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In-person and virtual social interactions improve well-being during the COVID-19 pandemic

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A B S T R A C T

Social interactions abound in everyday life. Face-to-face interactions, in particular, catalyze the social connection necessary for psychological well-being. What happens, then, when a global pandemic disrupts normal patterns of socialization? In March 2020, the world uploaded much of its face-to-face interactions online, transitioning en masse to remote work. These circumstances provided a natural experiment for studying how virtual versus face-to-face interactions facilitate psychosocial well-being. We conducted two studies measuring how eight types of interactions related to people's positive affect and social connection. Study 1 tracked virtual interactions and well-being (n = 996) in three waves from May 2020–2021. Study 2 measured participants' (n = 249) virtual interactions and well-being three times daily for two weeks. Both studies indicate that voice calling, group calling, and online messaging are associated with increased social connection and positive affect in the short- and long-term. However, the benefits of face-to-face interactions consistently eclipsed those of all virtual surrogates under investigation.

1. The impact of virtual social Interaction on well-being during the COVID-19 pandemic

> "I admire machinery as much as anyone, and am as thankful to it as anyone can be for what it does for us. But, it will never be a substitute for the face of another, with their soul in it."
>
> —Charles Dickens and Wilkie Collins, *The Wreck of the Golden Mary*
>
> "We're better off inside of the screen sometimes."
>
> —Lauren Mayberry of CHVRCHES, "Lullabies" from *Screen Violence*

Social interaction is the cornerstone of humanity: individuals engage in myriad interactions on a daily basis with close friends, family and complete strangers (Franck, 1980; Sander et al., 2017). Social interactions offer people both a proximal, intrinsic reward (Kawamichi et al., 2016; Krach et al., 2010; Walter et al., 2005), and help to satisfy a fundamental need for social connection (Batson, 1990; Baumeister & Leary, 1995; Hari et al., 2015; Levinson, 2006). Fulfilling this need for social connection is as essential for well-being as the meeting of basic physical needs (Eisenberger & Lieberman, 2005). In fact, independent of the actual enjoyment they might reap from shared experiences, people are motivated to pursue them as a function of the increased social connection they expect to achieve along the way (Jolly et al., 2019).

In recent years, the proliferation of digital devices has enabled widespread virtual interactions—including social media, texting, and voice and video calling. Despite the growing popularity of these virtual interactions, face-to-face interaction—the in-person communicative exchange of verbal and non-verbal social cues—still seems to represent the ideal form of social engagement (Duncan & Fiske, 2015; O'Malley et al., 1996). In the present research, we aim to empirically clarify how

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they compare: did Dickens and Collins long foresee the failure of virtual interaction, or does Mayberry's pandemic-era songwriting reflect a new reality? Can virtual interactions *truly* satisfy our idiosyncratic hunger for social connection?

The COVID-19 pandemic curtailed face-to-face interaction in 2020 on a global scale. In the absence of physical interpersonal contact, people turned to phones, tablets, and computers to facilitate social interaction. We assessed the effectiveness of the most popular forms of virtual interaction on social connection and positive affect relative to face-to-face interaction to determine if they are interchangeable in terms of the psychological outcomes they predict.

1.1. The importance of social relationships

People are driven to fulfill their social needs through frequent engagement in enduring, emotionally satisfying social interactions (Baumeister & Leary, 1995; Cacioppo & Patrick, 2008; Leary, 2010; Lieberman, 2013; Mesoudi et al., 2006). The need to foster connection can manifest as strongly as biological demands for food, sleep, and shelter. Indeed, these motivations are all instantiated in common neural systems (Eisenberger, 2012, 2013; Eisenberger & Cole, 2012; Eisenberger & Lieberman, 2005; Matthews & Tye, 2019).

People who successfully develop and maintain strong social bonds experience countless mental and physical health benefits (Cohen, 2004; House et al., 1988). Both quantity *and* quality of social interaction (Zhaoyang et al., 2019) impact well-being in the short- and long-term (Carmichael et al., 2015; Fiorillo & Sabatini, 2011; Kuczynski et al., 2022; Sun et al., 2020). More social interactions are better: frequent and longer interactions buffer against negative health outcomes and enhance cognitive performance (Ren et al., 2022; Vlahovic et al., 2012; Zhaoyang et al., 2021), with an optimal frequency ranging from every few days to weeks (Luo et al., 2022; Stavrova & Ren, 2021). More social ties are also better: people with a rich network of social ties experience enhanced well-being (Seeman, 1996; Tay et al., 2013). The quality of social interactions likewise matters. High-quality socialization with close ties—such as long-term partners, spouses, and family—predicts psychological benefits of reduced stress and increased life satisfaction (Fuller-Iglesias, 2015; Levitt et al., 1986; Nezlek et al., 2002; Thomas et al., 2017). These high-quality relationships facilitate positive health behaviors including adherence to medical advice, a healthy diet, and proper exercise that further bolster physical and mental well-being (Bloom, 1990; Umberson et al., 2010).

