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Leveraging Online Social Networks for the Adoption of HIV Pre-Exposure Prophylaxis

By

CHRISTOPHER CALABRESE  
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## **ABSTRACT**

Online social networks have the potential to influence individuals' health, from providing information to influencing beliefs and behaviors. They provide key differences from offline social networks, including the ability to maintain anonymity and make new connections in online support groups. It is important to develop an understanding on how online networks can be leveraged to influence health outcomes. The promotion of HIV pre-exposure prophylaxis (PrEP), which refers to taking a daily oral medicine to reduce the risk of contracting HIV, may benefit from the potential effects and mechanisms that online networks possess. This body of work consists of two comprehensive studies that examine the role of online networks for PrEP adoption.

The first study involves a quantitative content analysis using a theoretically grounded framework to examine Twitter discussions surrounding PrEP from April 2019 to April 2020, six months before and after the approval of Descovy for PrEP. The contents, sources, and sentiments and emotions expressed in tweets were examined. Through the lens of the Theory of Planned Behavior (TPB), I extract the beliefs and barriers that are related to PrEP adoption behaviors. Results indicate, after the approval of Descovy, there was a significant decrease in tweets on barriers to PrEP, specifically relating to access. In addition, there was a significant increase in positive emotions expressed by users. However, the lack of tweets that involve attitudes, norms, and behavioral control prompt a need for future work in addressing these beliefs when promoting the uptake of PrEP. Implications on developing message strategies are discussed.

The second study involves an online, one-week network intervention employed through a mobile app. This field experiment randomly assigned participants into a social support condition or information-only control, where participants are placed into homophilous, clustered networks.

Both conditions involved an information component consisting of messages, guided by TPB, aimed at addressing knowledge, beliefs, and barriers related to PrEP adoption. Social support was operationalized through an online chatting tool where participants can discuss topics surrounding PrEP. Results indicate that the intervention overall increased participants familiarity with PrEP, as well as their knowledge of how much consistent use of PrEP reduces the likelihood of HIV acquisition. Further, the intervention increased participants' intentions and attitudes toward taking PrEP, such that users had higher intentions and more positive views toward starting PrEP after the mobile app intervention.

Overall, these studies illuminate the potential capabilities of online networks to promote positive health behaviors. Assessing online discourse surrounding a health topic may be particularly useful for reaching vulnerable populations. Leveraging online networks to develop interventions can provide researchers and practitioners with the tools to promote healthy behaviors, especially behaviors that are often stigmatized. Theoretical contributions relating to the effects and mechanisms of online networks on health behaviors, as well as the practical implications, are discussed.

## **CHAPTER 1. Online Networks and Health**

## **1.1 Online Networks and Health**

In recent years, there have been an increase in empirical studies that have examined the effects of online networks on health. Research on the influences of online networks stems from previous studies that have examined the effects of social networks, in general, on health. Social networks, referring to individuals and their ties and connections among others, may serve as a powerful tool to influence people's health; there is even evidence that suggests that tapping into one's network is more influential in changing health behaviors than traditional mass media messaging (Zhang et al., 2015).

Causal theoretical mechanisms were previously difficult to uncover because individuals within a social network are interdependent, violating the assumptions of traditional methods. However, longitudinal studies have allowed researchers to examine social networks on health outcomes over time while controlling for confounding factors (Christakis & Fowler, 2007). Further, the causal effects of social networks on health have been tested through recent work with online network experiments (Centola, 2010, 2011), These studies have led to many theoretical advancements relate to social networks.

## **1.2 Related Conceptual Frameworks**

Much theoretical and empirical advancements with social networks and health stems from foundational work in sociology. Durkheim (1897) found that the level of social integration of one's groups played a role in one's suicide. Though not directly attempting to explain the effects of one's ties on health, the piece alludes to a strong case that network ties, and their tie strength, may have an influence on one's health outcomes.

Berkman et al. (2000) developed a conceptual framework for the influences of social networks on health. Social networks, specifically their ties and structure, were shown to



influence individuals' physiological, psychological, and behavioral health through several psychosocial mechanisms (Berkman et al., 2000). Specifically, the authors argued that these mechanisms included social support, social influence, social engagement, physical contact, and access to resources (Berkman et al., 2000).

While Berkman and colleagues' (2000) conceptualization of how social networks influence health has provided a strong foundation for understanding their effects, it does not consider how technology or online contexts play a role in this framework. For example, online networks do not require close physical proximity between ties, and individuals may be able to receive social support through others that are geographically distant from them. With the proliferation of the Internet and social media use in recent years, it is important to explicate how networks online influence health, and why or how these online networks influence individual health outcomes.

### **1.3 Features of Online Networks**

Online networks have many different characteristics that are distinct from traditional social networks. They are often defined through the media or sites in which the individuals are connected. For example, boyd & Ellison (2007) refer to social network sites as an online platform that consists of a profile, a list of connections, and the ability to interact with other connections. Centola (2013) defines two types of online networks, including open social networks and intentionally designed social networks, where the networks are developed for a specific goal. This distinguishes from offline networks since online networks are contained by their web-based platforms.

Another distinction between online and offline networks is that online networks have the potential to provide anonymity (DeAndrea, 2015), removing any potential biases one may have

if faced with an offline network connection. Anonymity allows for online discussions surrounding stigmatized issues that individuals would not feel comfortable to discuss in person. Further, barriers that may inhibit offline networks, such as geographic proximity, are removed through online contexts (Caplan & Turner, 2007). Individuals are not limited to exchange messages within their local community. These differences can make online networks in some ways advantageous compared to offline networks.

#### **1.4 Mechanisms**

Online networks have been examined to influence health through three primary mechanisms: social influence, social capital, and social support (Zhang & Centola, 2019). Social influence refers to how individuals may change their beliefs and behaviors according to the beliefs and behaviors of their close networks (Cialdini & Trost, 1998). In this context, social networks can impact health through social influence. For example, Poirier and Cobb (2012) found that those with network ties were more likely to visit and engage with an online health intervention website in comparison to those without the social network ties. This may indicate that individuals in the intervention viewed their network ties' activities, which prompted them to also engage with the health website.

In addition, social capital has also shown to mediate the relationship between online networks and health. Though there are different definitions among scholars regarding social capital, many refer to social capital as including both the network structure and potential to access resources (Putnam, 2000; Shen et al., 2014). In the context of this paper, social capital refers to the potential and actual resources one can attain from their social connections (Lin, 1999; Zhang & Centola, 2019). An online network's structure influences how individuals can receive resources from their social connections, which then may influence their health. For

example, having a large online network may increase the chances that an individual has a connection with information and resources for PrEP, which may then influence their own adoption of the medication (Kuhns et al., 2017).

Furthermore, social support has also been studied as a mechanism in which online networks may influence health. Social support is also often defined in terms of both structure, such as having close connections, and function, such as the perception or actual support received from others (Barrera, 1986); it has also defined as an aspect of social capital itself (Lin, 1999). This paper conceptualizes social support as the perceived or actual support, usually emotional, that one may receive from their social connections. This makes a clear distinction between the structure of one's social network itself, the perceptions and actions one can receive from the network, and the resulting health impacts that occur from the social support received. Meng et al. (2021) found that among members of cancer support communities, having a larger online network size influenced emotional well-being through perceived informational social support. Surprisingly, the opposite was found for offline networks, where offline network size was negatively related to well-being through informational support (Meng et al., 2021). This further exemplifies some differences that can occur between online and offline contexts, and the potential for online networks to improve health through social support.

### **1.5 Spread of Behavior**

How online networks influence health, including, health information, beliefs, and behaviors, also depends on how the health outcome is spread through the network. The rate at which these processes occur depends on its way of diffusion, such as through simple or complex contagion (Centola & Macy, 2007; Granovetter, 1973). Unlike the spread of diseases which are represented by simple contagion, complex contagion refers to the spread of adopting beliefs or

behaviors depending upon a threshold of social reinforcement (Centola & Macy, 2007). For example, individuals may not believe in vaccination misinformation until they see that their online network peers have those misperceptions. The spread of these beliefs rely on social reinforcement often due to their credibility and legitimacy (Centola & Macy, 2007).

Online networks influence information exposure, exchange, and dissemination, differing from offline contexts due to the decision-making needed before posting or sharing contents. Studies have shown that information diffusion through online networks is dependent on the network structure of users (Lerman & Ghosh, 2010). Lyson et al. (2019) found that online networks influenced participants' awareness of HPV through disseminating information surrounding cervical cancer prevention. In addition, health information exposure can have influences on subsequent behaviors. (Dunn et al. (2017) found that information exposure from Twitter influenced levels of vaccine coverage within the US, where states with Twitter discussions consisting of negative views towards vaccines had lower vaccine uptake.

Furthermore, online networks may influence people's beliefs. Recent work on collective intelligence has found that social learning in decentralized or random networks were more likely to increase accurate estimations than in centralized networks (Becker et al., 2017). Further, social learning among decentralized networks improved individuals' health risk estimations related to climate change and smoking (Guilbeault et al., 2018; Guilbeault & Centola, 2020). For example, the constructed online networks of smokers and non-smokers significantly improved risk perceptions of smoking than perceptions of individuals alone (Guilbeault & Centola, 2020). This advancement contradicts previous notions that social influence hinders the effects of the wisdom of crowds (Galton, 1907), and highlights the potential for online networks.

There has been considerable work on the realm of how online networks influence health behavior. Centola (2010) experimentally tested the effects of network structure on individuals' registration for a health forum. He found that individuals within clustered networks adopted the behavior faster and further than individuals within random networks. The study provided evidence for complex contagion, where behaviors require social reinforcement before individuals adopt them. In another study, Centola (2011) tested the effects of homophily on the adoption of an online diet diary. By defining homophilous networks as those with similar gender, age, and body mass index, he found that those in homophilous networks were more likely to adopt the health behavior than those in unstructured networks. These findings uncover the importance of how clustered structures and homophily play a causal role in influencing the adoption of health behaviors.

Similar research has found through online mobile app data that individuals were influenced to exercise by their peer network's exercise behaviors (Aral & Nicolaides, 2017). The study measured physical activity of individuals and their peers through the use of weather as an instrumental variable to estimate a causal effect of peer influence (Aral & Nicolaides, 2017). Cobb et al. (2016) found that through peer-recruitment, adoption of a smoking cessation app increased, indicating that social influence plays a large role in influencing smoking behaviors. Young et al. (2014) found through a peer-led HIV prevention online program that network ties positively influenced participants likelihood of testing for HIV and retaining and engaging in the health program. This further illustrates the influence of online networks in promoting health behaviors.

More recently, online network interventions have been conducted to examine the effects of online networks on health behaviors. While there have been an overall significant

improvement in health outcomes of social network health interventions, the effects are generally small (Laranjo et al., 2015; Maher et al., 2014; Vereen et al., 2021; Yang, 2017), which may be due to the lack of a strong theoretical frameworks that guide these interventions.

However, some interventions have utilized conceptual frameworks that tie online networks and health with success. Zhang et al. (2016) tested whether social support or social comparison increased physical activity among online networks in a field experiment. It was found that leveraging social comparison was more effective in increasing attendance to exercise classes, indicating that social comparison may have been the key mechanism that linked online networks with physical activity. Further work with online network interventions is needed to uncover the main effects and mechanisms by which online networks influence health behaviors, from socially desirable behaviors like physical activity to stigmatized behaviors like PrEP adoption and adherence for HIV prevention.

## **CHAPTER 2. Promoting the Adoption of Pre-Exposure Prophylaxis**

## 2.1 Pre-Exposure Prophylaxis

In 2020, roughly 1.5 million people worldwide became infected with HIV (Joint United Nations Programme on HIV/AIDS, 2021). While there is still a search for a cure, public health professionals have focused their efforts on prevention, such as promoting abstinence, condom use, and more recently, PrEP uptake. Pre-exposure prophylaxis (or PrEP) refers to taking a daily oral medicine to reduce the risk of contracting HIV, commonly known by the brand name Truvada or Descovy. PrEP (as Truvada) has shown to be an effective additional preventative measure for reducing the risk of HIV transmission among men who have sex with men (MSM) and transgender women (Grant et al., 2010; Molina et al., 2015), heterosexual individuals (Baeten et al., 2012; McCormack et al., 2016; Murnane et al., 2013; Thigpen et al., 2012), and people who inject drugs (Choopanya et al., 2013). Because of the effectiveness of PrEP and potential to decrease the rates of HIV infection worldwide, it is important to develop interventions to educate, provide, and sustain PrEP use among these high-risk populations.

There are several barriers that impede efforts to improve PrEP care for HIV prevention. These include societal barriers of HIV-related stigma (Golub, 2018; Oldenburg et al., 2015), structural barriers related to access and costs (King et al., 2014), and individual and community-level barriers related to adherence (Corneli et al., 2016). For example, trials in South Africa failed to show that PrEP was effective because of low adherence to the medicine due to false perceptions and community stigma against HIV (van der Straten, Stadler, Luecke, et al., 2014; van der Straten, Stadler, Montgomery, et al., 2014). Addressing all levels of PrEP care is necessary to improve HIV prevention efforts.

Nunn et al. (2017) defines three major levels to address within this PrEP care continuum: awareness, uptake, and adherence and retention. This dissertation focuses on examining the



behavioral determinants that lead to the initiation of PrEP. It important for public health professionals to tackle this first step through educating and bringing awareness of the medication to individuals who are at a high-risk for contracting HIV infection.

The adoption rates of PrEP are relatively low and vary by racial groups. Among the estimated 1.2 million eligible for PrEP in the US, only 18.1% of those individuals were prescribed in 2018 (Harris et al., 2019). Further, while 42.1% of eligible White individuals were prescribed with PrEP, only 5.9% of Black/African American and 10.9% of Hispanic/Latino eligible individuals have been prescribed (Harris et al., 2019). There is currently no data on the proportion of PrEP coverage by transmission type; however, the most recent study estimated that roughly 813,970 MSM individuals, 258,080 at-risk heterosexual individuals, and 72,510 persons who inject drugs are considered eligible to initiate PrEP (Smith et al., 2018). There is a substantial need to address these disparities as well as further improve the levels of PrEP adoption among those who are at risk for HIV infection.

## **2.2 Theoretical Frameworks for PrEP Adoption**

Some studies addressing PrEP adoption follow the information-motivation-behavioral skills (IMB) model (Dubov et al., 2018; Fisher et al., 2009). This framework highlights several behavioral determinants that influence PrEP initiation. While not the primary goal of the model, no causal pathway or mediation between these constructs have been tested. In addition, the IMB model has several similarities with other health behavior change models and may not be advantageous compared to them (Champion & Skinner, 2008; Fishbein & Ajzen, 2011).

This dissertation utilizes the Theory of Planned Behavior (TPB) (Fishbein & Ajzen, 2011) as the theoretical framework that guides both studies in message coding and message construction. TPB is an advantageous model because it addresses the specific constructs that may

influence behavior change. The model posits that an individual's attitudes, perceived norms, and perceived behavioral control may influence their intention to conduct a behavior, which in turn may influence one's actual behavior (Fishbein & Ajzen, 2011). An individual's attitude refers to their positive or negative evaluation of conducting a behavior (Fishbein & Ajzen, 2011).

Perceived norms refer to one's perception of other's expectation of them performing a behavior (injunctive norm) or one's perception of other's performing a behavior (descriptive norm) (Fishbein & Ajzen, 2011). Perceived behavioral control refers to one's view on their capabilities of performing a behavior (Fishbein & Ajzen, 2011). In addition, the model posits that other factors may directly influence behavior change, including knowledge and environmental constraints (Fishbein & Ajzen, 2011). Environmental constraints can include barriers such as costs and access, as well as stigma.

While some studies have examined PrEP adoption and adherence behaviors utilizing TPB as a theoretical framework (Dai & Calabrese, 2021; Dai & Harrington, 2020), future research is necessary to gauge the currently beliefs and barriers related to PrEP and utilize the framework to guide message development and interventions.

