0.6384**	0.4127	0.9773				
Gender					-0.7460 *0.5227*	**0.4743**	0.1684	1.3171	-0.8895 . *0.5100*	**0.4109**	0.1494	1.1124
Age (years)					-0.0230 *0.0145*	**0.9773**	0.9495	1.0054	-0.0244 . *0.0142*	**0.9759**	0.9488	1.0032
Length of diagnosis with TMD (years)					0.0303 *0.0290*	**1.0308**	0.9739	1.0914	0.0212 *0.0280*	**1.0215**	0.9668	1.0792
Length of TMD symptoms before treatment (years)					0.0161 *0.0271*	**1.0162**	0.9635	1.0718	0.0266 *0.0253*	**1.0270**	0.9773	1.0795
Number of practictioners					0.0864 *** *0.0854*	**1.0903**	0.9218	1.2963				
Number of previous TMD Treatments					-0.0766 *0.1439*	**0.9263**	0.6967	1.2268	0.0714 *0.1310*	**1.0740**	0.8294	1.3884
Total cost of TMD symptom treatment ($100s US dollars)					0.0016 *0.0013*	**1.0016**	0.9992	1.0048				
Number of comorbidities					0.0405 *0.0794*	**1.0413**	0.8911	1.2177	0.0486 *0.0784*	**1.0498**	0.9002	1.2255

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1" 1. OR is Odds Ratio.

The second model of Table 3 reinforces the findings of the first model, with the magnitude of the effect of painful symptom severity decreasing slightly. The implied percentage

change of WD is about 36% and -12% for painful and non-painful symptom severity, respectively. The controlling variables' coefficients in the second model are smaller in magnitude than the two variables of interest and not significant, meaning that work distraction is not affected by the controlling variables.

Tables 4 and 5 report the ordered logit model results for the effects of painful and non-painful symptoms on the likelihood of high work distraction (HWD) and any work distraction (AWD), respectively. The results of interest are the odds ratios (OR) in bold. The coefficients for Tables 4 and 5 are the same but show opposite signs, meaning that the ordered logit model specifications are the same but the direction of interest (i.e., higher versus lower) and thus the OR calculations differ. Each table has three model specifications, the first showing only the effects of painful and non-painful symptoms, the second showing the full model effects, and the third showing only variables passing the parallel regression assumption of ordered logit models (Brant test in R).

Additionally, in all ordered logit models (including the count models in Tables 7 and 8), the WD categories are 0-4, where 0 is no WD and 4 is the highest WD. In the data, the WD categories are 0-5, and we collapsed categories 4 and 5 together in the main results due to a low reporting of category 5 (n=2 for category 5). We ran robustness tests where we dropped category 5 altogether and the results show no substantial differences from reported results.

Table 4 reports the ordered logit results for the effects of painful and non-painful symptom severities on the likelihood of high work distraction (HWD). In Model 1 of Table 4, a one-unit increase in the average intensity of painful symptoms decreases the likelihood that individuals in this model will have lower levels of work distraction by about 71%. This means that as painful symptom intensity increases, individuals are 71% more likely to report the highest level of work distraction. For a one-unit increase in non-painful symptoms, individuals are about 50% more likely to have lower levels of work distraction. This effect is counterintuitive, though significant at the 5% level. The counterintuitive findings of non-painful symptoms stem from how a non-painful symptom is reported by an individual, and we elaborate more on this finding later in this section.

In Model 2 of Table 4, we show that all control variable effects hover around 1, which is interpreted as no effect. The one exception is gender, where women are two times as likely to report lower levels of work distraction than men. No control variables show significance at the 10% level in Model 2. In Model 3 of Table 4, a one-unit increase in painful symptoms is related to a 64% increase in an individual reporting HWD, meaning individuals with more intense painful symptoms are more likely to report HWD. Gender in our model is a binary variable where Woman = 1 and Man = 0. Women in our sample are about 2.5 times less likely to report HWD than men in our sample (significant at the 10% level). In Model 3, age becomes a significant explanatory variable for HWD (significant at the 10% level). An increase of 10 years in age implies a 25% decrease in the likelihood of reporting HWD. This can be explained by older workers with a long history of HWD leaving the labor force and thus our sample, or it can be explained by older workers becoming used to working with severe TMD symptoms and underreporting their level of WD.

In order to investigate the effect of non-painful symptom intensity on work distraction, we separately regressed the intensity of the 10 non-painful symptoms to see if any of them drove the significant results presented above. Though most of the individual non-painful symptoms passed the parallel assumption, none of the effects were significant. We can conclude that non-painful symptom intensity is not a driving factor of work distraction. One reason for this might be that non-painful symptom intensity cannot be measured in the same way as painful symptom intensity. E.g., how does an individual define intensity as it relates to jaw locking? A better measure of intensity of non-painful symptoms might be by counting instances of experiencing the symptom in the past week. Future research should consider this when measuring the intensity of non-painful TMD symptoms.