Even minimally social interactions can improve well-being. Interactions with strangers such as service workers contribute to happiness and feelings of belonging (Sandstrom & Dunn, 2014a; 2014b). Merely "catching up" in everyday conversation boosts emotional connection (Hall, 2018) and positive affect (Reece et al., 2023). People who engage in more social activities report greater life satisfaction (Rohrer et al., 2018). Thus, even a little socializing can go a long way, although a lot can go even further.

In contrast, people who lack frequent, sustained, or meaningful social interactions experience adverse outcomes: they miss both the momentary and long-term benefits of social interaction for health and well-being (Holt-Lunstad, 2021). Reduced interpersonal contact predicts a 13% increase in mortality (Shor & Roelfs, 2015); loneliness predicts a 32% increase in mortality (Holt-Lunstad et al., 2015), an effect larger than commonly recognized public health crises such as excessive smoking, obesity, and chronic inactivity (Holt-Lunstad et al., 2010). Loneliness also heightens the risk of suicide (Stravynski & Boyer, 2001), depression and anxiety (Beutel et al., 2017; Nezlek et al., 1994; Wang et al., 2018), dementia (Evans et al., 2019), inflammatory stress responses (Jaremka et al., 2013), and cardiovascular problems (Schwerdtfeger & Friedrich-Mai, 2009). Cacioppo and Cacioppo (2014) explain these findings in an account of self-reinforcement—that social isolation, in fact, goads our inherent sociality into entering a psychologically and physically draining state of "self-preservation."

Healthy social interactions are necessary for momentary and long-term well-being. In the current research, we aim to study the impact of social interaction on two factors that contribute to well-being—positive affect and social connection—that capture the shorter term impact of social connectedness on affect, or feelings, and the longer-term impact on social flourishing, respectively (Diener et al., 2010; Linley et al., 2009; Ryff & Keyes, 1995).

1.2. From in-person to virtual interaction

Given the importance of social connection, people are highly motivated to fulfill their everyday social needs (Buijs et al., 2021; Maslow, 1943; Tay & Diener, 2011). Indeed, social interaction permeates almost every aspect of our everyday life. Ecological momentary assessment (Bernstein et al., 2018; Zhaoyang et al., 2018), diary (Cornwell, 2011), and epidemiological contact tracing (van de Kassteele et al., 2017) studies converge in demonstrating that adults engage in an average of 10–15 unique interactions daily, and spend up to 40–60% of their daily waking time in some form of social interaction.

Face-to-face interaction is the gold standard of human communion. It comprises the majority of individuals' daily reported interactions, particularly those between close connections (Baym et al., 2004; Macdonald et al., 2021; Subrahmanyam et al., 2020). Additionally, it is the only form of interaction experienced early in human development (Davies, 2012). Face-to-face interaction offers the richest form of interaction, with its synchronously exchanged, multimodal social cues (Sauppé & Mutlu, 2014; Tanis & Postmes, 2003). Specifically, face-to-face communication helps to transmit nonverbal information, including posture, facial expression, direction of gaze, and physical gestures, which promote unambiguous, fluid interactions. Consequently, it reliably engenders feelings of social connection (Pea et al., 2012; Wohn et al., 2017), relationship satisfaction (Goodman-Deane et al., 2016), positive affect (Drolet & Morris, 2000), psychological well-being (Chan, 2018; Marinucci et al., 2022; Subrahmanyam et al., 2020), workplace productivity (Battiston et al., 2020), and decreased stress (Ono et al., 2011). The more "lifelike" a social interaction, the more strongly people will experience these positive outcomes. Indeed, less natural exchanges can even make people feel more isolated and unsatisfied (Petrova & Schulz, 2022).

Yet, virtual interactions abound more and more frequently (Lieberman & Schroeder, 2020). As of 2021, 97% of Americans own a mobile phone, 85% own a smartphone, 93% access the internet, and 72% actively use social media; among individuals visiting Facebook, Snapchat, Twitter, Instagram, and YouTube, between 45 and 70% report at least daily usage (Pew Research Center, 2021a; 2021b; 2021c). Nearly half of 18-49-year-olds report being online almost constantly (Perrin & Atske, 2021). Adolescents spend on average about 2 h each day on virtual interactions and exchange well over 100 texts with friends and family (Manago et al., 2020). Taken together, these studies underscore the frequency of daily virtual interactions in which individuals participate, especially young adults. In the past, when circumstances such as geographical distance, natural disasters, or plague prevented physical contact, people had no alternative routes to connect with others. In the present day, however, technology has provided numerous new routes of bridging even some of the most monumental physical divides.

1.3. Virtual interaction and well-being

Face-to-face interaction offers well-established advantages for well-being. To what extent do virtual interactions offer the same? Research on this question offers mixed answers. On one hand, virtual interactions have been linked with adaptive emotion regulation (Hoffner & Lee, 2015), better health, and less depression as a function of reduced loneliness (Chopik, 2016). On the other, digital modes of interaction can also intensify depression and anxiety and diminish well-being, especially when they displace face-to-face interaction (Booker et al., 2015;

Hoge et al., 2017; Rosen et al., 2014; Shakya & Christakis, 2017; Twenge, 2019; Twenge & Campbell, 2018; Twenge et al., 2018). How do we reconcile this apparent contradiction? One potential explanation is that the effectiveness of a given virtual interaction for well-being depends on the richness of the social experience it affords.