### **2.3 Online Interventions for PrEP Adoption**

With PrEP being a new addition for HIV preventative programs, there have been a few interventions that specifically target its adoption or initiation. PrEP Chicago is a current social network intervention with a focus to increase the adoption of PrEP among young Black MSM (L. E. Young et al., 2018). The intervention itself involves workshops to increase knowledge about PrEP and to increase people's communication with others about PrEP. To gather participants, snowball sampling was conducted, where they identified key influencers in the community, and instructed them invite six peers to the study, of which each new participant would refer six more

(L. E. Young et al., 2018). Young and colleagues (2018) infer that this type of peer-referral intervention will improve PrEP adoption through several mechanisms, such as social influence and social support. Though not the primary goal of the study, the intervention cannot identify the main theoretical mechanism that influences this adoption behavior. Identifying the key mechanism that facilitates behavior change among these populations is key to conduct interventions efficiently and effectively, especially with limited resources.

Another intervention that is currently undergoing for the adoption of PrEP is the E-PrEP study for young Black and Latino gay and bisexual men (Patel et al., 2018). With diffusion of innovations theory (Rogers, 2010) as a framework, this intervention focuses on training peer leaders, members of the community with a large number of friends, to deliver PrEP informational and educational materials to participants through private Facebook groups. These materials aim to educate, motivate, and increase one's skills surround PrEP, guided by the IMB model (Fisher et al., 2009). While this study utilizes social media to both recruit hard-to-reach populations and run the intervention online, it is unclear of which effect is the primary driver for influencing people's adoption of the behavior. Several confounding factors could play a role in influencing these peers' behaviors within groups of varying levels of homophily and interpersonal attraction, as well as varying levels of social influence from their peer leaders. This lack of control for many potential influencing factors may hinder the results of the intervention.

#### **2.4 Limitations of Extant Literature**

The theoretical processes behind how these online interventions influence PrEP adoption remain unclear. Current online interventions utilize several different theories to inform their message designs and lessons. Because many of these interventions are practical in nature rather than theoretical, they may suffer from lacking the potential benefits of having an established

theoretical framework, such as TPB (Fishbein & Ajzen, 2011) or the conceptual framework of social integration and health (Berkman et al., 2000), to inform their studies. Furthermore, beyond message construction, several factors related to the online networks themselves remain untested. Research is necessary to fully understand how these online interventions can influence the adoption of PrEP.

Though network interventions have been used for PrEP adoption to some degree, they have not been utilized to their full potential. Using participants' social networks for recruitment can influence participants to further adopt safer behaviors but can also backfire without adequate control. In addition, the effects of these network interventions can be conflated with other confounding variables. The current studies do not isolate the potential causal effects that online network experiments can provide. Future research is needed to uncover the exact mechanisms that drive behavior change and experimentally test the effects of the intervention components.

Online network interventions may provide a strong solution for future work in PrEP adoption. They have the ability to facilitate anonymous social support through artificially constructed, homophilous, clustered networks. This controlled environment provides the optimal conditions for participants to receive social support from their peer networks without any outside influences that could hinder the effects on health outcomes. Theoretical implications can be derived from these causal studies, which can further aid in the development of future interventions to improve the adoption of PrEP.

The following chapters involve two comprehensive studies with the goal of developing a theoretically driven online intervention to improve intentions to start PrEP. First, I examine the current landscape of individuals' perceptions of PrEP on Twitter (Chapter 3) through the lens of TPB. Then, I develop an online network intervention experiment utilizing messages informed by

TPB while also isolating the effects of the networks by artificially constructing peer group networks (Chapter 4). In addition, I examine the potential mediating role of social support. Lastly in Chapter 5, I provide a general discussion of the findings of the two comprehensive studies and discuss theoretical and practical implications, as well as future work for communication scholars and public health professionals.

## **CHAPTER 3. Perceptions of HIV Pre-Exposure Prophylaxis on Twitter**

## **ABSTRACT**

HIV pre-exposure prophylaxis (PrEP) is a preventative strategy that involves taking a daily, oral medication to reduce the risk of contracting HIV. Advancements in recent years may have changed the ways in which PrEP is discussed, sparking new concerns surrounding its effectiveness and accessibility. I conducted a quantitative analysis to examine the contents, sources, and sentiments and emotions expressed in Twitter discussions surrounding PrEP from April 2019 to April 2020, six months before and after the approval of Descovy for PrEP. Coding for tweet contents were guided by the Theory of Planned Behavior. Results indicate, after the approval of Descovy, there was a significant decrease in tweets on barriers to PrEP, specifically relating to access; further, information significant increased after the approval. Individual users made up of 75% of messages surrounding PrEP. Sentiment analyses found a significant increase in positive emotions expressed after the approval of Descovy. However, there was a lack of tweets that involve attitudes, norms, and behavioral control, prompting a need for future work to addressing these beliefs when promoting the initiation and uptake of PrEP.

### 3.1 Introduction

HIV pre-exposure prophylaxis, or PrEP, is a preventative strategy that involves taking a daily, oral medication to reduce the risk of contracting HIV. Though this method has shown to be effective in preventing HIV acquisition in several clinical trials (Baeten et al., 2012; Choopanya et al., 2013; Grant et al., 2010, 2014; McCormack et al., 2016; Molina et al., 2015, 2017; Thigpen et al., 2012), PrEP uptake is still relatively low (Harris et al., 2019). For example, a recent national survey found that only 7.8% of eligible sexually active gay and bisexual men were taking PrEP. Thus, there is a need to promote PrEP among populations disproportionately affected by HIV through the development of message strategies that address the beliefs and concerns surrounding the medication.

With most US adults on social media (Auxier & Anderson, 2021), examining online discussions surrounding new issues may be useful for assessing people's attitudes and opinions. Especially regarding stigmatized behaviors like PrEP adoption, assessing online discourse can provide naturalistic data that evades the social desirability biases that often come with traditional survey measures (Babbie, 2016). Further, examining online behavioral data may be advantageous to reach individuals and populations that may otherwise be difficult to contact when using traditional methodologies. Since roughly 42% of young adults ages 18 to 29 use Twitter (Auxier & Anderson, 2021), examining discussions on the social media platform can provide the information necessary to understand the current discourse surrounding PrEP.

To further illustrate the need to examine online discussions surrounding PrEP, the HIV National Strategic Plan for the United States 2021-2025 (U.S. Department of Health and Human Services [HHS], 2021) has prioritized several target goals; the first focusing on preventing new HIV infections. For example, the HHS has proposed strategies to increase the public's awareness



of HIV, including developing prevention messages and campaigns that are clear, appropriately tailored, and reflect recent advancements in science. Further, it is suggested that these campaigns are created specifically to be spread through either traditional or social media by expert organizations and influencers. Because of the growing developments relating to PrEP, as well as the increasing need to develop tailored, up-to-date messaging, further investigation on the current discourse surrounding PrEP is needed.

This study examines discussions involving PrEP on Twitter six months before and after the Food and Drug Administration's (FDA) approval of Descovy for PrEP (U.S. Food and Drug Administration, 2019). With an additional option for PrEP, it is essential to examine people's beliefs toward the medication, as well as the barriers that impede individuals from taking PrEP. This can aid in guiding researchers and public health professionals to promote its use to the populations most at risk of contracting HIV. To examine these beliefs and barriers, the present study utilizes the Theory of Planned Behavior (TPB) as a coding framework for analyzing the tweet contents. In addition, I investigate the sources of these messages to provide a deeper picture in how individuals or organizations may promote PrEP. Lastly, I examine the sentiment and emotions expressed within the Twitter posts to understand whether users had favorable or unfavorable views toward PrEP. Findings from this study will help guide future interventions and campaigns in developing relevant and theoretically driven message strategies to promote initiation and uptake of PrEP.

### **3.2 Literature Review**

Daily, oral PrEP was first approved by the FDA in 2012 (Centers for Disease Control and Prevention [CDC], 2012), under the brand name Truvada, as a medication to prevent HIV transmission among those who may be at-risk for contracting HIV. In 2014, the CDC later

published clinical guidelines for PrEP, offering more specific criteria for prescribing PrEP, as well as advice on how to promote and support those who take the medication (CDC, 2014).

While PrEP has a potential game-changer for HIV prevention, there have been several barriers to initiate PrEP, including its costs and accessibility (Bauermeister et al., 2013; Grov et al., 2015), as well as the stigma surrounding taking an HIV medication that can be falsely perceived as promoting “promiscuity” (S. K. Calabrese & Underhill, 2015).

Several advancements since the initial endorsement of PrEP may have changed the ways in which PrEP is perceived by the general public. While only 18.1% of eligible PrEP users have ever been prescribed the medication, there has been an increase in prescriptions over the past few years (Harris et al., 2019), which may indicate that people’s knowledge and awareness of PrEP has shifted. For example, among a probabilistic national sample of gay and bisexual men, PrEP uptake increased to about 7.8%, while familiarity increased to roughly 92% (Holloway et al., 2020). With many studies finding that awareness is a common barrier to PrEP use (Eaton et al., 2017; Garnett et al., 2018; Marcus et al., 2019), as the general public becomes more familiar with the medication, their beliefs surrounding PrEP may change and become more favorable.

Furthermore, the FDA recently approved another medication, Descovy for PrEP, among men and transgender women who have sex with men (FDA, 2019). This additional medication to prevent HIV may have sparked new concerns surrounding its effectiveness and accessibility. Thus, it is important to understand the current discourse on PrEP: what type of contents are currently most salient, who are posting these contents, and what are the general sentiments and emotions expressed within these discussions. Further, assessing the current barriers to PrEP will allow researchers to focus their resources on the more relevant environmental constraints. This

understanding will provide the information necessary for health professionals to further tailor their intervention materials and better address the needs and concerns of the population.

### **Social Media and PrEP**

Since the FDA approval of Truvada for PrEP in 2012, there have been several studies examining the online discourse surrounding PrEP (An et al., 2014; Chan et al., 2021; Hannaford et al., 2018; Hill et al., 2018; Kecojevic et al., 2018, 2020; McLaughlin et al., 2016; Schwartz & Grimm, 2017; Walsh-Buhi et al., 2021). For example, Kecojevic et al. (2018) conducted a content analysis of the 217 most viewed YouTube videos involving PrEP in 2016. The authors found that over 83.4% were promotional videos for PrEP uptake; however, there were a smaller number of videos that discussed potential barriers to PrEP such as access, costs, side effects, or its safety (Kecojevic et al., 2018). Roughly 29.0% of the videos were created by individuals who use PrEP, while the remaining majority were posted by medical, community, or news organizations (Kecojevic et al., 2018). In addition, Walsh-Buhi et al. (2021) analyzed 250 Instagram posts related to PrEP from April 2019 to April 2020, and found that the majority of the posts provided a definition of what PrEP was, but less than 40% promoted the medication's use or effectiveness. Organizations consisted of 77.2% of all post creators and were more likely to discuss information on how to use PrEP than individual posters; however, individuals were more likely to post about potential side effects (Walsh-Buhi et al., 2021).

Previous research has examined PrEP on Twitter when the FDA first approved Truvada in 2012 (An et al., 2014; McLaughlin et al., 2016), and when the CDC endorsed PrEP in 2014 (Schwartz & Grimm, 2017). Through an analysis of 774 English tweets posted from November 5 to December 27, 2012, McLaughlin et al. (2016) found that negative affective tone was associated with the spread of PrEP messages, indicating that tweets with a negative tone were

more likely to be reposted on Twitter. Within the content of the tweets, about 21.6% specified the target populations for PrEP, 10.2% discussed the effectiveness of the medication, and 6.8% revolved around moral judgements surrounding its use (McLaughlin et al., 2016). Further, in contrast to findings on YouTube and Instagram, about 60.2% of the tweets were made by individuals, while the rest varied between nonprofit, academic, commercial, or news organizations (McLaughlin et al., 2016).

Among the top tweets relating to PrEP, Schwartz and Grimm (2017) analyzed the contents of roughly 1,093 tweets between May 2013 to 2015. The authors found that over half the tweets provided information about PrEP, while 14.7% focuses on barriers to PrEP, 13.6% involved the limitations of PrEP (e.g., does not protect against other STIs), 8.8% were tweets voicing against stigma, and 5.6% included stigmatizing tweets (Schwartz & Grimm, 2017). Barriers against PrEP were relatively matched with arguments challenging them, and included costs, access, side-effects, and adherence (Schwartz & Grimm, 2017). For example, the number of tweets discussing cost as a barrier to take PrEP were relatively equal to the number of tweets arguing about its affordability, potential creating a sense of uncertainty about PrEP among Twitter users. In addition, 56% of posts were sent by individuals, while the remaining were from organizations (Schwartz & Grimm, 2017).

While these studies provide a broad overview of several social media platform discussions surrounding PrEP, further investigation is needed as scientific advancements and public views toward PrEP may change over time. For example, with the addition of Descovy, there have been no studies to our knowledge that specifically utilized the keyword for examining perceptions of the medication online. In addition, to provide a deeper understanding of users' perceptions of PrEP, further study is necessary to examine large or complete datasets that are

representative of the social media platform. Rather than examining a small sample of posts, examining the full dataset of posts or tweets may provide a more accurate depiction of online discourse surrounding a topic. Lastly, further research is necessary to examine individuals' beliefs and barriers to PrEP through a theoretically driven approach. In this way, researchers and public health professionals can focus on the specific theoretical constructs that predict behavior change, and further develop messages strategies based on the concerns and needs mentioned by social media users.

### **Theory of Planned Behavior**

The Theory of Planned Behavior (TPB) is a behavior change model that provides an excellent framework for examining individual's perceptions of PrEP (Fishbein & Ajzen, 2011). TPB posits that one's attitudes, perceived norms, and perceived behavioral control may influence one's intention to perform a behavior, which in turn, will lead to the behavior (Fishbein & Ajzen, 2011). An attitude can be defined as one's positive or negative evaluation of a behavior (Fishbein & Ajzen, 2011). For example, if an individual believes that PrEP is a good medication and is useful, the individual will have a positive attitude toward PrEP. Perceived norms can be defined as either injunctive or descriptive norms: injunctive norms refer to whether one believes others would expect them to perform a behavior, and descriptive norms refer the perception of whether others are performing a behavior (Fishbein & Ajzen, 2011). For example, if someone believes others would expect them to take PrEP, that person would have a high perceived injunctive norm; whereas, if someone believes that most of their friends are taking PrEP, then that person would have a high perceived descriptive norm. Perceived behavioral control refers to whether one believes they have the ability or confidence to perform a behavior (Fishbein & Ajzen, 2011). For example, if an individual does not believe that are able to take PrEP consistently every day,

they would have low perceived behavioral control. Intention refers to one's inclination to perform an behavior (Fishbein & Ajzen, 2011), such as one's believe that they are likely to start taking PrEP. Intention is the most direct belief toward actual behavior.

In addition to beliefs, there are other factors that may influence behavior. First, knowledge or awareness may play a direct role in influencing one's behaviors (Fishbein & Ajzen, 2011). For example, without the knowledge of HIV or PrEP, one may not be inclined to take the medication. Lastly, and one of the most important, environmental constraints may impede one from performing a behavior. As previously mentioned, barriers such as costs, access, and stigma may all prevent individuals from taking PrEP (Bauermeister et al., 2013; S. K. Calabrese & Underhill, 2015; Grov et al., 2015).

Because of the comprehensive nature of this theoretical model for behavior prediction, it provides an excellent framework to analyze the beliefs surrounding online posts relating to PrEP. Previous work has utilized TPB as a theoretical framework as a guide for content analyses on reddit discussions on bone marrow donation (O'Donnell & Guidry, 2020). For this study, I focus on six distinct theoretically derived constructs: attitudes, norms, behavioral control, intention/behavior, knowledge/awareness, and actual barriers. Through analyzing these different dimensions of the behavior model, researchers can pinpoint which constructs are necessary to focus on in future interventions. Thus, the following research questions are proposed:

RQ1. Which behavioral predictors of TPB are discussed on Twitter?

RQ2. Which barriers are most discussed on Twitter?

### **Source Characteristics**

In addition to beliefs expressed online, another primary component of Twitter posts is the source. Expert sources may be influential in disseminating information, and source credibility

has shown to be a persuasive cue compared to sources with low credibility (Pornpitakpan, 2004). However, individuals can give personal narratives with compelling stories that may impact one's behaviors (Kecojevic et al., 2020; Surian et al., 2016; Zhang et al., 2019). For example, Zhang et al. (2019) experimented tested whether organizational versus informational online posts relating to cervical cancer were more likely to be shared, and found that organizations posts were more likely to be shared.