Table 5 reports the ordered logit results for the effects of painful and non-painful symptom severities on the likelihood of any work distraction (AWD). Unsurprisingly, AWD is positively affected by painful symptom severity. In Model 1, a one-unit increase in the average intensity of painful symptoms increases the likelihood that individuals in this model will have work distraction by 347% (or are about three and a half times more likely to have work distraction that is not zero). However, a one-unit increase in the average intensity of non-painful symptoms decreases the likelihood that individuals will have work distraction by about 33% (0.67 – 1 x 100). This is counterintuitive to prior beliefs about the non-painful symptom's effect on work distraction. While this effect is significant at the 5% level, the parallel regression assumption for this variable does not hold.

In Model 2 of Table 5, we show all control variables except gender have no effect on the likelihood of having work distraction. In this case, no effect is characterized by an odds ratio near 1. Model 2 also shows that the number of practitioners seems to be a significant variable but does not pass the parallel regression assumption. Model 3 results imply that only the severity of painful symptoms, gender, and age have significant and large effects on an individual experiencing AWD. A one-unit increase in the severity of painful symptoms implies that an individual is nearly three times (275%) more likely to experience any work distraction. When gender increases by one unit (i.e., the individual is a woman), the likelihood that the individual will experience AWD decreases by 59%. This is driven by the low representation of men in our sample (only 20%) and that the men in our sample have a lower frequency of experiencing no work distraction relative to the women in our sample. For a 10-year increase in age, the likelihood of experiencing AWD decreases by 24%, and the reasons are likely those presented above in the results for HWD (e.g., older worker leaving work force).

Robustness: Using Painful and Non-painful Symptom Count Variables

As a robustness check on the symptom severity results, the models above were run with the painful and non-painful symptom count variables. Both count and severity variables measure the intensity of the painful or non-painful symptoms. As outlined in the descriptive statistics, individuals experience an average of about 7.71 painful symptoms and 7.75 non-painful symptoms. Table 6 presents the OLS results of the count model for WD. An additional painful symptom increases WD by 13% (using the sample mean of 2.13 for WD) in the first model and

14% in the second model. Both models' painful symptom count coefficients are significant at the 1% level.

Table 6
WORK DISTRACTION (WD) OLS MODEL RESULTS
Symptom Count

	(1)			(2)		
		95% CI			95% CI	
	Coefficient	Lower	Upper	Coefficient	Lower	Upper
Count of Painful Symptoms	0.2777 ** *0.0827*	0.1239	0.4315	0.3008 *** *0.0838*	0.1657	0.4358
Count of Non-Painful Symptoms	0.0322 *0.0645*	-0.0979	0.1623	-0.0491 *0.0684*	-0.1951	0.0969
Gender				-0.1376 *0.3280*	-0.7422	0.4670
Age (years)				-0.0088 *0.0091*	-0.0288	0.0111
Length of diagnosis with TMD (years)				0.0147 *0.0184*	-0.0150	0.0444
Length of TMD symptoms before treatment (years)				0.0208 *0.0176*	-0.0051	0.0467
Number of practictioners				0.0712 *0.0530*	-0.0484	0.1908
Number of previous TMD Treatments				0.0440 *0.0921*	-0.0902	0.1783
Total cost of TMD symptom treatment ($100s US dollars)				0.0007 *0.0007*	-0.0012	0.0027
Number of comorbidities				0.0673 *0.0519*	-0.0413	0.1758

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 7
HIGH WORK DISTRACTION (HWD) ORDERED LOGIT MODEL RESULTS
Symptom Count

	(1)				(2)				(3)			
			95% CI				95% CI				95% CI	
	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper	Coefficient	OR	Lower	Upper
Average Count of Painful Symptoms	-0.4194 *** *0.1340*	**0.6574**	0.5000	0.8484	-0.4825 *** *0.1434*	**0.6172**	0.4610	0.8109	-0.4836 *** *0.1423*	**0.6166**	0.4615	0.8085
Average Count of Non-Painful Symptoms	-0.0403 *0.0967*	**0.9605**	0.7934	1.1607	0.0681 *0.1065*	**1.0705**	0.8679	1.3200	0.0611 *0.1054*	**1.0630**	0.8636	1.3078
Gender					-0.0057 *0.5064*	**0.9943**	0.3654	2.6838	0.0347 *0.5018*	**1.0353**	0.3840	2.7702
Age (years)					0.0158 *0.0145*	**1.0160**	0.9874	1.0454	0.0192 *0.0141*	**1.0194**	0.9915	1.0482
Length of diagnosis with TMD (years)					-0.0210 *0.0278*	**0.9792**	0.9271	1.0342	-0.0228 *0.0276*	**0.9774**	0.9257	1.0319
Length of TMD symptoms before treatment (years)					-0.0328 *0.0265*	**0.9677**	0.9184	1.0193	-0.0449 . *0.0250*	**0.9561**	0.9098	1.0039
Number of practictioners					-0.1400 *0.0882*	**0.8693**	0.7262	1.0301				
Number of previous TMD Treatments					-0.0375 *0.1342*	**0.9632**	0.7402	1.2550	-0.1252 *0.1278*	**0.8823**	0.6862	1.1341
Total cost of TMD symptom treatment ($100s US dollars)					-0.0016 *0.0013*	**0.9984**	0.9952	1.0009				
Number of comorbidities					-0.0886 *0.0776*	**0.9152**	0.7851	1.0655	-0.1251 *0.0763*	**0.8824**	0.7588	1.0246

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. OR is Odds Ratio.