Media Richness Theory (Daft & Lengel, 1986), Media Naturalness Theory (Kock, 2005), and Social Presence Theory (Short et al., 1976) all suggest that media that offer more saturated sensory stimulation and salient social signals will facilitate more effective, more engaging, more socially satisfying interpersonal communication. Voice, video, and group calling (i.e., with two or more people concurrently) offer particularly rich media experiences (Goodman-Deane et al., 2016). Indeed, these are also the modalities most consistently positively associated with well-being: voice calling predicts higher subjective well-being and social capital (Chan, 2015); video calling predicts social success and satisfaction (Nowak et al., 2009; Shen et al., 2017; Xu et al., 2021); both voice and video calling predict improved life and relational satisfaction (Goodman-Deane et al., 2016; Wang et al., 2015); and group calling boosts both social connection and feelings of social support (Black et al., 2020).

Online messaging represents a more subdued form of interpersonal communication. Communicators receive neither facial nor vocal cues from interaction partners, and receive only intermittent responses (Goodman-Deane et al., 2016). Yet, mobile online communication can still increase self-esteem, psychological well-being, positive affect, social capital, and feelings of social support and friendship satisfaction while decreasing depression (Chan, 2015, 2018; Shaw & Gant, 2004). People who exchange more text messages experience greater intimacy and relationship satisfaction (Park et al., 2016). However, those who spend more *time* texting experience decreased relationship satisfaction, life satisfaction, and psychological well-being (Goodman-Deane et al., 2016; Park et al., 2016). People who engage in more email correspondence and participate in more group chats also experience more negative emotions and feelings of entrapment (Chan, 2018). Thus, the benefits associated with texting may hinge on contextual factors including breadth and depth of engagement, frequency, and duration.

Social media likewise represents a double-edged sword: on one hand, *active* social media use—engaged commenting and posting—has been linked to greater feelings of social connection (Burke & Kraut, 2016; Deandrea et al., 2012), improved psychological well-being (Burke & Kraut, 2016) and reduced depression (Escobar-Viera et al., 2018). Successfully achieving a sense of online social connectedness on Facebook predicts lower anxiety and depression and greater life satisfaction (Grieve et al., 2013). On the other hand, *passive* social media use—-browsing without direct communication with others—represents the most impoverished form of virtual interaction and is associated with the most negative impacts on affect and social connection. For example, passive Facebook use either lowers (Burnell et al., 2019; Hall et al., 2019; Thorisdottir et al., 2019; Verduyn et al., 2015) or does nothing (Burke & Kraut, 2016; Orben & Przybylski, 2019) for affective well-being and social connection. Indeed, browsing is a quick way to consume large amounts of media, a phenomenon associated with reduced bridging and bonding social capital and increased loneliness (Burke et al., 2010). Overall, the *mode* of social media engagement does seem to influence improved or impaired affect and social connection: media richness appears to moderate the relationship between virtual interactions and well-being.

1.4. Social interaction during COVID-19

The COVID-19 pandemic limited in-person social interactions starting in March 2020 (Bloom et al., 2020; Lucchini et al., 2021; Parr et al., 2020). Governments raced to implement social isolation policies to stop the spread of the disease. In the U.S., mobile location tracking data reflected a 8% national increase in stay-at-home behavior and up to a 39% increase in time spent at home during lockdown (Brzezinski et al., 2020). These changes corresponded to employees working from home (Parker et al., 2022) and students enrolled in remote courses (National Center for Education Statistics, 2022).

The ensuing months of social distancing, sheltering in place, and quarantining upon infection resulted in a significant decline in face-to-face interaction. Between March and September 2020, the first wave of COVID-19 prompted an 80% decline in face-to face interaction (Feehan & Mahmud, 2021). The pre-pandemic average of between 7 and 26 face-to-face meetings per day dipped to as low as 2–5 (Liu et al., 2021). Younger adults—college students, in particular—noted 0.80 fewer interaction partners and 0.46 fewer study partners (Elmer et al., 2020), translating to a drop in average daily socialization from 90 to 30 min a day (Giuntella et al., 2021). Simultaneously, people turned to technology to facilitate their recreational and professional social interactions in new ways (Huckins et al., 2020; McClain et al., 2021; Stevic et al., 2021). Young adults reported an average of 5 h of screen time a day during spring 2020, more than double the 2 h reported in 2019 (Giuntella et al., 2021). Among a representative sample of U.S. adults, 20–40% of people reported increased engagement across texting, voice and video calling, email communication, online gaming, and social media during spring 2020 (Nguyen et al., 2020). COVID-19 precipitated an upheaval of the modern norms of interpersonal communication as people replaced face-to-face interaction with virtual alternatives.