Further, while source type may influence one's behaviors and beliefs associated with those behaviors, providing a full picture of the current discourse surrounding PrEP will allow researchers and practitioners to have a baseline understanding of which actors are involved in online media. Previous research has found that over half of the tweets related to PrEP were from individuals rather than organizations (McLaughlin et al., 2016; Schwartz & Grimm, 2017). As PrEP becomes more known by the public, it is important to understand whether the source types have shifted over time. The following research question is proposed:

RQ3. What type of source is more likely to include TPB constructs in their discussions?

### **Sentiments and Emotions**

Lastly, I am interested in examining the sentiment of Twitter discussions surrounding PrEP over time. Previous work has examined sentiments of online posts for various health and science topics, including vaping (Martinez et al., 2018), HPV vaccination (Kearney et al., 2019; Massey et al., 2020; Zhang et al., 2021), and gene editing (C. Calabrese et al., 2019, 2020). To our knowledge, research examining PrEP discussions on Twitter have yet to specifically measure both the expressed sentiments and emotions.

Messages that express certain sentiments or emotions may have an impact on individuals' beliefs toward a health topic; for example, a negative sentiment toward PrEP may deter others

from becoming willing to start taking the medication. It is also important to understand how Twitter users feel about PrEP, and whether future work is needed to further promote the positive aspects of the preventative medication. Thus, I propose the research question:

RQ4. What are the sentiments and emotions expressed on PrEP discussions?

### **Approval of Descovy**

Lastly, this study examines the contents, sources, and sentiments and emotions of tweets related to PrEP before and after the approval of Descovy. The addition of another medication for PrEP, though only approved for MSM and transgender women, may change the ways in which PrEP is discussed, who are discussing PrEP, and the general sentiments and emotions expressed. Previous research has found that the contents and sentiments of discussions surrounding health and science topics may change after news or large events (C. Calabrese et al., 2020; Guidry et al., 2020). Thus, I propose the final research question:

RQ5. How do the contents, sources, and sentiments and emotions change after the approval of Descovy?

## **3.3 Methods**

### **Data Collection**

I conducted a quantitative content analysis to examine Twitter discussions surrounding PrEP from April 2019 to April 2020, six months before and after the approval of Descovy (FDA, 2019). Using the R package *twint* (Zacharias, 2020), a comprehensive list of English-language tweets was collected with the search terms “pre-exposure prophylaxis,” “Truvada,” and “Descovy,” as well as the hashtag “#PrEP.” These hashtags were utilized based off of search terms used in previous research (McLaughlin et al., 2016; Schwartz & Grimm, 2017), as well as a preliminary search on Twitter. The hashtag “PrEP” was chosen over the keyword “PrEP,”



because the vast majority of search results for the keyword were unrelated (e.g., meal prep). Only original tweets were collected (retweets were excluded from analysis). After the removal of duplicates, there were 16,138 tweets that resulted.

### **Coding Framework and Analysis**

For the content analysis, I conducted systematic random sampling where every 16<sup>th</sup> tweet was selected. The resulting sample of 1,008 tweets was manually coded based on our codebook. A coding framework was developed based on the theory of planned behavior (Fishbein & Ajzen, 2011); see Table 3.1 for categories and frequencies. The coding categories include attitudes, norms, perceived behavioral control, intention/behavior, information/knowledge, and barriers. Among barriers, costs, access, issues with the pharmaceutical companies, and stigma were coded. These barriers were chosen based off previous research (McLaughlin et al., 2016; Schwartz & Grimm, 2017).

Source type was coded as either an individual or organization. For example, LGBT News and CDC were coded as organizations, while accounts with full names (including public figures) were coded as individuals. Previous work has separately categorized different organizations, such as news media and community based organizations (McLaughlin et al., 2016; Schwartz & Grimm, 2017; Walsh-Buhi et al., 2021); however, this study examines organizations as one category to make meaningful comparisons for analyses.

After pretesting and training, two coders independently coded 20% of the sample and achieved a satisfactory inter-coder reliability (Cohen's kappa ranging from .8 to .91) (McHugh, 2012). The coders then coded about 400 remaining tweets each. Chi-squared tests were conducted to examine differences before and after the approval of Descovy, as well as

differences by source type. For content categories with expected values less than five, I conducted Fisher's exact tests.

### **Linguistic Analysis**

I ran Linguistic Inquiry and Word Count (LIWC) to examine the sentiment of all 16,138 tweets; LIWC is a validated dictionary-based analysis software that provides the emotions and sentiments of words in a message (Pennebaker et al., 2015; Tausczik & Pennebaker, 2010). To obtain the positive and negative emotions expressed in the tweets, LIWC outputs the percentage of positive and negative emotion words within each tweet; this allows us to control for word count. Several studies have utilized LIWC to examine the expressed emotions and sentiments of online health discussions (Rains et al., 2021; Zhang et al., 2021). For example, Zhang et al. (2021) examined the emotion and sentiments expressed by public Facebook groups and pages relating to the HPV vaccine. To examine differences between emotional language used before and after the approval of Descovy, I conducted Welch's t tests, which account for unequal variances and sample sizes.

Lastly, subsequent analyses were conducted to ensure the findings were robust. Mann Whitney U tests were conducted to provide stricter criteria for all comparisons. Further, I also used Botometer (Sayyadiharikandeh et al., 2020) to classify tweets that were likely created by bots and re-ran all analyses. Except for one finding, there were no significant differences between the "no bot" and regular sample results. The results can be found in the Appendix. All analyses were conducted in SPSS Version 27.

### **3.4 Results**

Figure 3.1 depicts the number of tweets that mentioned PrEP over time by month. There were about 8,402 tweets before the approval of Descovy and 8,097 tweets posted after the

approval. Aside from the sentiment and emotion analyses, the following results are based on the systematic random sample of coded tweets.

Overall, most of the tweets posted on PrEP were related to barriers (38.2%). Among the barriers, 36.6% were related to costs, 36.4% focused on accessibility, 21.3% delved into issues related to the pharmaceutical companies, and 5.7% related to stigma and stigmatizing tweets. Roughly 25.8% of tweets discussed information or knowledge about PrEP, while 7.9% expressed PrEP uptake behaviors or intentions. Lastly, only 6.2% expressed attitudes toward PrEP, 1.2% discussed norms supporting PrEP, and 1.7% discussed behavioral control with taking PrEP. For source type, most of the tweets were composed by individuals (74.9%), while organizations consisted of about one fourth of the tweets.

Regarding the sentiments expressed in the full sample of tweets, the average percentage of positive emotion expressed was 2.01 (SD = 3.06), while the average negative emotion expressed was 1.34 (SD = 2.66). For the three discrete emotions, the average percentage of emotion expressed was .33 (SD = 1.0) for anxiety, .34 (SD = 1.44) for anger, and .21 (SD = .96) for sadness.

## **Comparisons by Time Period**

### ***TPB Constructs and Source Type***

The results of the content analyses comparing differences between time periods can be found in Table 3.2. I found that there was a significant decrease in barriers discussed after the FDA approval of Descovy,  $\chi^2(1, N = 1008) = 26.57, p < .001$ . Furthermore, the number of informational posts increased after the FDA approval,  $\chi^2(1, N = 1008) = 9.10, p = .003$ . There were no significant differences in tweets for attitudes, norms, behavioral control, or intention/behavior.

Among the specific barriers (See Table 3.3), there was a significant decrease in posts regarding access to the medication  $\chi^2(1, N = 385) = 5.15, p = .023$ . There were no significant differences in cost, issues with the pharmaceutical companies, and stigma.

In addition, there were no differences between individual and organizational posts after the approval of Descovy.

### ***Sentiments and Emotions***

Compared to before the FDA approval of Descovy ( $M = 1.72, SD = 2.91$ ), the percentage of positive emotion significantly increased ( $M = 2.11, SD = 3.27$ ),  $t(15944.10) = -7.96, p < .001$ . There was no significant difference in expressed negative emotion. For discrete emotions, the percentage of anger expressed in tweets decreased from before ( $M = .43, SD = 1.70$ ) to after the FDA approval ( $M = .33, SD = 1.44$ ),  $t(15686.81) = 4.03, p < .001$ . There were no significant differences in anxiety or sadness.

### **Comparisons by Source Type**

#### ***TPB Constructs***

Table 3.4 compares the TPB constructs by source type. Among organizational tweets, information (44.7%) and barriers (40.3%) were most discussed, while less than 2% of the tweets discussed attitude, norms, behavioral control, or intention/behavior. Similarly, most individual tweets discussed barriers (37.5%) and information (19.3%), while roughly 10.1% of the tweets discussed intention/behavior, 8.1% discussed attitude, 2.1% discussed behavioral control, and 1.2% discussed norms.

Individuals discussed their attitudes toward PrEP ( $\chi^2(1, N = 1008) = 19.38, p < .001$ ) and PrEP uptake behaviors or intentions ( $\chi^2(1, N = 1008) = 18.67, p < .001$ ) significant more than organizations. However, organizations provided a significantly higher number of informational

tweets ( $\chi^2(1, N = 1008) = 62.84, p < .001$ ) than individuals. There were no differences between the two source types for norms and behavioral control, as well as barriers.

When examining specific barriers, individuals were more likely to post about the costs of PrEP,  $\chi^2(1, N = 385) = 6.16, p = .013$ , and stigma associated with PrEP,  $\chi^2(1, N = 385) = 5.77, p = .016$ , compared to organizations. However, organizations were more likely to post about issues with the accessibility of PrEP,  $\chi^2(1, N = 385) = 12.81, p < .001$ . There were no differences in source type with regard to issues with pharmaceutical companies.

### ***Sentiments and Emotions***

Individual posters expressed a higher percentage of positive emotion words ( $M = 2.22, SD = 3.29$ ) compared to organizations ( $M = 1.48, SD = 2.18$ ),  $t(654.09) = -3.95, p < .001$ . However, there were no significant differences in negative emotion by source type.

Organizations expressed significantly more anxiety ( $M = .45, SD = 1.17$ ) than individual posters ( $M = .29, SD = .94$ ),  $t(366.92) = 1.97, p = .049$ . There were no significant differences between individuals and organizations for anger or sadness.

## **3.5 Discussion**

This study examined the content and sources of tweets related to PrEP through a systematic random sample of tweets, as well as the sentiments expressed within all tweets that mentioned PrEP between April 2019 to April 2020. By examining these three main features of the social media posts, researcher can identify key socio-behavioral factors that may influence behavior change, specifically relating to PrEP uptake. Further, there were several differences before and after the approval of Descovy.

Overall, about 38.2% of tweets discussed related to barriers to PrEP, among which costs and access were most discussed. Our results indicate after the approval of Descovy, there was a

significant decrease in the discussions surrounding barriers to PrEP; specifically, there was a decrease in posts regarding issues with access. Despite this reduction, a large proportion of posts still discussed barriers after the FDA approval. Barriers directly hinder people's ability to start taking PrEP and adhere to the medication.

Most of the barriers discussed refer to costs, access, and issues related to the pharmaceutical companies. There are several federal and state assistance programs that provide individuals with the medication at a significantly reduced cost. For example, the "Ready, Set, PrEP," program will provide the medication at no costs for those who are uninsured. However, there are different eligibility criteria and several steps to enroll in a program, and many of these programs do not also cover the required laboratory tests and clinical visits. Public health practitioners should focus on providing information to the public on how to afford PrEP and access these resources. Further, efforts should also focus on reducing cost barriers not directly related to the medication, including lab and clinic visits. The decrease in tweets relating to access issues serves as a positive sign, especially with generic versions of PrEP now available (Highleyman, 2020, 2021), but future work must be done to reduce barriers for those who need the medication the most.

The percentage of positive emotion words in PrEP discussions significantly increased after the approval of Descovy, indicating that continuing to increase access to the medication may be viewed favorably by Twitter users. In addition, anger decreased after the approval of Descovy, potentially indicating that individuals may feel some relief after having an additional option to access PrEP. The changes after the approval of another medication serves as an example that increasing access to a medication can really have a large positive impact, and

further illustrates the need for policies to enable individuals to obtain PrEP and eliminate barriers.

Compared to organizations, individuals were more likely to discuss their attitudes and intentions surrounding PrEP and less likely to post informational tweets. While this makes intuitive sense, organizations should start developing messages that are tailored toward people's beliefs to promote PrEP adoption. With TPB as the guiding framework for the study, having messages relating to attitudes, norms, or behavioral control may contribute to behavior change. For example, messages that indicate that most gay and bisexual men have favorable attitudes toward taking PrEP may be helpful in promoting the medication to the public.

Further, individuals were more likely to express positive emotion compared to organizations, while organizations were more likely to express anxiety. This may partially be due to the language used when organizations are communicating about the risks of contracting HIV. However, organizations should pay particular attention on how they are constructing their messages to ensure that they are showing PrEP in a favorable light, rather than a neutral or negative tone.

While the discussion of barriers was no different between individuals and organizations, among specific barriers, individuals were more likely to discuss the costs and stigma related to PrEP, while organizations were more likely to discuss access to PrEP. Organizations should continue their efforts in addressing the costs of the medication, as well as addressing the stigma associated with HIV-preventive behaviors. Promoting PrEP should be one part of an organization's HIV prevention toolkit; comprehensive efforts with messaging that includes condom use, HIV testing, PrEP uptake, and HIV stigma would be very beneficial.

Lastly, there was a lack of tweets that involved attitudes, norms, and behavioral control. This sparks a need for future work in addressing these beliefs in relation to PrEP uptake. For example, interventions that harness social influence may be particularly helpful for promoting PrEP. Attitudes, norms, and behavioral control are three primary socio-behavioral factors that influence behavior change, and future research should focus on developing message strategies that address these beliefs.

### **Limitations and Future Directions**

There are several limitations to this study. First, this study examines perceptions of PrEP through only one social media platform during one time point. Twitter is not a representative sample of the general public (Wojcik & Hughes, 2019), nor is it representative of the social media landscape. Further research is necessary to understand perceptions of PrEP in other online contexts, such as anonymous support forums and groups. I also did not content analyze the images and videos that may be attached to tweets; however, it is believed that the initial focus of the social media platform is to convey short text-based messages to audiences and an analysis of the texts in tweets may be ideal. Previous work has examined the contents related to PrEP on image and video-based platforms such as Instagram and YouTube (Kecojevic et al., 2018, 2020; Walsh-Buhi et al., 2021). In addition, while the study focused on the differences before and after the approval of Descovy, future work should examine perceptions of PrEP over time as new advancements in HIV prevention develop. Lastly, the study utilized LIWC (Pennebaker et al., 2015), a dictionary-based tool to assess expressed emotions and sentiments. While the software has been validated in previous studies, recently developed new machine learning tools may provide a more sophisticated output for sentiments expressed in messages. Despite these limitations, findings from this study provide a detailed analysis of the perceptions, sentiments,



and emotions of Twitter discussions surrounding PrEP, as well as the sources that disseminate these tweets, which will help inform future interventions for promoting PrEP.

### **3.6 Conclusion**

This study examined the contents, sources, and sentiments and emotions of PrEP discussions on Twitter over a one-year time period. I found that the number of tweets discussing barriers decreased after the approval of Descovy, specifically relating to the accessibility of the medication. However, barriers still dominated the discussion of PrEP overall. With recent news regarding the availability of generic PrEP, health practitioners should continue focusing on reducing barriers to PrEP. Further, the number of tweets related to attitudes, norms, and behavioral control were limited on the platform, especially from organizational sources. Health communication researchers should focus on developing message strategies that target these constructs to promote the adoption of PrEP among key target populations. By examining the discussions through the lens of TPB, one can pinpoint specific beliefs related to behavior change, which may better inform future health interventions.

**Table 3.1***Coding Categories and Examples*

Category	Definition	Example
TPB Construct Attitude	Positive or negative evaluation of PrEP.	Stupid ass Truvada is causing these really annoying headaches at night.
Norm	Perception of what others expect people take PrEP or what others are taking PrEP.	Many of us have already been switched, @GileadSciences CEO reported that already 25% of PrEP pts are on Descovy rather than Truvada. This is consistent with what @PrEP4AllNow has found, with Descovy Rx's surging more than 70% since Descovy was FDA approved back in October.
PBC	Perceptions of the level of control or capabilities for taking PrEP.	That's where you make empowered decisions through your own discernment. Truvada ain't the only PrEP option.
Intention/Behavior	Likelihood of taking PrEP or are taking PrEP.	Day 2 on Descovy i hope my white blood cells are chillin
Information/knowledge	Information about PrEP.	What is PrEP? #PrEP stands for pre-exposure prophylaxis. This involves taking medicine that can give you protection against HIV if you have unprotected sex with someone who is HIV-positive.
Actual barriers	Barriers or facilitators for taking PrEP.	[Examples provided below.]
Cost	Issues with cost of PrEP.	Rep. Alexandria Ocasio-Cortez (D-N.Y.) confronted a CEO Thursday for pricing the anti-HIV drug Truvada, aka, PrEP, at \$8 in Australia but over \$1,500 in the U.S.
Access	Issues related to PrEP access not	Gilead will donate HIV prevention Truvada drug to 200k Americans

directly related to costs.