Table 8
Any Work Distraction (AWD) Ordered Logit Model Results
Symptom Count

	(1)					(2)					(3)				
				95% CI				95% CI					95% CI	
	Coefficient		OR	Lower	Upper	Coefficient		OR	Lower	Upper	Coefficient		OR	Lower	Upper
Average Count of Painful Symptoms	0.4195 ***		**1.5211**	1.1788	2.0001	0.4825 ***		**1.6202**	1.2332	2.1691	0.4836 ***		**1.6219**	1.2369	2.1669
	0.1340					*0.1434*					*0.1423*				
Average Count of Non-Painful Symptoms	0.0403		**1.0411**	0.8615	1.2604	-0.0681		**0.9342**	0.7576	1.1522	-0.0611		**0.9408**	0.7647	1.1579
	0.0967					*0.1065*					*0.1054*				
Gender						0.0058		**1.0058**	0.3726	2.7367	-0.0346		**0.9659**	0.3610	2.6044
						0.5064					*0.5018*				
Age (years)						-0.0158		**0.9843**	0.9565	1.0128	-0.0192		**0.9810**	0.9540	1.0086
						0.0145					*0.0141*				
Length of diagnosis with TMD (years)						0.0210		**1.0212**	0.9670	1.0787	0.0228		**1.0231**	0.9691	1.0802
						0.0278					*0.0276*				
Length of TMD symptoms before treatment (years)						0.0328		**1.0333**	0.9810	1.0888	0.0449	.	**1.0460**	0.9961	1.0991
						0.0265					*0.0250*				
Number of practictioners						0.1400		**1.1503**	0.9708	1.3771					
						0.0882									
Number of previous TMD Treatments						0.0375		**1.0382**	0.7968	1.3510	0.1252		**1.1334**	0.8817	1.4574
						0.1342					*0.1278*				
Total cost of TMD symptom treatment ($100s US dollars)						0.0016		**1.0016**	0.9991	1.0048					
						0.0013									
Number of comorbidities						0.0886		**1.0927**	0.9386	1.2737	0.1251		**1.1333**	0.9760	1.3178
						0.0776					*0.0763*				

Source: Author's Calculations
Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. OR is Odds Ratio.

Tables 7 and 8 report the results for HWD and AWD using the symptom count variables. These models generally support the findings of the severity models, with increases in painful symptom counts increasing the probability of HWD and AWD and non-painful symptoms decreasing the probability of HWD and AWD. For the HWD model, an additional painful symptom increases the probability of HWD by about 38% in the final model (Model 3). An additional non-painful symptom decreases the probability of HWD by about 6% in the final model. For the AWD model, an additional painful symptom increases the probability of AWD by about 62% in the final model, while an additional non-painful symptom is associated with a 6% decrease in AWD. In the symptom count models, we investigate if the number of TMD symptoms influences work distraction. As the count models show, the count of non-painful symptoms is not a better predictor of work distraction, underscoring the need for a better measure of non-painful symptom intensity.

To test the sensitivity of collapsing categories 4 and 5 of WD into one category, we also conducted tests where we removed category 5 and tested the effects of the type of symptom on HWD and AWD using categories 0-4 only. Results remained robust, both in magnitude and significance.

The models suggest, and the robustness tests confirm that painful symptoms are a larger part of work distraction than non-painful symptoms, even as the individuals in the sample have about the same number of painful versus non-painful TMD symptoms prior to treatment with the Urbanek Splint (U.S.).

Costs of Work Distraction to Employers

Table 9 reports the per-person costs of work distraction for those in the sample based on imputed hourly wages and weekly hours worked matched to our sample using location, age, and gender. Imputed hourly wages and weekly hours are presented in the appendix. Table 9 also reports the 95% confidence interval of costs of work distraction. The per-person average cost of work distraction for six months (using the estimate of 34.6 workdays with painful symptoms in a six-month period) ranges from $2,055 to $3,245 for women in the sample MSA and ranges from $1,963 to $2,721 for men. Using the mean six-month cost of work distraction, the total six-month cost to employers of work distraction for the sample is $286,118 for women and $46,837 for men.

The costs for the selected cities across the United States are also reported by using the same methodology and the work distraction measures for the sample.