In the present research, we join a growing wave of researchers exploring how this forced shift to virtual modes of socialization during the height of the pandemic impacted well-being among the general U.S. population (Choi & Choung, 2021; David & Roberts, 2021; Lee et al., 2023; Maheux et al., 2021; Marinucci et al., 2022; Monninger et al., 2023; Newson et al., 2021; Nguyen et al., 2021; Sahi et al., 2021; Stevic et al., 2021; Stuart et al., 2021; Tibbetts et al., 2021; Towner et al., 2022; Watson et al., 2021; Xu et al., 2021). These previous studies of virtual interaction have shown how social distancing has impacted social connection and well-being and that smartphones may, depending on the context of their usage, either attenuate or exacerbate potential negative experiences during the pandemic. For example, using virtual media for communication predicted decreased loneliness, increased satisfaction with life (Choi & Choung, 2021), and increased friendship satisfaction over time (Stevic et al., 2021). On the other hand, media use for information-seeking purposes or other non-communicative ends led to a direct reversal of, or null, effects (Choi & Choung, 2021; Stevic et al., 2021), demonstrating the importance of directed usage on the relationship between virtual engagement and well-being. Additionally, researchers have found that online social connections can substitute for offline interactions (Marinucci et al., 2022) and help improve health anxiety (Stuart et al., 2021). However, these benefits appear to be restricted to times of isolation (Marinucci et al., 2022; Stuart et al., 2021). This work also demonstrates the positive relationship between the number of virtual interaction partners and improved mental health (Sahi et al., 2021). The overall consensus is that face-to-face contact is consistently, positively associated with well-being (Monninger et al., 2023; Newson et al., 2021; Tibbetts et al., 2021; Towner et al., 2022).

Here, we add to this literature by assessing the relationships between a comprehensive set of virtual and face-to-face interactions and both social and affective dimensions of well-being among a representative sample using both longitudinal and momentary detail.

1.5. Current studies

To what extent does virtual interaction predict well-being during a global pandemic? Here, we test how virtual interactions and face-to-face interaction relate to well-being across two studies. In both, participants self-reported their virtual interaction habits and well-being in terms of positive affect and social connection. Study 1 was a longitudinal investigation, where participants completed up to three surveys from May 2020 to May 2021. Study 2 was an experience sampling study conducted in the winter of 2020, where participants completed surveys three times

a day for two weeks. We measured the extent to which virtual interactions—social interactions conducted through a mobile phone device—filled the social interaction void caused by the pandemic and enhanced well-being. We expected that engaging in virtual interactions during this unusual period of social distancing would be associated with enhanced affective experiences and feelings of social connection—albeit less robustly than would be observed with face-to-face interaction.

2. Study 1

In this study, we measured how multiple modes of interaction related to well-being during the first year of the COVID-19 pandemic. We tested the preregistered hypotheses that face-to-face interaction would positively predict both positive affect and social connection, and that it would do so more effectively than all virtual alternatives. We aimed to identify the extent to which each form of virtual connection could serve as a viable alternative to capture the same benefits enjoyed during face-to-face interaction.

The yearlong observational study was administered at three-time points with identical questionnaires indexing participants' face-to-face interactions, seven types of virtual interactions, and momentary well-being. We assessed how well-being, measured in terms of positive affect and social connection, was related to each interaction type.

2.1. Method

Data for this study were collected as part of a broader research project on the effects of social isolation during the COVID-19 pandemic (Mildner & Tamir, 2022). We preregistered our primary hypotheses and analyses on OSF prior to data analysis. This study was approved by the Institutional Review Board of Princeton University. All materials and data are hosted online: osf.io/rzdgx.

2.2. Participants

Participants comprised a representative sample matched to the U.S. Census values for sex, age, and ethnicity through Prolific Academic Ltd. (www.prolific.co). Eligible participants who provided written informed consent were invited to participate within three data collection periods: May 20–28, 2020, then June 17–24, 2020, and lastly April 29, 2021. 996 participants completed the initial survey; 829 the second survey; and 472 the third survey, for a total of 2296 data points. Because one participant responded with a >24-h response for their time spent voice calling within the past day, we removed their one data point from the dataset—leaving us with a total of 2296 (995, 829, and 472, respectively) responses.

We aimed to collect at least 1000 participants based on an *a priori* power analysis using the simr package in R (Green & MacLeod, 2016; R Core Team, 2020). This sample size allowed us to detect the smallest predicted fixed effect of virtual interaction on well-being ($b = 0.02$) with approximately 98.1% power (95% CI [97.05, 98.85]). This effect size was estimated from pilot data from an independent sample of participants ($n = 462$) who completed the same measures used in this study.

2.3. Procedures

After consenting to participate, participants completed the study through an independently hosted website. Over three data collection periods, participants completed identical measures of social interaction, positive affect, energy, social connection, and various other constructs included in the larger study (e.g., life satisfaction, loneliness, self-esteem, mood and anxiety, social thought).

2.4. Measures

Because data for this study were collected as part of a broader research project answering several independent questions, we report only the relevant subset of our materials.