Issues with Pharmaceutical Company

Issues with the pharmaceutical company including mistrust or patents.

The Pharma Industry is a huge Mafia Cartel. They don't necessarily create cures, they only create more customers!

Stigma

Issues related to stigmatizing beliefs.

Does anyone else besides me think the Truvada commercials not are only nauseating, but sends a wrong message to our youth. Wtf..has this country become.. liberals are destroying the future and indoctrinating the young.

**Table 3.2***Characteristics of PrEP Tweets by FDA Approval of Descovy Time Period (N = 1008)*

Variable	Before FDA	After FDA	<i>p</i>
	Approval	Approval	
	N (%)	N (%)	
<b>TPB Construct</b>			
Attitude	28 (5.3%)	34 (7.1%)	.247
Perceived norm	9 (1.7%)	3 (.6%)	.113
Perceived behavioral control	6 (1.1%)	11 (2.3%)	.157
Intention/behavior	35 (6.6%)	45 (9.4%)	.111
Information/knowledge	115 (21.8%)	145 (30.3%)	.003
Actual barriers	241 (45.7%)	144 (29.9%)	<.001
Other	93 (17.6%)	99 (20.6%)	.236
<b>Source</b>			
Individual	392 (74.4%)	363 (75.5%)	.692
Organization	135 (25.6%)	118 (24.5%)	

*Note:* P-values were calculated from  $\chi^2$  tests; all cells had expected values over 5.

**Table 3.3***Types of Actual Barriers by FDA Approval of Descovy Time Period (N = 385)*

Variable	Before FDA	After FDA	P-value
	Approval	Approval	
	N (%)	N (%)	
Cost	85 (35.3%)	56 (38.9%)	.476
Access	98 (40.7%)	42 (29.2%)	.023
Issues with Pharmaceutical Company	48 (19.9%)	34 (23.6%)	.392
Stigma	10 (4.1%)	12 (8.3%)	.087

*Note.* P-values were calculated from  $\chi^2$  tests; all cells had expected values over 5.

**Table 3.4***Characteristics of PrEP Tweets by Source (N = 1008)*

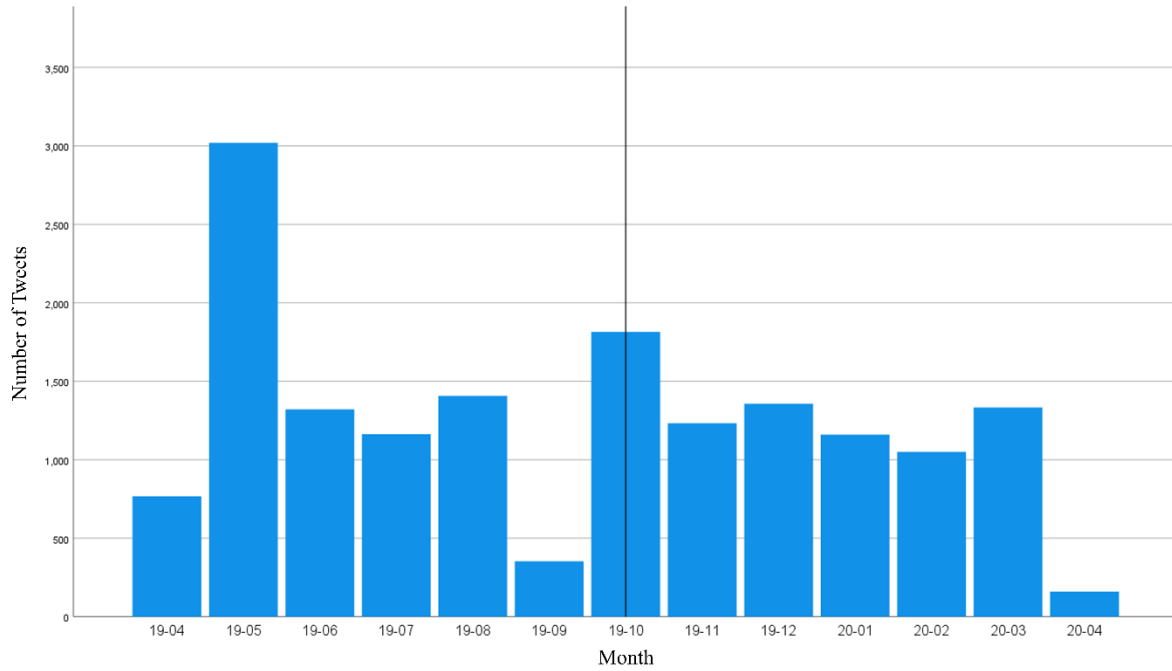
Variable	Organization	Individual	<i>p</i>
TPB Construct			
Attitude	1 (.4%)	61 (8.1%)	<.001
Perceived norm	3 (1.2%)	9 (1.2%)	1.0 <sup>a</sup>
Perceived behavioral control	1 (.4%)	16 (2.1%)	.088 <sup>a</sup>
Intention/behavior	4 (1.6%)	76 (10.1%)	<.001
Information/knowledge	113 (44.7%)	146 (19.3%)	<.001
Actual barriers	102 (40.3%)	283 (37.5%)	.422
Other	29 (11.5%)	163 (21.6%)	<.001

*Note:* P-values with expected values over 5 were calculated from  $\chi^2$  tests.

<sup>a</sup> P-values were calculated using Fisher's exact tests.

**Figure 3.1**

*Number of Tweets Discussing PrEP over Time*



## **CHAPTER 4. Online Network Intervention to Increase HIV Pre-Exposure Prophylaxis**

### **Intention: A Mobile App-Based Experiment**



## **ABSTRACT**

HIV pre-exposure prophylaxis (or PrEP) refers to taking a daily, oral medication to reduce one's risk of HIV transmission. Despite its effectiveness, there is a need for public health interventions to promote PrEP among populations disproportionately affected by HIV. I conducted a one-week, online network intervention employed through a mobile app to increase intention to start PrEP among young gay and bisexual men. To examine whether social support is the primary mechanism that drives intention, participants were randomized into a social support condition, operationalized as an online chatting tool, or an information-only condition, a diary tool. Results indicate that the intervention overall was successful in increasing participants familiarity with PrEP, knowledge about PrEP consistent use and effectiveness, attitudes toward starting PrEP, and intentions to initiate PrEP. Theoretical and practical implications are discussed. Overall, a small group intervention may be particularly helpful in promoting intentions to start PrEP; however, future research is necessary to examine the relationship between online networks and health outcomes.

## 4.1 Introduction

HIV pre-exposure prophylaxis (or PrEP) refers to taking a daily, oral medication to reduce one's risk of HIV transmission. Despite its potential for HIV prevention, studies have indicated that PrEP use is relatively low among sexually active gay and bisexual men (Dodge et al., 2019; Holloway et al., 2020). This indicates there is a need for public health interventions to promote PrEP adoption among populations disproportionately affected by HIV.

An online network intervention may be ideal for promoting the adoption of PrEP. Through leveraging the connections between individuals, these interventions facilitate health behavior change (Valente, 2012), and can provide anonymous support that transcends geographical boundaries (DeAndrea, 2015). There are several ways in which online networks may influence health (Berkman et al., 2000); however, in the context of HIV prevention, social support may serve as the primary mechanism that influences the adoption of PrEP. Previous research has found that social support has generally reduced HIV-related risky behaviors (Qiao et al., 2014).

To examine whether an online intervention can be effective in promoting positive behavioral outcomes, and to examine whether social support influences intention to start taking PrEP, I conducted a one-week, online network intervention employed through a mobile app among sexually active young gay and bisexual men. Participants were randomized into a social support or information-only control condition and participated in the mobile app intervention. Findings from this study will (1) further our understanding of the effectiveness of online network interventions in promoting positive health behaviors and (2) contribute to the literature on the theoretical mechanisms (specifically examining social support) behind how online networks influence health outcomes.

## 4.2 Literature Review

### *PrEP and HIV Prevention*

PrEP involves taking a daily, oral medication to reduce one's risk of contracting HIV. Among the men who have sex with men (MSM) population, there have been several clinical trials that demonstrate the effectiveness of PrEP (Grant et al., 2010, 2014; Molina et al., 2015, 2017). Despite the potential of PrEP to reduce HIV transmission, several studies have found that the adoption of the medication is still relatively low (Dodge et al., 2019; Holloway et al., 2020). In a study that surveyed a probabilistic sample of US gay and bisexual men in 2018, Dodge and colleagues (2019) found that only 6.7% have taken PrEP within the last 6 months. Similarly, another study examining trends related to PrEP found that only 7.8% of a national probability sample of sexually active gay and bisexual men used PrEP in 2018 (Holloway et al., 2020). These numbers are vastly below the goals of the *HIV National Strategic Plan for the United States* (HHS, 2021) to increase PrEP coverage to fifty percent. Thus, there is a dire need to improve PrEP coverage and adoption among populations most at risk for HIV.

In addition to other important target populations disproportionately affected by HIV, gay and bisexual men remain to be a priority group for HIV prevention. The gay and bisexual male population make up of 69% of new HIV diagnoses, and 64% of those new diagnoses are among younger gay and bisexual men ages 13 to 34 (CDC, 2020). Further, within a two year span, HIV diagnoses have increased by 6% among gay and bisexual men ages 25 to 34 (CDC, 2020), sparking a definite need to intervene and promote HIV preventative behaviors among this population.

To address the low uptake of PrEP and the increasing HIV diagnoses among young gay and bisexual men, I propose an online network intervention employed through a mobile app.

Guided by the theory of planned behavior (TPB) (Fishbein & Ajzen, 2011) and the theoretical framework of social integration and health (Berkman et al., 2000), this study utilizes a mobile app to push theoretically-grounded messages to promote PrEP, and the study examines the effects of the network condition on intention to initiate PrEP among young gay and bisexual men. Mobile app field experiments have the potential to reach larger audiences and control randomization, and they have the ability to collect both behavioral and self-report data (Zhang et al., 2018). Thus, conducting a mobile app experiment will be ideal to test the theoretical mechanisms and to reach a larger number of potential participants.

### ***Theoretical Frameworks***

To promote intention to start taking PrEP, TPB (Fishbein & Ajzen, 2011) is used to guide message development within the intervention. This behavioral prediction model posits that one's attitudes toward a behavior, norms supporting a behavior, and perceived behavioral control regarding a behavioral predicts one's intention to perform the behavior (Fishbein & Ajzen, 2011). Intention, along with other factors, such as knowledge and environmental constraints, influence actual behaviors directly (Fishbein & Ajzen, 2011). The intervention can push out messages that address each construct to elicit a perception of positive beliefs toward PrEP initiation. For example, a message that discusses the positive aspects of PrEP may be seen favorably by participants, which in turn may lead to higher intentions to start the medication.

Before delving into the effects of the networks themselves, it is first important to examine whether the intervention is effective in improving intentions to start taking PrEP among participants. Furthermore, the intervention may also improve behavioral determinants such as knowledge, attitudes, perceived norms, and perceived behavioral control related to initiating PrEP. Thus, the following research question is proposed:

RQ1. Will there be an increase in TPB-related behavioral outcomes after the intervention compared to before?

In addition to examining the effects of intervention overall, this study also examines the influence of the network type on health behavior. By experimentally testing the two conditions, we can isolate the causal link between online networks and health outcomes. The social integration and health framework created by Berkman et al. (2000) may be used to identify the link between one's social network and health. The model posits that network characteristics, such as size and density, may influence health outcomes through different psychological mechanisms, such as social support or social influence (Berkman et al., 2000).

Previous research has tested this conceptual framework to examine which psychological mechanism may mediate the relationship between online networks and health. For example, one study found that compared to social support, eliciting social comparison was most effective in improving physical activity among graduate students (Zhang et al., 2016). Despite these findings, further research is necessary to measure the potential mediation between networks and health outcomes. In addition, further research is necessary to examine what mechanisms explain the relationship between networks and non-socially desirable behaviors.

For example, Mehrotra et al. (2018) examined the role of social relationships among participants in the iPrEx open-label extension study (Grant et al., 2014). The authors measured participants disclosure of their participation in the iPrEx study or their LGBT identity to close others (friends, partners, family, etc.), as well as their involvement in LGBT organizations, to examine whether there was an association with PrEP uptake and adherence (Mehrotra et al., 2018). They found that disclosing participant information to parents and disclosing LGBT status to their own social networks were significantly related to PrEP uptake; in addition, the more

LGBT organizations the participant was involved in, the more likely they took and adhered to PrEP (Mehrotra et al., 2018). While not directly measuring social support, discussing PrEP with one's social networks may help improve PrEP uptake and adherence.

Social support may improve individuals' behavioral determinants of PrEP initiation. The peer networks may provide emotional or information support that may influence participants' knowledge and beliefs surrounding initiating PrEP. Several studies have found a relationship between social support and positive health outcomes, such as increased emotional well-being (Meng et al., 2021) and increased HIV testing and PrEP awareness (Lelutiu-Weinberger et al., 2020; Painter et al., 2019). For example, Lelutiu-Weinberger et al. (2020) found among a sample of young Black men and transgender women who have sex with men or transgender women that having a higher level of social support was associated increased knowledge about HIV testing and PrEP, increased self-efficacy regarding HIV prevention methods, and increased intention to get an HIV test within the next 6 months. Social support from peer networks may be particularly useful in improving behavioral outcomes among the young gay and bisexual male population. Thus, the following hypotheses are proposed:

H1-3: Participants in the social support condition will have (1) more knowledge, (2) more positive attitudes, (3) higher intention to initiate PrEP than those in the information-only condition.

Lastly, it is important to understand the primary mechanism that influences behavioral outcomes. This study tests whether social support mediates the relationship between network type and intention to start taking PrEP. Previous research has found that informational support mediated the relationship between online network size and emotional well-being among cancer patients (Meng et al., 2021). In the context of PrEP initiation, users in the social support

condition may perceive that they receive more information or emotional support compared to the information-only condition, which in turn may influence their intentions to start PrEP. Thus, the final hypothesis is proposed:

H4. Perceived social support will mediate the relationship between condition type and behavioral intention.

### **4.3 Methods**

This study was approved by the university's institutional review board, as well as their IT security and privacy teams. Through a mobile app, I conducted an online network intervention to promote intention to start PrEP. After consenting to the study and completing the pre-survey, participants downloaded the app and were randomized into one of two conditions: an information-only or a social support condition. For 7-days, participants took part in the intervention. After the one week, participants completed a post-survey and were given \$5 for compensation.

#### ***Participants***

To be eligible for the study, participants had to identify as a gay or bisexual cis-gendered male, be between the ages of 18 and 35, have had at least one sexual partner in the last year, identify as HIV-negative, must not currently be on PrEP, and must currently use an Android phone. Participants were recruited from either Prolific, a participant recruitment platform (<https://prolific.co/>), or via social media. Due to the nature of Prolific and the eligibility requirements of the study, several participant screenings were conducted in addition to the pre-screening already performed by the platform. The participant flow can be found in Figure 4.1.

For a one-tailed paired t-test with a medium effect size (Cohen's  $d=.5$ ) and  $\alpha$ -error probability = .05, a power of .8 would require at least 27 participants; however, for a one-tailed

independent t-test with a medium effect size (Cohen's  $d=.5$ ) and  $\alpha$ -error probability = .05, a power of .8 would require at least 51 participants per condition (Faul et al., 2009). Despite the need for at least 102 participants to reach an adequate power for condition comparisons, roughly 33 participants completed the post-survey.