Table 10 shows the calculations of the total MSA-level costs of work distraction and savings after treatment, using the work distraction measures in the sample and imputed values from Table 9 and the post-intervention level of work distraction. For the per-person savings due to use of the U.S. and subsequent decrease in work distraction, the average reduction in work distraction after treatment is about 68% for women and 74% for men. For a six-month period, the per-person savings due to reduced work distraction after treatment ranges from $1,347 to $2,205 for women and $1,464 to $2,031 for men. The total six-month savings for employers using the mean per-person savings is $191,740 for women and $34,953 for men.

For the MSA-level costs of work distraction and savings after treatment, since the age distribution from the sample is used, the city estimates for costs and savings at the MSA level are only for comparison to the sample MSA. This does not account for 2019 estimates of full-time work for women and men at the national level (see Methodology). For the sample's MSA, the MSA-level six-month cost of work distraction is $40,779,993 for women and $9,731,556 for men. The imputed MSA-level average six-month savings using treatment results from the U.S. is $27,328,429 for women and $7,262,307 for men. Considering these numbers, the costs to employers (aggregated yearly) in the sample MSA represent 0.073% of the total MSA GDP for 2019 (FRED Database: NGMP34980).

The cost and savings information presented in this section show that those with TMDs have moderate work distraction levels. This distraction decreases with decreases in TMD symptom severity due to effective TMD treatment (the Urbanek Splint).

Table 9
PER-PERSON COSTS TO EMPLOYERS FOR WORK DISTRACTION

				Per Person Average Cost Per Day of Work Distraction			Per Person Average Cost Per Six Months of Work Distraction			
	Count in Sample	Average Work Distraction	Average Hours of Work Per Day	Lower Bound of Hourly Wages	Mean of Hourly Wages	Upper Bound of Hourly Wages	Lower Bound of Hourly Wages	Mean of Hourly Wages	Upper Bound of Hourly Wages	Total Mean Lost Wages for Sample
Sample MSA										
Women	108	2.19	8.58	$59.39	$76.57	$93.77	$2,054.73	$2,649.24	$3,244.55	$286,118.21
Men	20	1.90	9.14	$56.73	$67.68	$78.65	$1,962.90	$2,341.87	$2,721.12	$46,837.40
Atlanta, GA										
Women			8.64	$68.08	$78.66	$89.26	$2,355.43	$2,721.48	$3,088.51	$293,919.73
Men			9.16	$65.69	$74.45	$83.29	$2,272.89	$2,575.98	$2,881.91	$51,519.57
Austin, TX										
Women			8.74	$62.01	$75.57	$89.13	$2,145.67	$2,614.84	$3,083.79	$282,402.94
Men			9.18	$58.12	$69.34	$80.57	$2,011.11	$2,399.25	$2,787.78	$47,984.94
Columbus, OH										
Women			8.55	$61.23	$76.74	$92.22	$2,118.63	$2,655.36	$3,190.66	$286,778.69
Men			9.08	$56.06	$68.71	$81.39	$1,939.61	$2,377.30	$2,816.10	$47,545.95
New York, NY										
Women			8.66	$84.78	$93.19	$101.60	$2,933.28	$3,224.32	$3,515.27	$348,226.15
Men			9.11	$80.31	$87.78	$95.20	$2,778.87	$3,037.20	$3,294.05	$60,744.01
Pheonix, AZ										
Women			8.63	$65.46	$77.76	$90.05	$2,264.78	$2,690.43	$3,115.81	$290,566.39
Men			9.01	$60.82	$69.16	$77.52	$2,104.27	$2,392.81	$2,682.05	$47,856.10
Seattle, WA										
Women			8.63	$64.36	$76.00	$87.61	$2,226.98	$2,629.50	$3,031.37	$283,985.67
Men			8.93	$60.66	$69.17	$77.67	$2,098.84	$2,393.11	$2,687.55	$47,862.23