Social Interaction. Our primary predictor variable was a measure of how frequently participants engaged in eight forms of interaction in the past day. Participants estimated how much time they had spent interacting with others in the following ways: (a) face-to-face; (b) video calls; (c) group calls (both voice and video); (d) voice calls; (e) messaging/texting; (f) posting to social media; (g) commenting on social media; and (h) browsing social media. Responses were recorded in free-response text boxes that accepted only numeric input with up to two decimal places. The numerical responses across all items had to add up to 24 h. If participants were unsure how much time they spent on any of the activities, they were asked to provide their best estimate.

Positive Affect. We measured our first, primary dependent variable, *positive affect*, with a single item on the state-level subscale extracted from the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) asking how "content" participants felt on a 4-point scale from 1 ("not at all") to 4 ("very much so"). This pre-registered operationalization of affect was determined based on analyses of pilot data.

Social Connection. We measured our second, primary dependent variable, *social connection*, using a 10-item version of the UCLA Loneliness Scale (Russell, 1996). Participants indicated how often they felt a particular way in a given question (e.g., "how often do you feel that you lack companionship?") on a 4-point scale from 1 ("never") to 4 ("always").

2.5. Results

2.5.1. The effects of virtual Interaction on well-being

First, we examined whether face-to-face and virtual interaction predicted positive affect and social connection. We implemented 16 linear mixed-effects models (LMEM) through the lme4 package in R (R Core Team, 2020) separately regressing the reported duration or participation in each of the eight modes of interaction (face-to-face, voice calling, video calling, group calling, online messaging/texting, browsing social media, commenting on social media, posting on social media) onto positive affect and social connection, respectively. We included participant ID in all models as random intercepts to control for our repeated-measures design. These analyses allowed us to estimate the associations between each modes of interaction and participants' momentary well-being. All analyses used a preregistered inference criterion of $p < 0.05$ to determine statistical significance.

Positive Affect. We first tested how each of the eight interaction modalities related to positive affect. We hypothesized that face-to-face interaction would positively predict positive affect. As expected, results showed that face-to-face interaction within the past day significantly predicted higher positive affect ($b = 0.02$, $SE = 0.01$, $t(2187) = 3.75$, $p < 0.001$; Fig. 1A). Exploratory analyses confirmed the robustness of this effect when controlling for all modes of virtual interaction as covariates in the same model and for household size (See Supplement A).

Additionally, we found that browsing social media within the past day significantly predicted lower positive affect ($b = -0.056$, $SE = 0.01$, $t(2285) = -4.56$, $p < 0.001$; Fig. 1A). We observed no significant association between any other form of virtual interaction and positive affect (Table 1). Therefore, face-to-face interaction was not only the strongest predictor of increased positive affect but also the *only* mode to predict positive affect significantly. Conversely, browsing social media was the least effective type of interaction: and it was also the only mode to exhibit a significant negative association with positive affect.

Social Connection. Next, we tested how each of the eight types of interaction related to feelings of social connection. In support of our second hypothesis, we found that face-to-face interaction significantly predicted social connection ($b = 0.08$, $SE = 0.02$, $t(1543) = 3.71$, $p < 0.001$). Several modes of virtual interaction also predicted increased social connection, including group calling ($b = 0.05$, $SE = 0.02$, $t(1655)$