### *Design*

The mobile app consists of three key components: an information feed, a social support chatting tool/individual diary, and a PrEP locator widget. The information feed tab pushed out messages that provided information and addressed beliefs and barriers surrounding PrEP and HIV prevention, guided by the reasoned action approach (Fishbein & Ajzen, 2011). Each message included a related image as well, and some messages also included links to outside sources like the CDC. Roughly every three hours within a 12-hour time window, four messages were pushed out each day. For example, at 7am PST, the following message addressing self-efficacy was published, "PrEP gives me the freedom to take control of my sexual health and prevent HIV" along with an accompanied image. On average participants spent about 5.33 minutes (320.24 seconds) total on this tab (SD = 344.24, Range = [44 to 1556]). See Figure 4.2 for an example screenshot.

The second tab involves the main manipulation of the study. Participants were either be randomly exposed to an online chatting tool (social support condition) or a diary (information-only control) (See Figures 4.3-4 for example screenshots). All participants were prompted to answer questions related to PrEP each day; however, participants in the social support condition were able to comment and respond to each other's posts within their peer networks. Participants were encouraged to be actively involved in the second tab.



Participants responded to several prompts that included responding to PrEP promotional videos and responding to questions such as, how to support a friend who wants to get on PrEP, how to establish a routine for PrEP, what sources to get LGBTQ+ health information, how to access PrEP if uninsured, and ways in which the US can improve access to PrEP. A full list of prompts can be found in the Appendix. Reminder messages were sent out to the feed each evening to encourage participants to respond to their daily prompts. On average participants spent about 14.69 minutes (881.58 seconds) total on this tab (SD = 800.00, Range = [6 to 3229]).

Lastly, the mobile app also had a tab for the PrEP locator widget (Siegler et al., 2017, 2019), which locates nearby clinics that can provide PrEP, including for individuals who are uninsured or need patient assistance programs (See Figure 4.5 for an example screenshot). On average participants in total spent less than a minute (56.67 seconds) on this tab (SD = 68.26, Range = [0 to 334]).

Whenever a new message in the feed or a new prompt in the chat/diary tab was sent out, participants received a notification on their phones with a message preview. For those in the social support condition, participants also received notifications when other peer members in their group wrote in the chat. It is important to note that the engagement within each tab may seem low due to participants reading the real-time notifications on their phone instead of having the app fully open on a tab.

### *Measures*

**Intervention Effects.** To assess the effectiveness of the intervention, we measured perceived familiarity, knowledge, attitudes, perceived injunctive norm, perceived descriptive norm, perceived behavioral control, and intentions to start PrEP in both the pre- and post-surveys (Fishbein & Ajzen, 2011).

Perceived familiarity with HIV and perceived familiarity with PrEP were each assessed using a 1-item measure indicating, “How familiar are you with human immunodeficiency virus (HIV)/HIV pre-exposure prophylaxis.” These measures were assessed on a 5-point scale from 1 (not at all familiar) to 5 (extremely familiar).

Knowledge about PrEP was measured with four separate items that assess functional knowledge of PrEP (Kahle et al., 2018); these items included questions related to the effectiveness of PrEP, PrEP and condom use, and PrEP and STIs, such as, “Among those who consistently take the medication, how much does daily oral PrEP reduce the risk of acquiring HIV?” Each knowledge item was given a score of “1” for the correct answer and a score of “0” for any incorrect answer.

Intention to start taking PrEP was measured with 3-items guided by previous research (Fishbein & Ajzen, 2011), on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). This measure included statements such as, “*I intent to/I want to/it is likely that I will start taking daily oral PrEP within the next 12 months.*” Intention was assessed twice (before and after the intervention) and had high reliability (pre-survey:  $\alpha = .95$ ; post-survey:  $\alpha = .94$ ).

Attitude toward initiating PrEP was measured using a 5-point semantic differential scale that asked, “In general, starting daily oral PrEP for me is...” with 4-items including, *Good/Bad*, *Useful/Useless*, *Foolish/Wise*, and *Harmful/Beneficial*. Two items were reverse coded to ensure the valence remained consistent. Attitude was assessed twice (before and after the intervention) and had good reliability (pre-survey:  $\alpha = .81$ ; post-survey:  $\alpha = .89$ ).

Perceived injunctive norm supporting initiating PrEP was measured with 4-items guided by previous research (Fishbein & Ajzen, 2011), on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). This measure included statements such as, “*My partner(s) would*

*expect me/my gay friends would encourage me/the gay community would expect me/my doctor would encourage me to start taking daily oral PrEP.*” Perceived injunctive norm was assessed twice (before and after the intervention) and had good reliability (pre-survey:  $\alpha = .86$ ; post-survey:  $\alpha = .84$ ).

Perceived descriptive norm supporting initiating PrEP was measured with 3-items guided by previous research (Fishbein & Ajzen, 2011), on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). This measure included statements such as, “*Most of my gay friends/most people in the gay community/most of my partner(s) have started taking daily oral PrEP.*” Perceived descriptive norm was assessed twice (before and after the intervention) and had acceptable reliability (pre-survey:  $\alpha = .69$ ; post-survey:  $\alpha = .80$ ).

Perceived behavioral control for starting to take PrEP was measured with 3-items guided by previous research (Fishbein & Ajzen, 2011), on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). This measure included statements such as, “I am confident that I could start taking daily oral PrEP every day.” Perceived behavioral was assessed twice (before and after the intervention) and had adequate reliability (pre-survey:  $\alpha = .78$ ; post-survey:  $\alpha = .76$ ).

**Differences by Condition.** In the post-survey, we measured empowerment support, informational support, and emotional support on 5-point scales from 1 (strongly disagree) to 5 (strongly agree). Empowerment support was measured with three items, such as “*I feel supported/I feel empowered by the interactions from the PRIME App to start taking PrEP.*” The measure had high reliability,  $\alpha = .97$ .

Informational support was measured with two items adapted from previous research (Dehlendorf et al., 2020; Moser et al., 2012). This measure included items such as, “The PRIME

App interactions *provided me with information about PrEP that I did not know about before/helped me better understand what it was like to be on PrEP.*” The measure had acceptable reliability,  $\alpha = .69$ .

Emotional support was measured with four items adapted from previous research (Moser et al., 2012). The measure included items such as, “The PRIME App interactions *made me feel understood about my concerns about PrEP/provided me with suggestions to deal with questions related to PrEP.*” The measure had high reliability,  $\alpha = .93$ .

### ***Analysis***

First, means, standard deviations, correlations, and reliabilities were conducted. Both specific beliefs and measure scales were assessed. For example, perceived behavioral control was assessed overall, but its three items were also individually measured as well. To examine the effects of the intervention overall, paired t-tests were conducted between the pre- and post-intervention outcome variables. Then, Welch’s t-test for unequal variances were conducted to compare outcome variables between conditions (social support versus individual). Correlation results can be found on Table S6 in the Appendix.

To ensure the results were robust, I also conducted nonparametric tests to examine the effects of the intervention overall, as well as to examine any differences between conditions. In addition, to examine the relationship between TPB construct variables, I also ran structural equation modeling to see which variable predicted behavioral intention. Results can be found in the Appendix. Aside from the structural equation modeling conducted in R (Version 4.0.3), all analyses were conducted in SPSS Version 27.

#### 4.4 Results

Sample characteristics can be viewed in Table 4.1. Of those that completed the post-survey, the average age was around 27.79 years. About 51.5% identified as White, while 18.2% were Asian, 6.1% were Hispanic/Latino, 9.1% were Black/African American, and about 15.2% were mixed race. Over 75% went to at least some college or received an Associate degree, while about 30.3% earned less than \$39,000, 33.3% earned between \$40,000 to 69,999, and 33.3% earned more than \$70,000. The sample was mostly liberal, and there were a relatively equal number of gay and bisexual men. Most were in a relationship, and participants had at least one sexual partner within the last six months. About 30% had condomless receptive anal intercourse within the last six months, and on average, condom use was used less than half the time during sexual intercourse. In addition, most participants have never been tested for HIV, but had health insurance.

There were no significant differences in demographic characteristics between the pre-survey and intervention samples aside from one finding. Those in the intervention were more likely to indicate they were unsure if they had health insurance compared to the pre-survey sample.

#### **Intervention Effects**

Means, standard deviations, and intervention effects on outcome variables can be seen in Table 4.2. Overall, the intervention was successful in promoting several beliefs. First, the intervention improved participants' perceived familiarity with PrEP,  $t(32) = -3.57, p = .001$ . With regard to actual knowledge, the intervention also improved participants knowledge about the consistent use of PrEP and HIV acquisition,  $t(32) = -5.16, p < .001$ .

In addition, participants had higher intention to start taking PrEP after the intervention,  $t(32) = -3.55, p < .001$ . All items for intention also individually significantly increased after the intervention. One individual who participated in the study indicated that they started taking PrEP.

For attitudes toward starting PrEP, overall participants had more positive attitudes after the intervention,  $t(32) = -2.94, p = .006$ . Specifically, participants found that starting PrEP was more ‘good than bad’ and ‘beneficial than harmful.’

The intervention did not improve perceived injunctive norm or descriptive norm overall; however, there was a significant increase in the perception that doctors would encourage the participant to initiate PrEP,  $t(32) = -2.61, p = .014$ . Similarly, the intervention did not improve perceived behavioral control overall, but there was a significant increase in the belief, “I am confident I could start taking daily oral PrEP every day,”  $t(32) = -2.80, p = .009$ .

Tables S1-2 in the Appendix reveal the relationship between TPB construct variables. Before the intervention, attitudes toward starting PrEP ( $b = .232, SE = .117$ ) and injunctive norm supporting PrEP ( $b = .553, SE = .119$ ) were significantly related to PrEP intention. However, after the intervention, the primary predictors of PrEP intention were attitudes ( $b = .601, SE = .148$ ) and descriptive norm supporting PrEP initiation ( $b = .469, SE = .198$ ). Perceived behavioral control did not predict intention to initiate PrEP either before or after the intervention.

### **Social Support versus Information-Only Conditions**

Table 4.3 depicts the means and standard deviations of outcome variables for mobile app participants by condition type. There were no significant differences between conditions for perceived familiarity, knowledge about PrEP, attitudes toward initiating PrEP, or norms supporting taking PrEP. However, for specific attitude beliefs, participants in the social support

condition were significantly more likely to rate starting PrEP as more wise than foolish,  $t(32) = -2.22$ ,  $p = .036$ .

There was a significant difference in perceived behavioral control in the opposite direction than expected, where those in the social support condition had lower perceived behavioral control compared to the information only condition,  $t(32) = 2.07$ ,  $p = .049$ . Specifically, those in the social support condition were less confident they could start taking PrEP daily,  $t(32) = 2.13$ ,  $p = .043$ .

There were no significant differences in empowerment support, information support, or emotional support. It is important to reiterate that due to the small sample size, there was not enough power to detect significant differences between condition. The majority of outcome variables were in the same direction as hypothesized though they were not significant.

## **4.5 Discussion**

This study involved a one-week online network intervention to promote intentions to initiate PrEP through a mobile app. Participants were randomized in one of two conditions: a social support condition or an information-only condition. Guided by both the reasoned action approach (Fishbein & Ajzen, 2011) and Berkman and colleagues' (2000) framework for social networks and health, the intervention overall improved participants perceived familiarity with PrEP, their knowledge about using PrEP to avoid HIV acquisition, their intentions to initiate PrEP, as well as their attitudes toward taking PrEP.

### **Intervention Effects**

A major strength of the study is the incorporation of theoretically driven messages that are disseminated via the app feed. These messages addressed several issues related to PrEP including barriers of access and costs, but also included texts that elicit positive attitudes, norms,

and behavioral control. By using TPB as a guiding framework, I found an increase in perceived and actual knowledge, attitudes, and intention. The mobile app itself may serve as an excellent source to push out messages that promote positive health behaviors, such as PrEP adoption.

Structural equation modeling found that both prior to and after the intervention, attitudes toward starting PrEP were consistently a predictor of intention to initiate PrEP. In fact, the strength of the coefficient for attitudes was stronger after the intervention. Because the intervention improved both attitudes and behavioral intentions, focusing on boosting positive attitudes toward PrEP may be most useful in supporting PrEP adoption behavioral intentions.

One finding to note is that there were no differences in norms, except for one specific normative referent: doctors. The mobile app significantly improved individuals' beliefs that doctors would expect them to start taking PrEP. This finding is important because by promoting information about the medication, participants may be more likely to visit or ask questions about PrEP with their doctor now that they are more familiar with it. Doctors serve as a gateway for individuals to get prescribed the medication, so this intervention may be particularly useful in improving users' perceptions of doctor's expectations. Some research has found that primary care providers have served as a perceived barrier for those interested in PrEP due to the stigma attached to an HIV preventative behavior (Brooks et al., 2020; Edeza et al., 2021; Hubach et al., 2017). Thus, it is vital to continue improving potential PrEP consumers' normative beliefs supporting PrEP use to promote PrEP adoption and remove any perception of barriers.

Similarly, the specific belief about being confident that one can take PrEP daily significantly increased after the intervention. Compared to the other items for perceived behavioral control, which were already very high, confidence was much lower before the app intervention. The mobile app may be improving people's confidence in taking PrEP now that



they are familiar with the medication. Promoting self-efficacy may help give PrEP-interested individuals the push needed to become willing to start taking PrEP.

Overall, perceived injunctive and descriptive norms remained unchanged after the intervention. Future work should examine the power of normative influences in different contexts. For example, this study artificially constructed peer networks within the app. However, especially with sensitive information and private behaviors, individuals may only feel comfortable discussing HIV related issues with their own friends and family outside the intervention. It may be due to this reason that there were no changes in perceived norms. Constructing networks has both costs and benefits; the advantage here compared to other studies that have utilized peer recruitment networks for enrollment (Patel et al., 2018; L. E. Young et al., 2018; S. D. Young et al., 2014), is that researchers can establish causal effects and mechanisms through randomized constructed networks. Future work should focus on ways in which we can elicit social norms related to PrEP. Some experimental work has examined how constructing peer networks with both current users and non-users of a birth control method may improve normative outcomes (Dehlendorf et al., 2020). Norms may also be elicited through other means, such as attaching information feed messages with additional cues, such as virality metrics (C. Calabrese & Zhang, 2019, 2021).

### **Social Support versus Information-Only Conditions**

There were no differences between conditions, except for a few outcome variables. Perceived behavioral control was significant in the opposite direction than expected, where those in the individual condition had higher perceived behavioral control than those in the social support condition. This may be explained by the context of the app, where individuals in the social support condition were expected to interact with online strangers in their peer groups.

Discussing a sensitive, private topic may have been a potential reason as to why the social support participants might have felt less confident about taking PrEP. Future research is necessary to ensure that these interventions do not backfire; and interventions should focus on developing an environment where participants feel comfortable sharing their thoughts and feelings about sensitive topics. However, it is important to note that it is difficult to make judgements from these results due to the small sample size.

Another difference between conditions involved participants in the social support condition indicating that it is more wise than foolish for themselves to initiate PrEP than those in the information-only condition. This finding is good news because it indicates that those in the social support condition believe that it is a good decision to get on PrEP. In addition, all other attitude items are in the hypothesized direction though not significant.

Due to the small sample size, I was unable to determine whether social support mediated the relationship between network type and intention to start PrEP. While empowerment support and emotional support results were in the anticipated directions, there were no significant differences. This study, however, does not provide evidence that social support did not explain how the network condition influenced behavior change; future research should examine this link with a larger sample size. Future interventions may still want to focus their resources on eliciting social support.

Lastly, participants' responses to the prompts also provide a nuanced understanding of their actual perceptions of PrEP and related topics. Future work should look at analyzing the contents and sentiments of these responses to provide additional insight on the current beliefs and barriers surrounding PrEP initiation, especially at a larger scale. Overall, the mobile app intervention not only pushed out theoretically derived messages to participants to improve

behavioral outcomes, but also brought about new discussions surrounding PrEP as participants began to learn more about the medication and responded to daily prompts.

### ***Limitations***

This study is not without limitations. First, this study involved a sample of young gay and bisexual cis-gendered men who use an Android device and have had at least one sexual partner within the last year, have not tested positive for HIV, and are not currently on PrEP. Because of these strict eligibility criteria, the resulting sample size was small and did not provide enough power to estimate differences when comparing conditions. Further, due to limited resources, I was only able to develop an app for Android phone users; thus, this study is not generalizable to the entire sexually active gay and bisexual male population. Future research should develop a mobile app that is compatible with all mobile phone devices, such as iPhones. Lastly, this study was only conducted for a 7-day period. Further investigation is needed to examine whether there could be long-term effects from the intervention. Despite these limitations, capturing the beliefs and behaviors surrounding this target vulnerable population will be particularly helpful in guiding future interventions.