Source: Author's Calculations using ACS 2019 data

Table 10
MSA-LEVEL COSTS AND SAVINGS FOR EMPLOYERS DUE TO WORK DISTRACTION

		Employed[1]	Women (50%)	Full time[2]	4.8% with Pain Around the TMJ[3,4]	Per Person Average Cost Per Six Months of Work Distraction	Per MSA Average Cost Per Six Months of Work Distraction	Per Person Average Savings Per Six Months of Work Distraction After US	Per MSA Average Savings Per Six Months of Work Distraction After US
Sample MSA									
	All	1,057,176							
	Women		528,588	395,912	15,393	$2,649.24	$40,779,993	$1,775.37	$27,328,429
	Men		528,588	455,643	4,155	$2,341.87	$9,731,556	$1,747.65	$7,262,307
Atlanta, GA									
	All	3,000,035							
	Women		1,500,017	1,123,513	43,682	$2,721.48	$118,880,150	$1,804.07	$78,805,580
	Men		1,500,017	1,293,015	11,792	$2,575.98	$30,376,702	$1,910.60	$22,530,314
Austin, TX									
	All	1,205,590							
	Women		602,795	451,493	17,554	$2,614.84	$45,901,111	$1,724.05	$30,264,025
	Men		602,795	519,609	4,739	$2,399.25	$11,369,640	$1,788.11	$8,473,568
Columbus, OH									
	All	1,066,992							
	Women		533,496	399,588	15,536	$2,655.36	$41,253,645	$1,745.76	$27,122,091
	Men		533,496	459,874	4,194	$2,377.30	$9,970,497	$1,765.08	$7,402,808
New York, NY									
	All	3,913,047							
	Women		1,956,524	1,465,436	56,976	$3,224.32	$183,709,141	$2,114.88	$120,497,822
	Men		1,956,524	1,686,523	15,381	$3,037.20	$46,715,462	$2,282.18	$35,102,345
Pheonix, AZ									
	All	2,382,993							
	Women		1,191,497	892,431	34,698	$2,690.43	$93,351,750	$1,773.52	$61,536,953
	Men		1,191,497	1,027,070	9,367	$2,392.81	$22,413,115	$1,760.29	$16,488,397
Seattle, WA									
	All	2,100,717							
	Women		1,050,358	786,718	30,588	$2,629.50	$80,430,039	$1,719.00	$52,580,056
	Men		1,050,358	905,409	8,257	$2,393.11	$19,760,711	$1,764.61	$14,570,970

Source: Author's Calculations

[1]BLS Databases: Nashville, TN (LAUMT473498000000006); Atlanta, GA (LAUMT131206000000005); Austin, TX (LAUMT481242000000006); Columbus, OH (LAUMT391814000000006); New York, NY (Special series: https://www.bls.gov/regions/new-york-new-jersey/data/xg-tables/ro2xgcesnyc.htm); Pheonix, AZ (LAUMT043806000000006); Seattle, WA (LAUMT534266000000004)

[2]BLS (2020); [3]NASEM (2020); [4]Durham et al. (2016b)

IMPLICATIONS AND LIMITATIONS

A limitation of this paper is the lack of work information for individuals in the sample, and there is a reliance on imputed values from Census data. To account for this limitation, the study matches as many variables as possible for wage estimates (e.g., city, age, full-time status, and gender). Hayes et al. (2013) use known occupations to impute wage estimates for the cost of work distraction. Even with imputed wage estimates, our estimates are within the ballpark of work distraction estimates found in prior research (Breckons et al., 2018; Edmeads and Mackell, 2002).

This paper concludes that TMD methods that target painful TMD symptoms are more likely to reduce work distraction and, subsequently, the costs of TMD-related work distraction to employers. This implies that this type of chronic pain intervention is successful in reducing the costs of work distraction for firms. The work distraction cost estimates imply that for the sample MSA, the effects of TMD symptoms make up a sizable portion of the total MSA GDP for 2019.

Previous research confirms that our human capital method may lead to estimates that are a lower bound than the true costs of work distraction due to chronic pain, as the type of firm (e.g., teamwork-based) is shown to have multiplying effects (Pauly et al.,2008). Managers of teamwork-based firms have more of an incentive to be aware of the reasons and solutions for workplace presenteeism based on illness or pain. Reducing the days of pain employees work increases the productivity of the team and the firm.

CONCLUSION

This paper finds the severity of painful TMD symptoms drives workplace distraction, over and above the severity of non-painful TMD symptoms. The OLS findings show that a one-unit increase in painful symptom severity is associated with a 36% increase in WD. The corresponding effect of non-painful symptom severity is negative and is about a third of the impact of the effect of painful symptoms (-12%). We consistently found a counterintuitive negative effect of non-painful symptoms on WD, which points toward a need for a better measurement of non-painful symptoms. Additionally, the larger effect for painful symptoms carries through in the models for HWD and AWD. For HWD, a one-unit increase in painful symptom severity is associated with a 64% increase in the probability of an individual having HWD. For AWD, a one-unit increase in painful symptom severity is associated with individuals being almost three times as likely to have AWD (probability increases by 275%). We also found some significant results by gender and age, where women and older workers are less likely to report HWD or AWD.

The per-person six-month cost estimates for work distraction for those in the sample are $2,649 for women (95% CI: $2,055 to $3,245) and $2,342 for men (95% CI: $1,963 to $2,721). This leads to for the total sample (women and men) a cost of $332,955 and for the total MSA cost of about $50 million for TMD-related WD. The per-person indirect work costs due to pain are higher than those found for individuals with migraines ($1,010 in 2019 dollars, Edmeads and

Mackell, 2002) and those with COFP ($2,059 in 2019 dollars, Breckons et al., 2018). Using the reduction in WD after treatment, the per-person six-month savings estimates for those in the sample are $1,775 for women (95% CI: $1,347 to $2,205) and $1,748 for men (95% CI: $1,464 to $2,031), implying a total savings of $226,693 to employers due to a reduction in WD after treatment for those in our sample. The total MSA estimated savings for a reduction in WD is about $34 million.