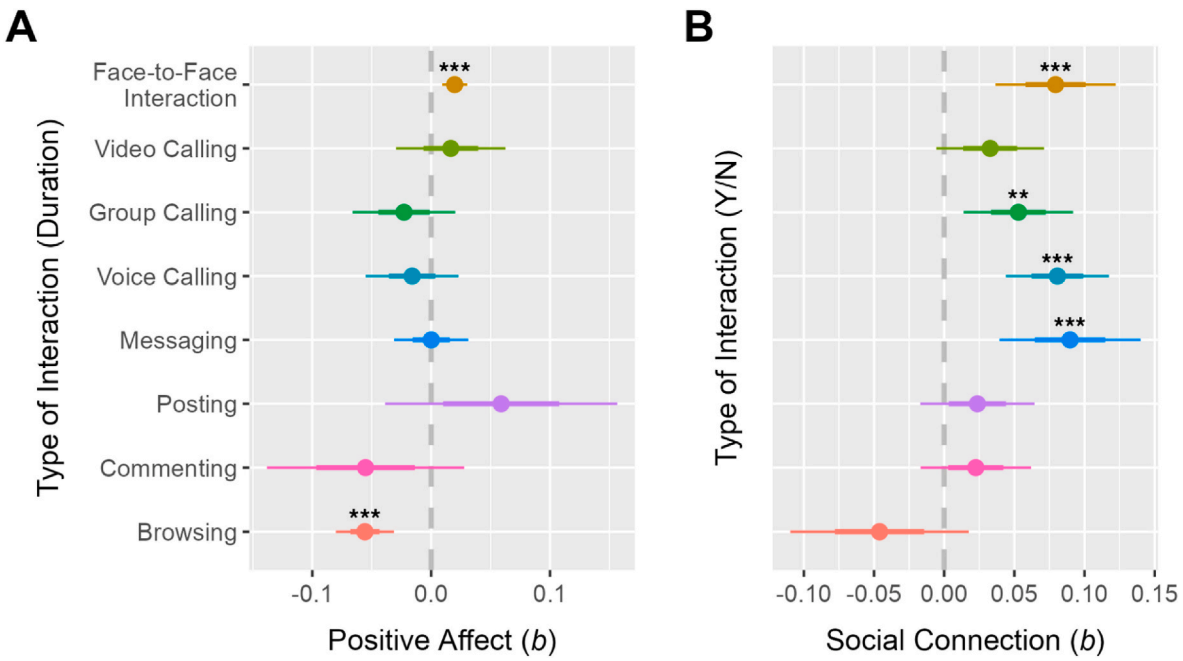

Fig. 1. Positive Affect and Social Connection Predicted by Face-to-Face and Virtual Interaction. Fig. 1 (A) Face-to-face interaction duration positively predicted feelings of positive affect while browsing social media predicted the opposite effect. All other relationships were non-significant. (B) Participation in at least one instance of face-to-face interaction, voice calling, group calling, or online messaging positively predicted feelings of social connection. Effect sizes reflect the results of linear mixed-effects regressions where participant ID was treated as a random intercept. Error bars represent one standard deviation. $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 1
LMEMs with virtual and face-to-face interactions predicting positive affect.

Predictor	*b*	*SE*	*t*	*p*
Face-to-Face Interaction	0.020	0.01	3.75	< 0.**001*****
Video Calling	0.017	0.02	0.72	0.473
Group Calling	−0.023	0.02	−1.06	0.290
Voice Calling	−0.016	0.02	−0.82	0.413
Online Messaging[a]	0.000	0.02	0.00	0.996
Posting on Social Media	0.059	0.05	1.21	0.228
Commenting on Social Media	−0.055	0.04	−1.33	0.184
Browsing Social Media	−0.056	0.01	−4.56	<**0.001*****

Note. Only fixed effects are listed. $^{***}p < 0.001$.
[a] This *b* rounded down from ~0.00007 and *t* rounded down from 0.004.

= 2.71, $p = 0.007$), voice calling ($b = 0.08$, $SE = 0.02$, $t(1674) = 4.39$, $p < 0.001$), and online messaging ($b = 0.09$, $SE = 0.03$, $t(1637) = 3.57$, $p < 0.001$) (Fig. 1B). No other form of virtual interaction significantly predicted social connection (Table 2). Exploratory analyses confirmed the effects for face-to-face interaction, voice calling, and online messaging when controlling for all modes of interaction as covariates in the same model and for household size (See Supplement A).

Table 2
LMEMs with virtual and face-to-face interactions predicting social connection.

Predictor	*b*	*SE*	*t*	*p*
Face-to-Face Interaction	0.08	0.02	3.71	< 0.**001*****
Video Calling	0.03	0.02	1.71	0.088
Group Calling	0.05	0.02	2.71	0.**007****
Voice Calling	0.08	0.02	4.39	< 0.**001*****
Online Messaging	0.09	0.03	3.57	< 0.**001*****
Posting on Social Media	0.02	0.02	1.16	0.245
Commenting on Social Media	0.02	0.02	1.14	0.253
Browsing Social Media	−0.05	0.03	−1.45	0.148

Note. Only fixed effects are listed. $^{**}p < 0.01$, $^{***}p < 0.001$.

2.6. Discussion

Prior research implicates face-to-face interaction as the best form of communication for increased well-being. Our results align well with this literature, finding strong evidence that face-to-face interaction positively predicts both positive affect and social connection. Exploratory analyses replicated these effects on a convergent measure wellbeing (i.e., anxiety; see Supplement A). However, given the reduction of in-person social interactions as a byproduct of COVID-19 social distancing measures, strong alternatives would prove invaluable.

Unfortunately, no other routes of social interaction predicted improved positive affect and social connection to the same extent (Fig. 2). While group calling, voice calling, and online messaging all significantly predicted greater feelings of social connection, they predicted null or even negative effects on positive affect. Thus, though no form of virtual interaction can fully replace face-to-face interaction, they may be better than no interaction at all. Other than passive browsing on social media, all other forms of virtual interaction still predicted increased social connection, and posting and commenting predicted increased positive affect (albeit not all significantly so). The degree to which online messaging predicted social connection eclipsed even that of face-to-face interaction.

3. Study 2

Study 1 demonstrated that face-to-face interaction, compared to various virtual interaction modes, was most reliably associated with positive affect and social connection. It also highlighted the potential of some forms of virtual interaction in enhancing feelings of social connection, specifically. In particular, voice calling, group calling, and texting all were associated with decreased loneliness. To test the generalizability of these findings in a more naturalistic context, Study 2 used experience sampling to investigate the associations between virtual and face-to-face interactions and the same indices of affect and social connection, in situ. Again, we sought to identify which modes of interaction might improve individuals' well-being during social distancing.