## **4.6 Conclusion**

The sexually active gay and bisexual male population is a target group disproportionately affected by HIV that may benefit from online health interventions. This study provides some evidence that an online network intervention may be a practical and effective way to promote intention and other beliefs to start taking PrEP. The study also does not eliminate social support as a potential mediating variable between network condition and intention to start PrEP. Future research should scale-up this study and utilize online networks to improve PrEP uptake among

our most vulnerable populations. Mobile apps may serve as an effective tool to promote taking PrEP and other health behaviors.

**Table 4.1***Sample Characteristics*

	Pre-survey (N=82)		Intervention (N=33)		p-value
	n	%	n	%	
Age, M (SD)	26.83	(4.29)	27.79	(4.14)	.490 <sup>e</sup>
Race/Ethnicity					
White	51	62.2	17	51.5	.602
Asian	11	13.4	6	18.2	
Hispanic/Latino	5	6.1	2	6.1	
Black or African American	8	9.8	3	9.1	
Mixed Race	7	8.5	5	15.2	
Education					.704
Less than HS	1	1.2	1	3.0	
HS diploma	12	14.6	7	21.2	
Some college/Associate degree	36	43.9	15	45.4	
Bachelor's degree	26	31.7	7	21.2	
Postgraduate degree	7	8.5	3	9.1	
Income					.411
Less than \$39,999	29	35.4	10	30.3	
\$40,000 - \$69,999	32	39.0	11	33.3	
\$70,000 or more	19	23.2	11	33.3	
Decline to state	2	2.4	1	3.0	
Liberal-conservative <sup>a</sup> , M(SD)	2.55	(1.53)	2.36	(1.34)	.759 <sup>e</sup>
Sexual orientation					
Gay	32	39.0	16	48.5	.582
Bisexual	46	56.1	15	45.5	
Prefer not to state <sup>b</sup>	4	4.9	2	6.1	
In a relationship	54	65.9	24	72.7	.649
Number of sex partners in last 6 months	3.22	(7.31)	1.30	(.95)	.280 <sup>e</sup>
CRAI within 6 months <sup>c</sup>	26	31.7	10	30.0	.618
Frequency of condom use <sup>d</sup>	2.84	(1.71)	2.36	(1.78)	.124 <sup>e</sup>
Last time tested for HIV					.592
Less than 6 months ago	11	13.4	3	9.1	
Between 6 and 12 months ago	13	15.9	5	15.2	
Over 12 months ago	16	19.5	7	21.2	

Never	42	51.2	18	54.5	
Health insurance					.006
Yes	63	76.8	21	63.6	
Unsure	19	23.2	12	36.4	

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Note:

<sup>a</sup> Liberal-conservative was measured on a scale from 1 (very liberal) to 7 (very conservative).

<sup>b</sup> Participants were screened as gay or bisexual but indicated ‘prefer not to state’ in the survey.

<sup>c</sup> Condomless receptive anal intercourse (CRIA).

<sup>d</sup> Frequency of condom use was measured on a scale from 1 (never) to 5 (always).

<sup>e</sup> Test statistic is a Welch’s t-tests for unequal variances, otherwise chi-squared tests were conducted.

**Table 4.2**

*Means, Standard Deviations, and Intervention Effects on Outcome Variables for Mobile App Participants (N = 33)*

	Pre- intervention M (SD)	Post- intervention M (SD)	t- statistic	p- value
<b>Familiarity</b>				
Familiarity with HIV	3.64 (.90)	3.76 (.83)	-.66	.513
Familiarity with PrEP	2.73 (1.10)	3.52 (.80)	-3.57	.001
<b>Knowledge</b>				
PrEP for reducing HIV acquisition	.45 (.51)	.91 (.29)	-5.16	<.001
PrEP consistent use and effectiveness	.97 (.17)	.97 (.17)	0	1.000
PrEP and condom use	1.00 (0)	.94 (.24)	1.44	.160
PrEP and other STIs	.82 (.39)	.82 (.39)	0	1.000
<b>Intention to start taking daily oral PrEP</b>				
I intend to start taking daily oral PrEP within the next 12 months	2.55 (1.11)	2.93 (1.16)	-3.55	<.001
I want to start daily oral PrEP within the next 12 months	2.38 (1.10)	2.81 (1.20)	-4.00	<.001
It is likely I will start daily oral PrEP within the next 12 months	2.78 (1.21)	3.19 (1.23)	-2.52	.017
It is likely I will start daily oral PrEP within the next 12 months	2.50 (1.16)	2.78 (1.24)	-2.74	.010
<b>Attitude toward starting daily oral PrEP</b>				
Bad – Good	3.59 (1.01)	4.02 (1.04)	-2.94	.006
Harmful – Beneficial	3.73 (1.15)	4.21 (.93)	-3.34	.002
Foolish – Wise	3.70 (.95)	4.12 (1.02)	-1.81	.080
Useless – Useful	3.48 (1.30)	3.97 (1.26)	-1.91	.065
Useless – Useful	3.33 (1.55)	3.76 (1.50)	-2.30	.028
<b>Perceived injunctive norm supporting starting daily oral PrEP</b>				
My partner(s) would expect me to start taking daily oral PrEP	3.01 (1.07)	3.28 (.89)	-1.94	.062
My gay friends would encourage me to start taking daily oral PrEP	2.67 (1.16)	2.64 (1.19)	.17	.869
The gay community would expect me to start taking daily oral PrEP	3.06 (1.32)	3.39 (.97)	-1.7	.102
My doctor would encourage me to start taking daily oral PrEP	3.12 (1.11)	3.48 (1.12)	-1.8	.083
My doctor would encourage me to start taking daily oral PrEP	3.06 (1.32)	3.61 (1.03)	-2.61	.014
<b>Perceived descriptive norm supporting starting daily oral PrEP</b>				
Most of my gay friends have started taking daily oral PrEP	2.58 (.63)	2.84 (.85)	-1.92	.064
Most within the gay community have started to take daily oral PrEP	2.73 (.72)	2.88 (.96)	-.30	.377
Most within the gay community have started to take daily oral PrEP	2.79 (.78)	3.15 (.97)	-1.75	.090

Most of my partner(s) have started taking daily oral PrEP	2.21 (.93)	2.48 (1.06)	-1.66	.107
Perceived behavioral control for starting daily oral PrEP	3.90 (.87)	4.18 (.74)	-1.67	.106
I am confident I could start taking daily oral PrEP every day	3.42 (1.03)	3.97 (.77)	-2.80	.009
Taking daily oral every day PrEP would be completely up to me	4.18 (.98)	4.24 (1.00)	-.31	.757
Taking daily oral PrEP every day would be under my control	4.33 (.92)	4.33 (.92)	-1.22	.233

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*Note:* Test-statistics were conducted using paired t-tests.



**Table 4.3***Means and Standard Deviations of Outcome Variables for Participants by Condition*

	Individual condition (N=17)	Social support condition (N=16)	t- statistic	p- value
<b>Familiarity</b>				
Familiarity with HIV	3.82 (.81)	3.69 (.87)	.463	.646
Familiarity with PrEP	3.59 (.80)	3.44 (.81)	.538	.595
<b>Knowledge</b>				
PrEP for reducing HIV acquisition	.82 (.39)	1.00 (0)	-1.852	.083
PrEP consistent use and effectiveness	.94 (.24)	1.00 (0)	-1.000	.332
PrEP and condom use	.88 (.33)	1.00 (0)	-1.461	.163
PrEP and other STIs	.88 (.33)	.75 (.45)	.960	.345
<b>Intention to start taking daily oral PrEP</b>				
I intend to start taking daily oral PrEP within the next 12 months	2.88 (1.30)	2.98 (1.04)	-.250	.804
I want to start taking daily oral PrEP within the next 12 months	2.81 (1.28)	2.81 (1.17)	.000	1.00
It is likely I will start taking daily oral PrEP within the next 12 months	3.00 (1.37)	3.38 (1.09)	-.859	.398
It is likely I will start taking daily oral PrEP within the next 12 months	2.81 (1.33)	2.75 (1.18)	.141	.889
<b>Attitude toward starting daily oral PrEP</b>				
Bad – Good	3.76 (1.11)	4.28 (.93)	-1.452	.159
Harmful – Beneficial	4.06 (1.03)	4.38 (.81)	-.986	.332
Foolish – Wise	4.00 (1.12)	4.25 (.93)	-.700	.489
Useless – Useful	3.53 (1.46)	4.44 (.81)	-2.220	.036
Useless – Useful	3.47 (1.62)	4.06 (1.34)	-1.144	.261
<b>Perceived injunctive norm supporting starting daily oral PrEP</b>				
My partner(s) would expect me to start taking daily oral PrEP	3.21 (.98)	3.36 (.80)	-.494	.625
My gay friends would encourage me to start taking daily oral PrEP	2.53 (1.33)	2.75 (1.07)	-.528	.601
The gay community would expect me to start taking daily oral PrEP	3.41 (.94)	3.38 (1.03)	.107	.915
My doctor would encourage me to start taking daily oral PrEP	3.41 (1.28)	3.56 (.96)	-.384	.704
My doctor would encourage me to start taking daily oral PrEP	3.47 (1.13)	3.75 (.93)	-.779	.442
<b>Perceived descriptive norm supporting starting daily oral PrEP</b>				
Most of my gay friends have started taking daily oral PrEP	2.86 (.95)	2.81 (.75)	.169	.867
Most within the gay community have started to take daily oral PrEP	3.12 (.99)	2.63 (.89)	1.507	.142
Most within the gay community have started to take daily oral PrEP	3.12 (.93)	3.19 (1.05)	-.202	.841

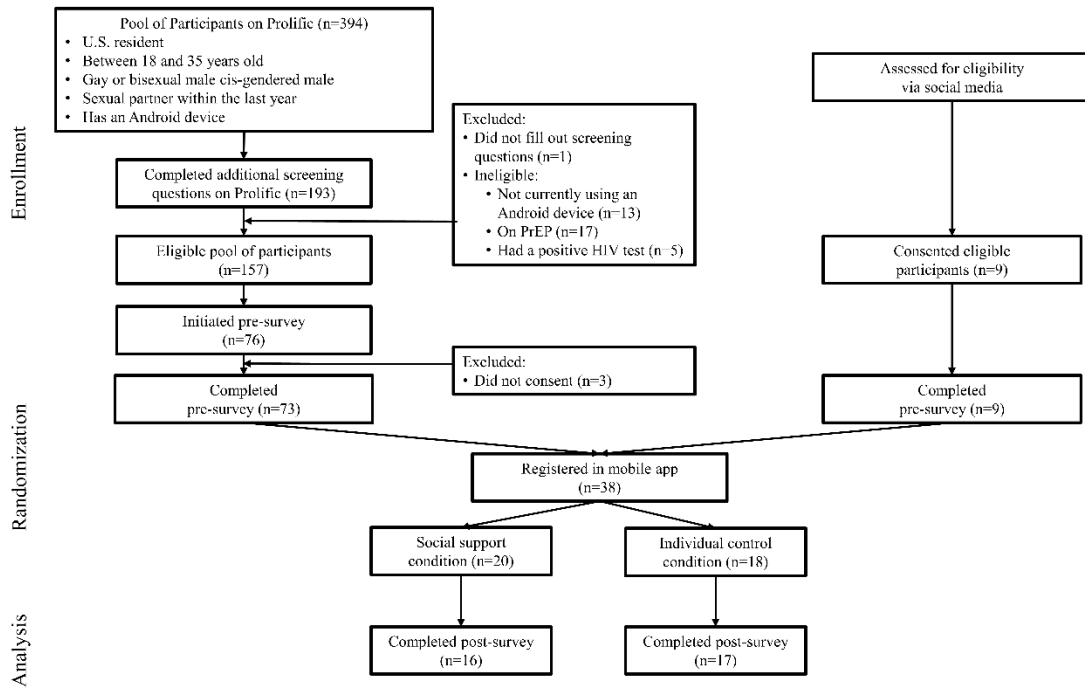
Most of my partner(s) have started taking daily oral PrEP	2.35 (1.22)	2.63 (.89)	-.736	.468
Perceived behavioral control for starting daily oral PrEP	4.43 (.54)	3.92 (.85)	2.069	.049
I am confident I could start taking daily oral PrEP every day	4.24 (.56)	3.69 (.87)	2.128	.043
Taking daily oral every day PrEP would be completely up to me	4.47 (.80)	4.00 (1.16)	1.353	.187
Taking daily oral PrEP every day would be under my control	4.59 (.51)	4.06 (1.18)	1.643	.116
Perceived empowerment support	3.78 (1.13)	3.81 (1.05)	-.074	.941
I feel supported by the interactions from the PRIME App to start taking PrEP	3.82 (1.19)	3.88 (.96)	-.138	.891
I feel empowered by the interactions from the PRIME App to start taking PrEP	3.76 (1.20)	3.69 (1.20)	.185	.854
The interactions from the PRIME App helped me believe that I could start taking PrEP	3.76 (1.09)	3.88 (1.09)	-.291	.773
Perceived informational support	3.85 (.98)	3.81 (.95)	.121	.905
The PRIME App interactions provided me information about PrEP that I did not know about before	4.18 (1.02)	3.94 (1.06)	.660	.514
The PRIME App interactions helped me better understand what it is like to be on PrEP	3.53 (1.33)	3.69 (.95)	-.395	.695
Perceived emotional support	3.69 (1.09)	3.67 (1.05)	.052	.959
The PRIME App interactions made me enjoy my time during the PrEP discussions	3.41 (1.28)	3.50 (1.27)	-.199	.843
The PRIME App interactions provided me with suggestions to deal with questions related to PrEP	3.82 (1.07)	3.88 (1.15)	-.133	.895
The PRIME App interactions made me feel understood about my concerns with PrEP	3.65 (1.22)	3.63 (1.15)	.053	.958
The PRIME App interactions made me feel included in PrEP discussions	3.88 (1.11)	3.69 (1.20)	.484	.632

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*Note:* Test-statistics were conducted using Welch's t-tests for unequal variances.