In conclusion, TMD-related symptoms impact an individual's level of work distraction, which leads to an increase in costs for employers. A reduction in the severity of TMD-related symptoms implies a decrease in work distraction and the costs of work distraction. Managers who are aware of this novel treatment for TMDs could save their employees days of working in pain and save their firms days of lower productivity, improving workforce satisfaction and profitability.

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APPENDIX

Table A1
Range Categories for Length of Time with Diagnosis and Length of Time with Symptoms Measures

How long have you been diagnosed with a TMD (temporomandibular disorder)?				
	Midpoint Used	n	Total	Percent of Total
Less than 1 year	0.5	11	127	9%
1 to 3 years	1.5	39	127	30%
4 to 6 years	5	28	127	22%
7 to 10 years	8.5	18	127	14%
11 to 15 years	13	7	127	5%
16 to 20 years	18	6	127	5%
More than 20 years	20	19	127	15%

How long had you experienced your TMD symptoms before you were diagnosed with a TMD?				
	Midpoint Used	n	Total	Percent of Total
Less than 1 year	0.5	15	127	12%
1 to 3 years	1.5	32	127	25%
4 to 6 years	5	22	127	17%
7 to 10 years	8.5	21	127	16%
11 to 15 years	13	12	127	9%
16 to 20 years	18	10	127	8%
More than 20 years	20	16	127	13%

Source: Author's Calculations using survey data

Table A2
Treatment Categories by Frequency in Sample

Treatment	n	Percent of total
Bite splints or occlusal guards	48	37.8%
Never treated for TMD symptoms	47	37.0%
Prescription medication	37	29.1%
Massage therapy	32	25.2%
Chiropractic	24	18.9%
Physical therapy	12	9.4%
Other	11	8.7%
Occlusion correction or braces	10	7.9%
Acupuncture	6	4.7%
Botox	6	4.7%
Surgery	3	2.4%

Source: Author's Calculations using survey data

Table A3
Comorbidities by Frequency in Sample

Comorbidity	n	Percent of total
Back neck and joint pain	76	59.8%
Headaches	76	59.8%
Respiratory conditions e g sinus trouble allergies or breathing difficulties	38	29.9%
Sinusitis	33	26.0%
Tinnitus	31	24.4%
Sleep disorders (insomnia or poor sleep quality)	30	23.6%
Hypertension	27	21.3%
Somatic and psychological symptoms (depression anxiety or post traumatic stress disorder)	25	19.7%
Vertigo	21	16.5%
Irritable bowel syndrome	16	12.6%
Osteoarthritis in body joints other than the TMJ	16	12.6%
Asthma	13	10.2%
Endometriosis	12	9.4%
Chronic fatigue syndrome	6	4.7%
Rheumatoid arthritis in body parts other than the TMJ	6	4.7%
Juvenile idiopathic arthritis in body parts other than TMD	0	0.0%
Vulvodynia	0	0.0%
Ankylosing spondylitis in body parts other than TMJ	ND	
Ehlers Danlos syndrome	ND	
Fibromyalgia	ND	
Interstitial cystitis painful bladder	ND	
Neural sensory conditions	ND	
Poor nutrition due to limited jaw function and or pain while chewing	ND	
Psoriatic arthritis in body parts other than the TMJ	ND	
Sjogren s syndrome	ND	
Systemic lupus erythematosus	ND	

Note: Comorbidity categories are from NASEM (2020). Categories with N.D. have a positive number of respondents, but less than six reported these comorbidities. For privacy, we do not report the frequencies for these comorbidities. N.D. is “not disclosed.”