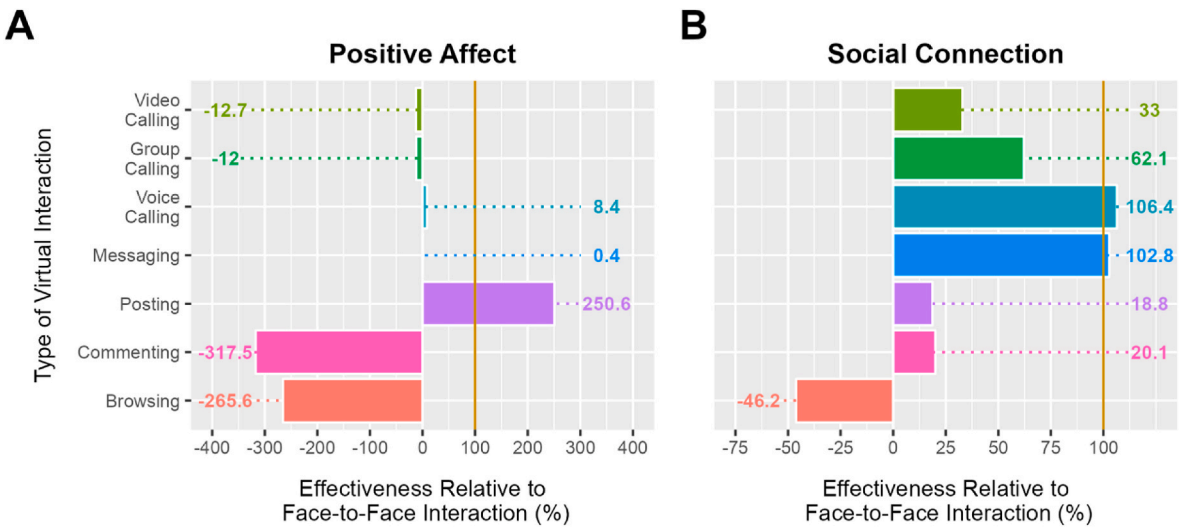

Fig. 2. Effectiveness of Virtual Interactions on Positive Affect and Social Connection Controlling for Face-to-Face Interaction. Fig. 2 (A) Only posting on social media predicted positive affect more strongly than face-to-face interaction. (B) The effects of voice calling and messaging were slightly greater than that of face-to-face interaction on social connection. Browsing social media was the only virtual activity that predicted decreased social connection. Negative values represent the reverse directional effect (i.e., decreased positive affect): only group calling and posting positively predicted positive affect.

During a 14-day study, participants filled out three daily questionnaires reporting similar measures of momentary well-being, virtual interactions, and face-to-face interactions as in Study 1. We assessed participants' self-reported affect and connection in relation to the same eight modes of interaction from Study 1.

3.1. Method

We preregistered our primary hypotheses and analyses on OSF prior to data collection. However, we had to discard our preregistered hypotheses, as they were informed by incorrectly preprocessed pilot data. Accordingly, we did not have specific predictions for this study, but we expected a pattern of results in line with that of Study 1. We retain our original preregistration to show which data we had planned to include in our primary analyses. This study was approved by the Institutional Review Board at Princeton University (approval number 15303). The data, materials and outdated preregistration are openly available on OSF at osf.io/nvu8z.

3.2. Participants

Participants (n = 301) were recruited through Prolific to complete the study through The Person Project, a mobile application (thepersonproject.org). We restricted our sample to Prolific users in the U.S./U.K. with at least 50 previously completed studies, a minimum approval rate of 95%, and access to a smartphone on which they could download the app. Participants were excluded from analysis if they failed to complete at least one daily survey after the intake survey (n = 51). Further exclusion of a redundant response by one participant yielded a final sample size of 249 participants (M_{age} = 34, 20 unreported; SD_{age} = 11; 133 females, 1 other; 70.7% White, 9.6% Asian, 5.2% Black or African American, 2.8% multiracial, 1.2% Hispanic or Latino/a/x, 0.4% Native Hawaiian or Pacific Islander, 0.4% American Indian or Alaska Native, 1.6% other, 8% unreported). Participants were recruited in six waves of ~60–75 people over a six-month period: pilot data was collected from October 8–November 11, 2020, and the preregistered data was subsequently collected from November 12, 2020–March 31, 2021.

We determined our target sample size of 250 participants based on available funding. Using pilot data, a simulation was run using the mixedpower package in the R programming environment (Kumle et al., 2020; R Core Team, 2020) to estimate the post-hoc power to detect the effect of online messaging/texting on feelings of social connection (a small effect size in our pilot data; η_p^2 = 0.001). With 1000 randomizations, the simulation showed that when extending the model to our expected sample size of 250 participants, we would have approximately 81% power to detect this effect (see Supplement H for details on the pilot dataset).

3.3. Procedure

Eligible participants signed an informed consent form to participate through The Person Project mobile application (thepersonproject.org). Participants first completed an intake survey that assessed trait well-being, virtual interactions, and social habits. Over the next 14 days, participants' interactions and well-being were sampled three times daily for momentary state data. Participants were notified to take all daily surveys through The Person Project application. A total of 42 were distributed at regular intervals: push notifications were delivered at 10:00, 15:00, and 21:00 daily with reminders occurring 15 and 30 min after initial notification. Morning (10:00) and afternoon (15:00) surveys were identical, while the evening survey (21:00) asked two additional questions about virtual interactions. Of the 10,458 possible daily surveys (249 participants × 14 days × 3 assessments/day), 6956 surveys (66.5%) were opened and at least partially completed.