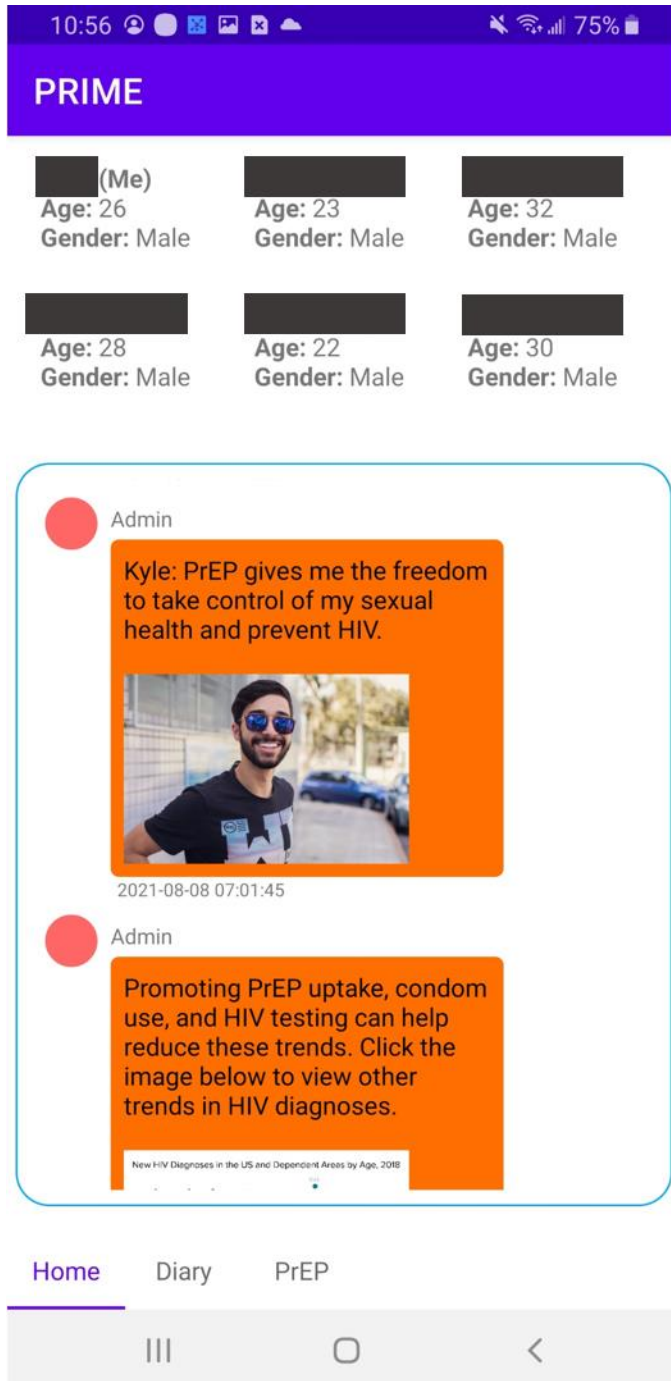
**Figure 4.1**

*Participant Flow*



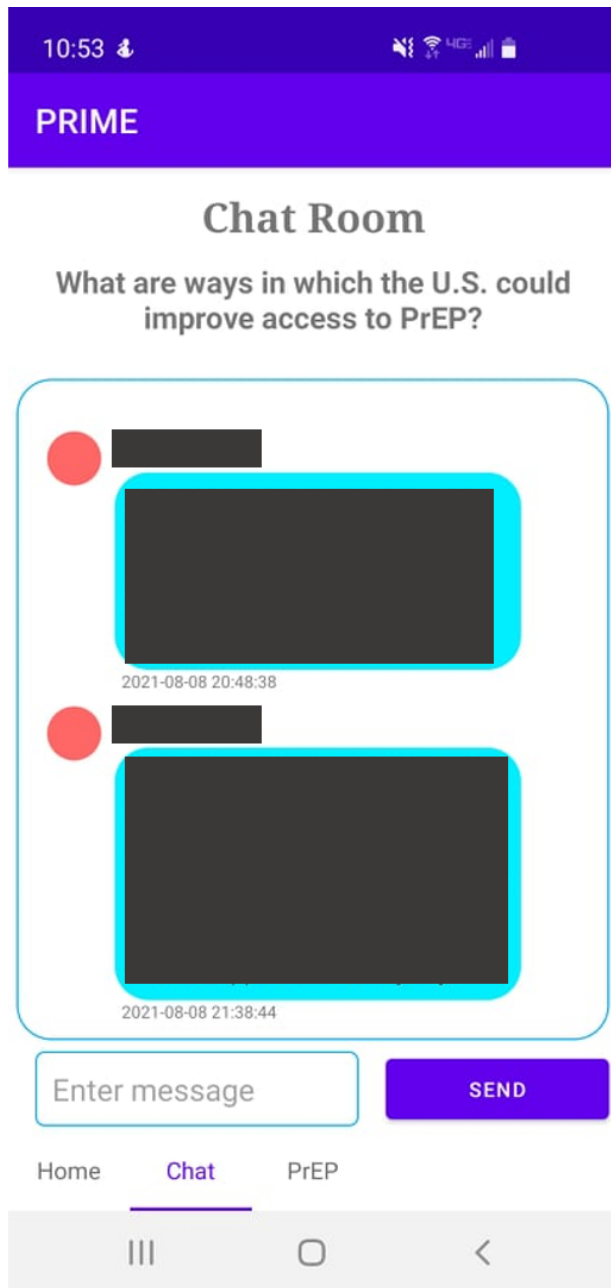
**Figure 4.2**

*Screenshot Example of the Information Feed Tab in the Mobile App*



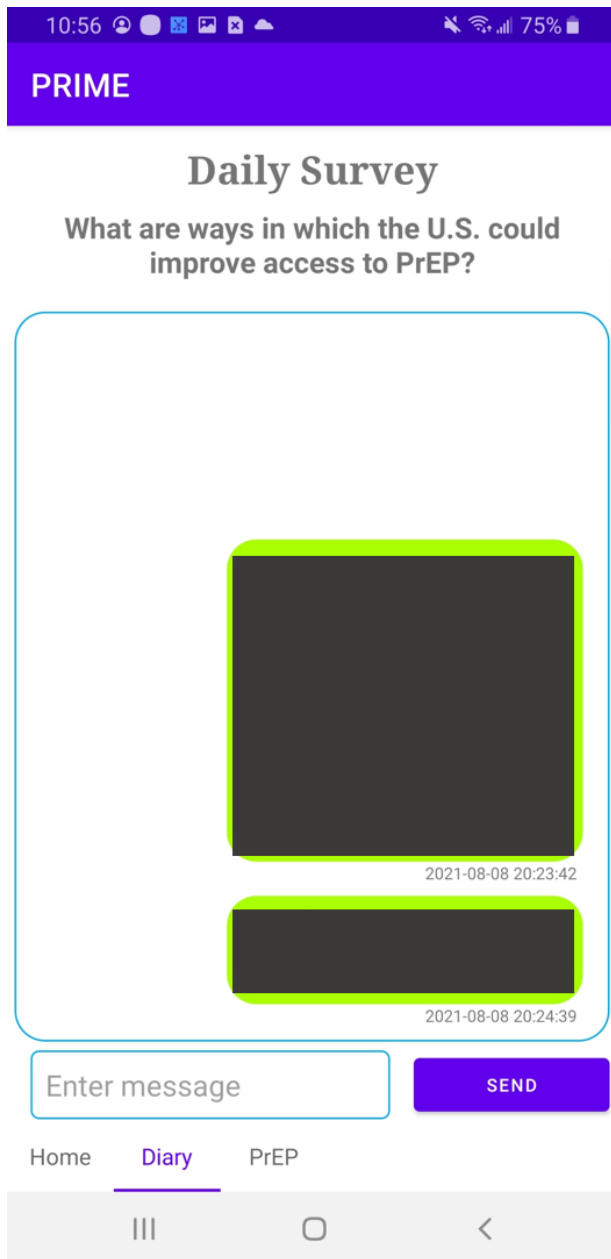
**Figure 4.3**

*Screenshot Example of the Chatroom (Social Support) Condition Tab in the Mobile App*



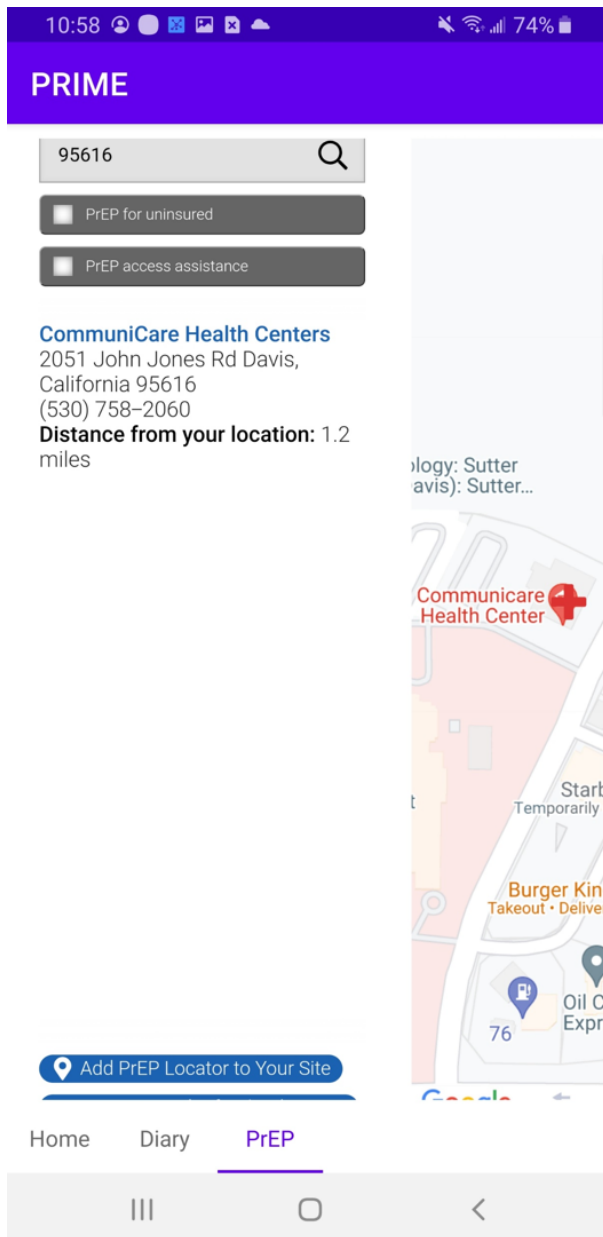
**Figure 4.4**

*Screenshot Example of the Diary (Information-only) Condition Tab in the Mobile App*



**Figure 4.5**

*Screenshot Example of the PrEP Locator Widget Tab in the Mobile App*



## **CHAPTER 5. Conclusion**



Online technologies are a ubiquitous part of our everyday lives. The majority of US adults use at least one social media platform (Auxier & Anderson, 2021). With new advancements in online technologies, there is a need to develop a theoretical framework and understanding of the primary causal influences that these technologies have on health outcomes. In addition, practitioners must become experts in online technologies to promote positive health behaviors and meet target populations where they are most available. There are ample opportunities to reach vulnerable populations through online technologies who previously may have been hard-to-reach. One aspect of new technologies, online networks, has shown to be particularly interesting to examine because they can be used as a tool to promote health outcomes by connecting individuals beyond geographical boundaries (DeAndrea, 2015).

The primary goal of this dissertation was to leverage the capabilities of online networks to promote pre-exposure prophylaxis (PrEP) intentions among young sexually active gay and bisexual men. This process involves both capturing people's perceptions of PrEP online through the lens of the Theory of Planned Behavior (TPB) (Fishbein & Ajzen, 2011), but also developing a theoretically driven mobile app intervention that leverages social support as the primary mediator between network type and behavioral intention. The results from this body of work illustrate several theoretical and practical contributions to literature in communication and public health.

In the first study, I captured people's real-time perceptions and behaviors related to PrEP through analyzing over 16k tweets that mentioned PrEP. Guided by TPB (Fishbein & Ajzen, 2011), this study found that most of the discussion surrounding PrEP related to environmental factors including barriers (costs, access, etc.) and information. The study further illustrated the

need for public health action to increase access to PrEP, even after the approval of an additional medication. Important for behavior change, there were a lack of tweets related to attitudes, norms, and perceived behavioral control. This provides a baseline understanding on how organizations may need to promote PrEP moving forward, eliciting positive attitudes toward taking PrEP, social norms supporting PrEP adoption, and high perceived behavioral control for initiating PrEP. As PrEP access increased with the addition of Descovy, positive emotion expressed in tweets also increased, which signal hope for the future of HIV prevention.

In the second study, I developed a mobile app intervention that leverages online networks to promote intention to start PrEP among sexually active young gay and bisexual men. Guided by TPB (Fishbein & Ajzen, 2011) and the theoretical framework of social integration and health (Berkman et al., 2000), the mobile app pushed out messages that elicit specific beliefs supporting PrEP use, while also experimentally tested the effects of network condition on behavioral intentions. By randomly constructing online networks, researchers can isolate the effects of the network conditions on health outcomes (Centola, 2010, 2011; Zhang et al., 2015, 2016). Further, we can examine the primary mechanism that drives these effects, such as social support.

The second study showed to be successful in improving intention to start taking PrEP overall, as well as improving perceived familiarity with PrEP and attitudes toward taking PrEP. From a theoretical perspective, this is an important finding because the results indicate that TPB has shown to be successful in promoting health outcomes in online and mobile intervention contexts. While a model of behavioral prediction rather than a theory, this study further illuminates that TPB is contextually transcendent and is extremely useful for guiding interventions and improving behavioral outcomes.

While the study did not find significant effects of network type on social support, whether empowerment, informational, or emotional, the study's small sample illustrates a need to further investigate whether social support mediates the effects of network condition on health outcomes on a larger scale, especially since the direction of many of the support items were in the hypothesized direction. PrEP adoption is a private and often stigmatized HIV-preventative behavior where social support is likely the primary mediator; however, it is important to not rule out other potential explanations. Based on Berkman and colleagues' (2000) framework for social networks and health, it may be that social influence or social capital that may be the primary mediator between online networks and health outcomes, though this could be dependent on certain contexts. This sparks future work for communication scholars and public health practitioners to investigate how to leverage online and mobile technologies to elicit these psychological mechanisms and promote positive health behaviors.

Overall, researchers and public health professionals should utilize online networks to understand and capture people's real-time perceptions and behaviors related to positive health behaviors, and they should leverage these online networks for promoting positive health behaviors through online interventions. Study 1 revealed the message contents, sources, and sentiments and emotions expressed in online tweets. Study 2, while it did not have a large enough sample size to test differences between conditions, was effective in improving attitudes and intention to initiate PrEP. Further investigation is needed to see whether social support serves as the key mechanism that explains how online networks can improve health outcomes.

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## Appendix

### Study 1. Perceptions of PrEP on Twitter

#### *Nonparametric Tests*

Differences in Coded Tweets After the Approval of Descovy  
Differences in Coded Tweets between Source Type  
Differences in Emotions and Sentiments after the Approval of Descovy  
Differences in Emotions and Sentiments by Source Type

#### *Removing “Bots”*

Table S1. Characteristics of PrEP Tweets by FDA Approval of Descovy  
Table S2. Types of Actual Barriers by FDA Approval of Descovy  
Table S3. Characteristics of PrEP Tweets by Source Type  
Table S4. Emotions and Sentiments of PrEP Tweets by FDA Approval  
Table S5. Emotions and Sentiments of PrEP Tweets by Source Type

### Study 2. Online Network Intervention to Increase HIV PrEP Intention

#### *Mobile App Information*

Daily Prompts for Mobile App Intervention

#### *Nonparametric Tests*

Intervention Effects (Pre- and Post-Intervention) on Outcome Variables  
Social Support versus Individual Conditions on Outcome Variables

#### *Correlations*

Table S6. Correlations between Outcome Variables

#### *Structural Equation Models*

Figure S1. Assessing the Relationship between TPB-Constructs Prior to Intervention  
Figure S2. Assessing the Relationship between TPB-Constructs After the Intervention

## Study 1. Nonparametric Tests

### *Differences in Coded Tweets After the Approval of Descovy*

Among coded tweets (N = 1008), Mann-Whitney U tests were conducted to compare differences in the Theory of Planned Behavior (TPB) constructs (Fishbein & Ajzen, 2011) and source before and after the approval of Descovy. These nonparametric tests further ensure the robustness of these results.

**TPB Constructs.** There were significantly more information tweets about PrEP after the approval of Descovy than before,  $U = 116193.5$ ,  $p = .003$ . Further, there were significantly less tweets discussing barriers to PrEP after the approval of Descovy,  $U = 106727$ ,  $p < .001$ . There were no significant differences in attitudes ( $p = .247$ ), norms ( $p = .113$ ), perceived behavioral control ( $p = .157$ ), and intentions/behavior ( $p = .111$ ) after the approval of Descovy.

**Specific Barriers.** Among tweets discussing barriers to PrEP, there were significantly less tweets discussing costs after the approval of Descovy than before,  $U = 121057$ ,  $p = .040$ . Further, there were significantly less tweets discussing access after the approval of Descovy than before,  $U = 114241$ ,  $p < .001$ . There were no differences in issues with pharmaceutical company ( $p = .237$ ) and stigma ( $p = .393$ ).

**Source Type.** There were no differences in source type (individual versus organization) before and after the approval of Descovy ( $p = .692$ ).

### *Differences in Coded Tweets between Source Type*

Among coded tweets (N = 1008), Mann-Whitney U tests were conducted to compare differences in TPB constructs by source type (individual versus organization). These nonparametric tests further ensure the robustness of these results.

**TPB Constructs.** There were significantly more informational tweets posted by organizations than individuals,  $U = 71445.5$ ,  $p < .001$ . In addition, there were significantly more tweets expressing attitudes posted by individuals than organizations,  $U = 88168.5$ ,  $p < .001$ . Further, there were significantly more tweets expressing intentions/behavior posted by individuals than organizations,  $U = 87403.5$ ,  $p < .001$ . There were no differences between source type for norms ( $p = .994$ ), perceived behavioral control ( $p = .065$ ), and overall barriers ( $p = .422$ ).

**Specific Barriers.** Among barrier tweets, there were significantly more individual tweets about costs ( $U = 12439.5$ ,  $p = .013$ ) and stigma ( $U = 13503.5$ ,  $p = .016$ ) compared to organizational tweets. However, there were significantly more organizational tweets that discuss access compared to individual tweets,  $U = 11563$ ,  $p < .001$ . There were no differences regarding issues with pharmaceutical company by source type ( $p = .938$ ).