Table A4
Imputed Hourly Wages and Daily Hours Worked by Gender, Age, and City

		Atlanta, GA		Austin, TX		Columbus, OH		Nashville, TN		New York, NY		Phoenix, AZ		Seattle, WA		Topeka, KS	
Gender	Age	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day	Wage/Hr	Hrs/Day
Female	20	9.14	8.12	8.98	7.94	9.82	8.03	9.01	8.07	10.31	8.30	10.28	8.26	11.13	8.34	9.02	9.60
Female	22	11.07	8.17	11.66	8.16	10.95	8.11	11.92	8.24	13.59	8.29	13.62	8.22	13.42	8.42	6.81	10.00
Female	23	14.16	8.46	14.76	8.33	14.51	8.26	14.75	8.28	19.16	8.52	14.53	8.38	18.02	8.27	19.01	8.53
Female	24	16.72	8.29	19.19	8.49	18.29	8.49	17.18	8.37	20.63	8.50	16.12	8.51	19.86	8.40	10.42	8.00
Female	25	20.39	8.45	21.35	8.39	20.93	8.24	20.76	8.45	24.50	8.61	18.00	8.27	26.02	8.30	16.38	8.00
Female	25	20.39	8.45	21.35	8.39	20.93	8.24	20.76	8.45	24.50	8.61	18.00	8.27	26.02	8.30	16.38	8.00
Female	26	21.55	8.72	24.42	8.46	20.25	8.40	19.50	8.36	26.86	8.63	18.99	8.46	24.26	8.61	17.19	8.20
Female	27	19.72	8.48	21.94	8.39	21.04	8.50	21.26	8.50	26.86	8.58	19.03	8.53	28.52	8.69	15.59	8.24
Female	28	22.71	8.63	25.39	8.47	20.96	8.41	19.11	8.40	28.07	8.76	20.25	8.37	29.05	8.55	15.39	8.53
Female	29	24.83	8.53	26.10	8.53	20.97	8.40	22.93	8.70	31.16	8.74	22.04	8.50	30.26	8.70	17.68	8.40
Female	29	24.83	8.53	26.10	8.53	20.97	8.40	22.93	8.70	31.16	8.74	22.04	8.50	30.26	8.70	17.68	8.40
Female	30	23.47	8.62	29.08	8.82	24.86	8.29	24.04	8.61	30.87	8.81	22.52	8.41	29.24	8.60	21.24	8.33
Female	31	26.55	8.69	23.30	8.62	25.78	8.62	27.67	8.45	33.12	8.76	23.14	8.45	30.78	8.69	15.93	9.00
Female	32	25.60	8.68	30.11	8.53	26.34	8.80	26.76	8.55	36.08	8.56	23.14	8.51	33.10	8.68	29.98	9.17
Female	33	25.36	8.66	29.20	8.65	25.57	8.23	22.01	8.69	36.00	8.73	26.08	8.45	33.99	8.56	17.65	8.29
Female	34	26.67	8.63	27.60	8.64	24.65	8.43	26.12	8.34	39.35	8.67	24.51	8.74	37.46	8.47	31.01	8.71
Female	35	30.35	8.65	27.99	9.01	31.73	8.51	23.34	8.82	39.00	8.75	30.46	8.76	35.68	8.67	16.10	9.00
Female	36	33.58	8.55	32.77	8.63	29.67	8.55	31.17	8.71	40.97	8.60	26.26	8.52	39.78	8.83	35.07	8.33
Female	37	32.76	8.72	31.31	8.72	29.19	8.77	29.09	8.54	37.70	8.68	29.19	8.52	38.48	8.46	21.90	9.05
Female	38	30.96	8.66	36.02	8.68	35.46	8.40	25.69	8.68	37.87	8.74	28.16	8.74	37.94	8.80	27.66	8.33
Female	39	31.18	8.53	29.83	8.81	27.45	8.75	30.75	8.68	40.87	8.64	28.36	8.86	38.99	8.77	22.90	8.36
Female	40	32.10	8.59	35.66	8.71	29.64	8.57	26.57	8.79	38.37	8.59	28.26	8.57	37.75	8.39	17.41	8.91
Female	41	31.17	8.65	43.62	9.02	29.20	8.22	30.28	8.41	44.09	8.67	30.58	8.68	44.61	8.80	24.65	8.71
Female	42	32.39	8.64	30.58	8.64	33.08	8.47	29.68	8.87	43.03	8.64	28.54	8.67	35.50	8.78	29.99	8.80
Female	43	30.97	8.67	33.94	8.87	28.10	8.98	26.04	8.47	40.23	8.68	28.82	8.40	40.04	8.64	18.84	8.65
Female	44	32.65	8.60	31.41	8.98	32.11	8.93	27.32	8.43	40.73	8.59	31.53	8.93	45.17	8.71	25.57	8.00
Female	46	33.43	8.73	37.67	8.77	32.03	8.58	26.93	8.51	41.16	8.68	28.75	8.96	39.63	8.92	21.01	8.33
Female	47	31.88	8.75	32.66	8.55	34.85	8.85	24.78	8.83	40.84	8.67	30.92	8.60	36.54	8.76	15.84	8.18
Female	48	34.08	8.71	34.79	8.66	29.91	8.49	33.84	8.60	40.99	8.65	33.15	8.93	38.29	8.81	24.53	8.70
Female	49	31.47	8.70	32.54	8.83	35.11	8.49	32.11	8.42	42.73	8.80	31.47	8.81	42.15	8.67	23.51	8.61