### *Differences in Emotions and Sentiments after the Approval of Descovy*

For the full dataset (N = 16139), Mann-Whitney U tests were conducted to compare differences in positive emotion, negative emotion, anxiety, anger, and sadness before and after the approval of Descovy. These nonparametric tests further ensure the robustness of these results.

**Positive and Negative Emotion.** There were significantly more tweets that expressed positive emotion after the approval of Descovy than before,  $U = 30240973$ ,  $p < .001$ . However, there were no significant differences in negative emotion ( $p = .576$ ).

**Discrete Emotion.** There were significantly less tweets that expressed anger after the approval of Descovy than before,  $U = 31923004.5$ ,  $p < .001$ . However, there were significantly more tweets that expressed sadness after the approval of Descovy than before,  $U = 32293740$ ,  $p = .041$ . There were no significant differences in anxiety ( $p = .543$ ).

### *Differences in Emotions and Sentiments by Source Type*

Mann-Whitney U tests were conducted to compare differences in positive emotion, negative emotion, anxiety, anger, and sadness by source type (individual vs. organization). These nonparametric tests further ensure the robustness of these results.

**Positive and Negative Emotion.** Tweets posted by individuals expressed significantly more positive emotion than organizational tweets,  $U = 86531$ ,  $p = .014$ . However, there were no significant differences in negative emotion ( $p = .638$ ).

**Discrete Emotion.** Organizational tweets expressed significantly more anxiety compared to individual tweets,  $U = 90177$ ,  $p = .018$ . However, there were no significant differences in anger ( $p = .159$ ) or sadness ( $p = .832$ ).

## Study 1. Removing “Bots”

In the following analyses, I ran Botometer (Sayyadiharikandeh et al., 2020), a bot classification tool based on a machine learning algorithm that outputs a score indicating whether a tweet was made from a human or a bot. Complete Automation Probability (CAP) scores provide the probability (from 0 to 1) that an account with a X% score or greater is likely a bot. Scores closer to 0 indicate that the tweet was likely from a human, and scores closer to 1 indicate that the tweet is likely from a bot account. I utilized a cutoff CAP score of 80% and re-ran analysis to examine any discrepancies between the “no bot” sample and the full coded sample. It is important to note that though this machine learning tool has been trained and extracts over 1000 different features to determine bot score (*Botometer*, 2021), these tools are not perfect and may incorrectly classify some tweets. For example, organizations that post content systematically may be identified as a bot by the classifier.

Tables S1-4 display the re-run analyses with only the “no bot” sample. Results remain consistent among all but one finding. In the “no bot” sample, there was not a significant difference in access tweets before and after the FDA approval; however, these findings should be taken with caution. This may be likely due the smaller sample size of barrier tweets or potentially by an error in the bot classification of the tweets.

**Table S1. Characteristics of PrEP Tweets by FDA Approval of Descovy (N = 786)**

Variable	Before FDA	After FDA	p-value
	Approval	Approval	
	N (%)	N (%)	
<b>TPB Construct</b>			
Attitude	26 (6.5%)	27 (7.0%)	.797
Perceived norm	8 (2.0%)	3 (.7%)	.142
Perceived behavioral control	5 (1.3%)	8 (2.1%)	.371
Intention/behavior	25 (6.3%)	37 (9.6%)	.087
Information/knowledge	82 (20.6%)	107 (27.6%)	.020
Actual barriers	176 (44.1%)	122 (31.5%)	<.001
Other	77 (19.3%)	83 (21.4%)	.454
<b>Source</b>			
Individual	323 (81.0%)	302 (78.0%)	.311
Organization	76 (19.0%)	85 (22.0%)	

Note: P-values were calculated from  $\chi^2$  tests; all cells had expected values over 5.

**Table S2. Types of Actual Barriers by FDA Approval of Descovy (N = 298)**

Variable	Before FDA	After FDA	p-value
	Approval N (%)	Approval N (%)	
Cost	68 (38.6%)	50 (41.0%)	.684
Access	69 (39.2%)	37 (30.3%)	.115
Issues with Pharmaceutical Company	33 (18.8%)	27 (22.1%)	.474
Stigma	6 (3.4%)	8 (6.6%)	.207

*Note.* P-values were calculated from  $\chi^2$  tests; all cells had expected values over 5.



**Table S3. Characteristics of PrEP Tweets by Source (N = 786)**

Variable	Organization	Individual	p-value
TPB Construct			
Attitude	0 (0%)	53 (8.4%)	<.001
Perceived norm	3 (1.9%)	8 (1.3%)	.705 <sup>a</sup>
Perceived behavioral control	1 (.6%)	12 (1.9%)	.485 <sup>a</sup>
Intention/behavior	1 (.6%)	61 (9.8%)	<.001
Information/knowledge	73 (45.3%)	116 (18.6%)	<.001
Actual barriers	67 (41.6%)	231 (37.0%)	.278
Other	16 (9.9%)	144 (23.0%)	<.001

*Note:* P-values with expected values over 5 were calculated from  $\chi^2$  tests.

<sup>a</sup> P-values were calculated using Fisher's exact tests.

**Table S4. Emotions and Sentiments of PrEP Tweets by FDA Approval (N = 12618)**

Variable	t-statistic	df	p-value
Positive emotion	-5.13	12575.78	<.001
Negative emotion	1.32	12597.52	.187
Anxiety	.57	12614.66	.571
Anger	3.84	12132.18	<.001
Sadness	.40	12485.72	.689

*Note:* T-statistics were conducted using Welch's t-tests for unequal variances.

*Table S5. Emotions and Sentiments of PrEP Tweets by Source Type (N = 786)*

Variable	t-statistic	df	p-value
Positive emotion	-2.83	357.24	.005
Negative emotion	-.48	298.50	.635
Anxiety	2.07	226.78	.039
Anger	-.471	305.89	.638
Sadness	-1.05	362.16	.293

*Note:* T-statistics were conducted using Welch's t-tests for unequal variances.

## Study 2. Mobile App Information

### *Daily Prompts for Mobile App Intervention*

Prior to Study	Welcome! Please type a message below to introduce yourself. You can send as many messages as you want on this tab.
Day 1	Please watch the linked video and discuss your thoughts and opinions about the video. <a href="https://www.youtube.com/watch?v=1_eo17YahCo">https://www.youtube.com/watch?v=1_eo17YahCo</a>
Day 2	What are ways in which you could support a friend who would like to start PrEP?
Day 3	Please watch the linked video. What do you think about Justus' story? <a href="https://www.youtube.com/watch?v=9IX6Y4eAsxI">https://www.youtube.com/watch?v=9IX6Y4eAsxI</a>
Day 4	What are some strategies that could help you or your friend establish a daily routine for taking PrEP?
Day 5	What are the most helpful sources for LGBTQ+ health information?
Day 6	Please review the linked website. If you are uninsured, how could you pay for PrEP? <a href="https://www.cdc.gov/hiv/basics/prep/paying-for-prep/index.html">https://www.cdc.gov/hiv/basics/prep/paying-for-prep/index.html</a>
Day 7	What are ways in which the U.S. could improve access to PrEP?
End of Study	The 7-days have completed. Please make sure to complete the post-survey to obtain your payment!

## Study 2. Nonparametric Tests

### *Intervention Effects (Pre- and Post-Intervention) on Outcome Variables*

The following results are based on Wilcoxon signed ranked tests to examine whether the intervention improved outcome variables.

#### Familiarity

Familiarity with HIV ( $p = .554$ )

**Familiarity with PrEP ( $p = .001$ )**

#### Knowledge

**PrEP for reducing HIV acquisition ( $p < .001$ )**

PrEP consistent use and effectiveness ( $p = 1.00$ )

PrEP and condom use ( $p = .157$ )

PrEP and other STIs ( $p = 1.00$ )

#### **Intention to start taking daily oral PrEP ( $p = .003$ )**

**I intend to start daily oral PrEP ( $p = .001$ )**

**I want to start daily oral PrEP ( $p = .022$ )**

**It is likely I will start daily oral PrEP ( $p = .013$ )**

#### **Attitude toward starting daily oral PrEP ( $p = .006$ )**

**Bad – Good ( $p = .003$ )**

**Harmful – Beneficial ( $p = .030$ )**

**Foolish – Wise ( $p = .037$ )**

**Useless – Useful ( $p = .034$ )**

#### Perceived injunctive norm supporting starting daily oral PrEP ( $p = .117$ )

My partner(s) would expect me to start daily oral PrEP ( $p = .906$ )

My gay friends would encourage me to start daily oral PrEP ( $p = .128$ )

The gay community would expect me to start daily oral PrEP ( $p = .100$ )

**My doctor would encourage me to start daily oral PrEP ( $p = .015$ )**

#### Perceived descriptive norm supporting starting daily oral PrEP ( $p = .071$ )

Most of my gay friends have started daily oral PrEP ( $p = .475$ )

Most within the gay community have started daily oral PrEP ( $p = .106$ )

Most of my partner(s) have started daily oral PrEP ( $p = .111$ )

#### **Perceived behavioral control for starting daily oral PrEP ( $p = .05$ )**

**I am confident I could start taking daily oral PrEP ( $p = .008$ )**

Taking daily oral PrEP completely up to me ( $p = .717$ )

Taking daily oral PrEP under my control ( $p = .199$ )

### *Social Support versus Individual Conditions on Outcome Variables*

Mann-Whitney U tests were conducted to examine whether social support improved outcome variables; however, there were no significant differences between conditions.

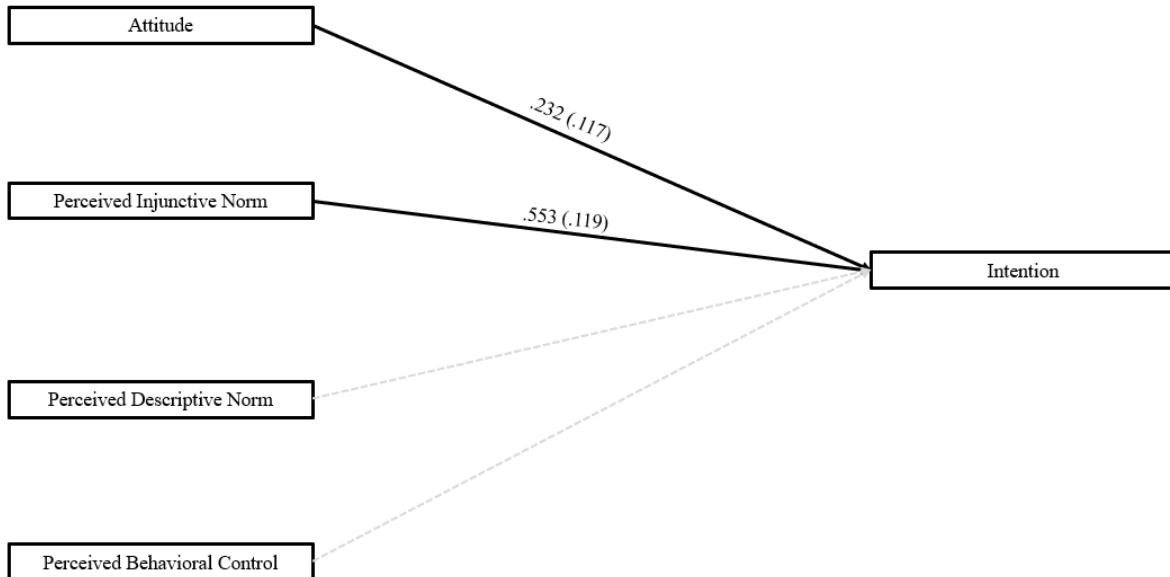
## Study 2. Correlations

*Table S6. Correlations between Outcome Variables*

	1	2	3	4	5	6	7	8	9	10	11	12
1. Pre-Intention												
2. Pre-Attitudes	.57**											
3. Pre-Injunctive Norm	.69**	.62**										
4. Pre-Descriptive Norm	.31**	.25*	.35**									
5. Pre-Perceived Behavioral Control	.38**	.34**	.34**	-.04								
6. Post-Intention	.86**	.60**	.77**	.24	.22							
7. Post-Attitude	.40*	.63**	.51**	0	.17	.62**						
8. Post-Injunctive Norm	.46**	.46**	.59**	.26	-.07	.52**	.43*					
9. Post-Descriptive Norm	.32	.27	.23	.47**	-.16	.40*	.06	.43*				
10. Post-Perceived Behavioral Control	-.09	.01	-.14	.19	.27	.07	.02	.17	.1			
11. Empowerment Support	.26	.25	.24	0	.11	.31	.43*	.56**	.18	.45**		
12. Information Support	.22	.24	.15	-.02	.18	.25	.40*	.40*	.19	.48**	.83**	
13. Emotional Support	.35*	.15	.24	.01	.03	.31	.29	.52**	.23	.40*	.88**	.72**

## Study 2. Structural Equation Models

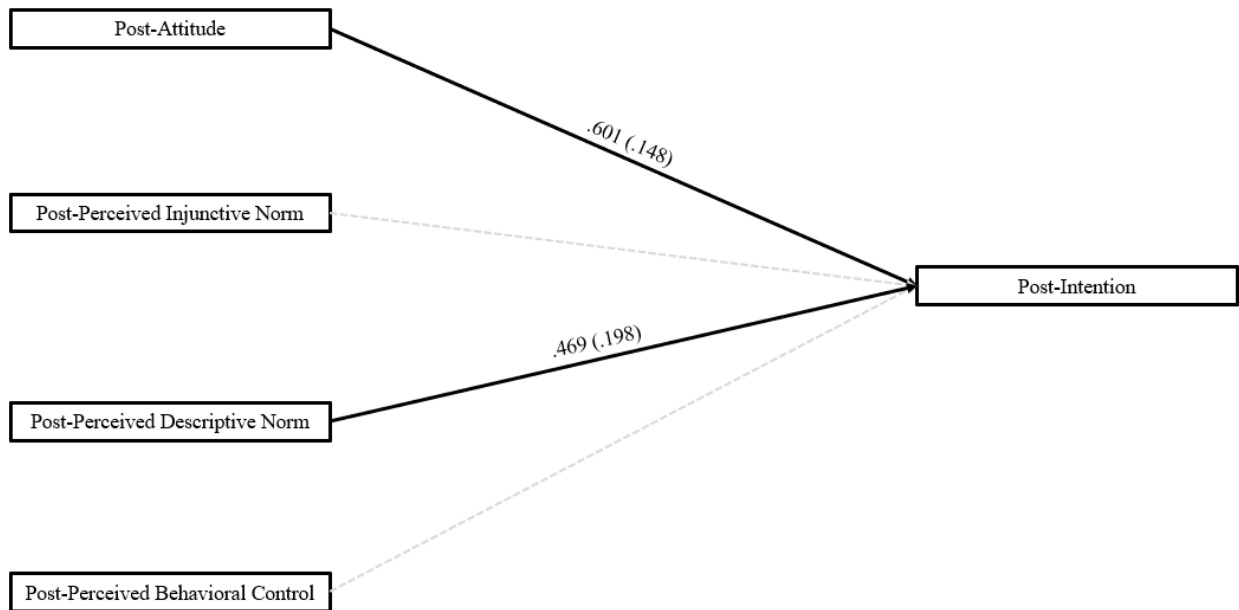
*Figure S1. Assessing the Relationship between TPB-Constructs Prior to Intervention*



*Note.* Structural equation model illustrating the relationship between attitude, norms, and behavioral control on intention to initiate PrEP. Bolded lines indicate a significant relationship between variables, and unstandardized coefficients are reported. Here we find that attitude toward starting PrEP and perceived injunctive norms supporting PrEP initiation were significantly associated with intention to start PrEP.



*Figure S2. Assessing the Relationship between TPB-Constructs After the Intervention*



*Note.* Structural equation model illustrating the relationship between attitude, norms, and behavioral control on intention to initiate PrEP after the intervention. Bolded lines indicate a significant relationship between variables, and unstandardized coefficients are reported. Here we find that attitude toward starting PrEP and perceived descriptive norms supporting PrEP initiation were significantly associated with intention to start PrEP. Interestingly, attitudes toward starting PrEP remained a consistent predictor of PrEP intention before and after the intervention.