Female	50	31.30	8.80	40.07	8.95	32.24	8.60	28.17	8.63	40.85	8.62	28.55	8.78	37.85	8.55	25.34	9.23
Female	51	30.31	8.55	32.59	8.84	26.97	8.50	26.47	8.65	39.94	8.72	32.61	9.02	41.32	8.75	13.94	7.89
Female	52	31.33	8.76	34.51	9.07	27.33	8.97	28.21	8.63	38.27	8.66	29.09	8.67	44.46	8.79	19.53	8.00
Female	53	32.43	8.75	28.63	8.93	34.34	8.66	31.60	8.91	40.26	8.71	29.85	8.53	32.60	8.59	26.09	8.27
Female	54	31.36	8.69	24.06	8.84	32.95	8.57	29.26	8.93	39.66	8.74	27.59	8.74	39.59	8.65	27.86	8.63
Female	55	32.31	8.98	32.05	8.82	27.83	8.55	27.88	8.71	37.59	8.74	28.03	8.70	33.20	8.63	15.16	8.23
Female	57	28.40	8.67	29.57	9.06	30.08	8.57	32.21	8.64	40.37	8.65	27.06	8.72	32.12	8.47	20.42	7.92
Female	58	29.07	8.72	31.35	8.57	28.02	8.59	28.56	8.58	38.40	8.58	31.42	8.60	35.68	8.73	20.16	8.52
Female	59	29.80	8.50	31.60	8.99	24.24	8.57	27.94	8.81	38.66	8.64	32.56	8.76	35.95	8.66	22.12	9.40
Female	60	30.30	8.63	32.84	8.84	26.87	8.54	24.43	8.48	39.26	8.76	28.87	8.79	34.89	8.46	16.78	8.38
Female	61	29.10	8.78	25.45	8.37	31.90	8.43	26.84	8.33	37.04	8.62	26.07	8.93	35.32	8.71	21.38	8.67
Female	62	27.41	8.66	34.58	8.58	34.22	8.50	26.97	8.75	37.10	8.62	23.57	9.26	30.66	8.66	20.70	8.50
Female	63	31.75	8.40	28.12	8.70	33.81	9.18	24.29	8.46	37.42	8.67	28.55	8.76	43.18	8.80	15.56	8.00
Female	64	31.06	8.72	23.08	8.65	27.10	8.48	24.97	8.36	35.95	8.49	28.91	8.53	39.89	8.64	22.40	8.55
Female	65	25.91	8.73	22.66	9.06	29.45	8.94	37.45	8.34	39.80	8.58	30.25	8.62	31.77	8.77	19.79	8.00
Female	66	26.33	8.50	35.01	8.82	23.63	8.09	42.34	8.29	34.89	8.49	27.10	9.02	31.57	8.83	37.15	8.00
Female	68	29.00	8.49	33.43	9.10	29.27	8.18	26.22	8.64	41.52	8.57	28.34	8.44	38.06	8.50		
Male	23	14.91	8.72	17.34	8.77	14.33	8.91	15.93	8.96	18.13	8.75	15.00	8.59	21.79	8.76	12.82	8.55
Male	33	33.51	9.14	33.43	8.92	31.80	8.78	32.48	9.04	39.11	9.09	29.56	8.96	42.76	8.98	25.76	8.38
Male	35	32.24	9.16	38.79	9.43	30.91	9.18	27.16	9.12	44.27	9.17	33.48	8.85	52.80	9.01	25.11	9.63
Male	37	38.23	8.94	43.99	9.06	36.49	9.06	27.49	9.22	49.06	9.10	34.55	9.03	52.29	9.02	18.05	10.36
Male	39	34.53	9.14	45.20	9.32	34.53	9.10	37.38	9.22	51.48	9.16	32.93	9.21	51.01	8.92	45.10	8.47
Male	44	40.39	9.23	45.68	9.23	44.86	8.88	38.09	9.01	52.68	9.06	34.20	9.03	62.39	8.99	23.06	9.68
Male	45	46.89	9.31	47.23	9.10	44.76	9.03	33.05	9.13	53.21	9.16	33.81	9.05	52.37	8.86	29.89	9.71
Male	54	44.51	9.28	46.26	9.33	32.62	9.07	36.42	9.16	54.39	9.20	39.18	9.26	54.55	8.94	31.71	9.60
Male	57	48.12	9.17	48.37	8.72	39.16	9.11	43.17	9.17	49.33	9.17	41.82	8.94	55.18	9.22	33.67	9.89
Male	58	42.63	9.22	42.18	9.29	40.10	9.13	34.28	9.05	53.87	9.13	41.29	9.29	45.84	9.09	28.64	8.60
Male	59	46.17	9.46	57.62	9.34	38.18	8.97	39.17	9.20	50.23	9.14	42.26	9.23	55.91	9.06	30.96	8.67
Male	63	42.65	9.23	42.28	9.59	44.84	9.00	38.49	9.02	51.01	9.10	38.72	9.15	39.47	8.92	18.71	8.50
Male	64	44.63	9.11	44.02	9.05	51.82	9.45	40.88	9.12	47.46	9.02	46.35	9.01	49.57	8.87	16.00	9.82
Male	70	33.15	8.50	43.76	9.06	38.08	9.43	52.36	8.91	58.04	8.96	38.35	8.42	45.54	8.55	25.70	8.20
Male	73	46.48	9.59	25.63	8.67	18.85	8.94	55.06	9.63	52.43	9.13	28.23	8.80	35.95	8.56		

Source: Author's Calculations using ACS 2019 Data