3.4. Measures

This study included four components: the intake survey, the matching daily morning and afternoon surveys, the daily evening survey, and, lastly, a custom results page.

Intake Survey. Upon signup, participants completed an intake survey to capture their baseline, everyday feelings and behaviors. Here, participants reported measures such as their average time spent daily on virtual media, daily interaction habits, and long-term well-being (e.g., the UCLA Loneliness Scale; Russell, 1996). This intake survey was included for exploratory purposes (see Supplement G for details on all measures).

Daily Notifications. The daily notifications were completed once in the morning (10:00), in the afternoon (15:00), and again at the end of each day (21:00) throughout the 14-day study period. The survey first asked participants to report whether they had engaged in media use within the past hour by checking off options from a list of activities

including: talking to another person by phone or another type of voice call; talking to another person on a video call such as Skype or FaceTime; simultaneously group calling with more than one other people (including both voice and video calls); messaging someone online or through text messages; browsing social media (e.g., Instagram, Twitter, Facebook, Reddit, YouTube, etc.); commenting on social media posts; and posting original content to social media. Binarized variations of each virtual interaction variable were dummy-coded as predictor variables.

Participants then rated their well-being within the past hour on continuous scales measuring positive affect ("very negative" to "very positive"), social connection ("very lonely" to "very connected"), energy ("very lethargic" to "very energetic"), and emotionality ("thinking" to "feeling") derived from previous work on mental states (Thornton & Tamir, 2020). These measures assessed the potential impact of social interactions. Analyses focused on the positive affect and social connection outcomes, mirroring those of Study 1. See supplement for additional results.

The final section prompted participants to report the total duration of their active (i.e., face-to-face) interactions in the past hour. This measure was dummy-coded after data collection to compare it against the dichotomous virtual interaction variables.

Results Page. After the final daily survey was completed on the last day of the study, participants received access to a custom results page where they could review summary information about their own habits and well-being (see Supplement G for an example results page). In analyzing the data collected in Study 2, we seek to understand how seven virtual interactions individually relate to well-being outcomes.

3.5. Results

3.5.1. The effects of virtual Interaction on well-being

Our analyses used data collected in the daily notifications to examine in parallel whether engagement in social interaction both face to face and virtually predicted improved or impaired momentary well-being. As in Study 1, we implemented 16 linear mixed-effects models in the lme4 package in R (R Core Team, 2020). These models regressed each of the reported virtual activities that involved social interaction (voice calling, video calling, group calling, online messaging/texting, browsing social media, commenting on social media, posting on social media), as well as engaging in face-to-face interaction, onto each measure of well-being (positive affect and social connection) separately. We included participant identification numbers in all models as random intercepts to control for repeated measures. Through mixed-effects modeling, we investigated whether significant relationships emerged between face-to-face as well as virtual interactions and participants' momentary well-being.

Positive Affect. We first tested how each of the eight types of interaction impacted positive affect. We predicted that affect would be *positively* predicted by face-to-face interaction. As expected, results showed that face-to-face interaction within the past hour was related to significantly higher momentary positive affect ($b = 6.08$, $SE = 0.51$, $t(6793) = 11.88$, $p < 0.001$; Fig. 3A). Some forms of virtual interaction likewise predicted positive affect. Specifically, voice calling ($b = 2.02$, $SE = 0.64$, $t(6849) = 3.17$, $p = 0.002$), and online messaging/texting ($b = 1.35$, $SE = 0.51$, $t(6846) = 2.66$, $p = 0.008$) in the past hour both related to significant increases in reported positive affect, and browsing social media marginally increased it as well ($b = 0.99$, $SE = 0.51$, $t(6865) = 1.96$, $p = 0.050$). Exploratory analyses showed that the effects of voice calling and face-to-face interaction persisted even when controlling for all other virtual and face-to-face interactions in the same model and for household size (see Supplement F). We observed no significant associations between video calling, group calling, or either posting to or commenting on social media and positive affect (Table 3).

Social Connection. We next tested how each of the eight types of interaction impacted feelings of social connection. Again, results

Table 3
Individual LMEMs with virtual and face-to-face interactions each predicting positive affect.

Predictor	*b*	*SE*	*t*	*p*
Face-to-Face Interaction	6.08	0.51	11.88	**< 0.001*****
Video Calling	1.21	0.99	1.22	0.223
Group Calling	−0.02	1.08	−0.02	0.984
Voice Calling	2.02	0.64	3.17	**0.002****
Online Messaging	1.35	0.51	2.66	**0.008****
Posting on Social Media	2.40	1.24	1.94	0.053
Commenting on Social Media	1.08	0.88	1.23	0.22
Browsing Social Media[a]	0.99	0.51	1.96	0.05

Note. Only fixed effects are listed. **p < 0.01, ***p < 0.001.
[a] The effect of browsing social media on positive affect was marginally significant with a *p*-value rounding down from 0.0503.

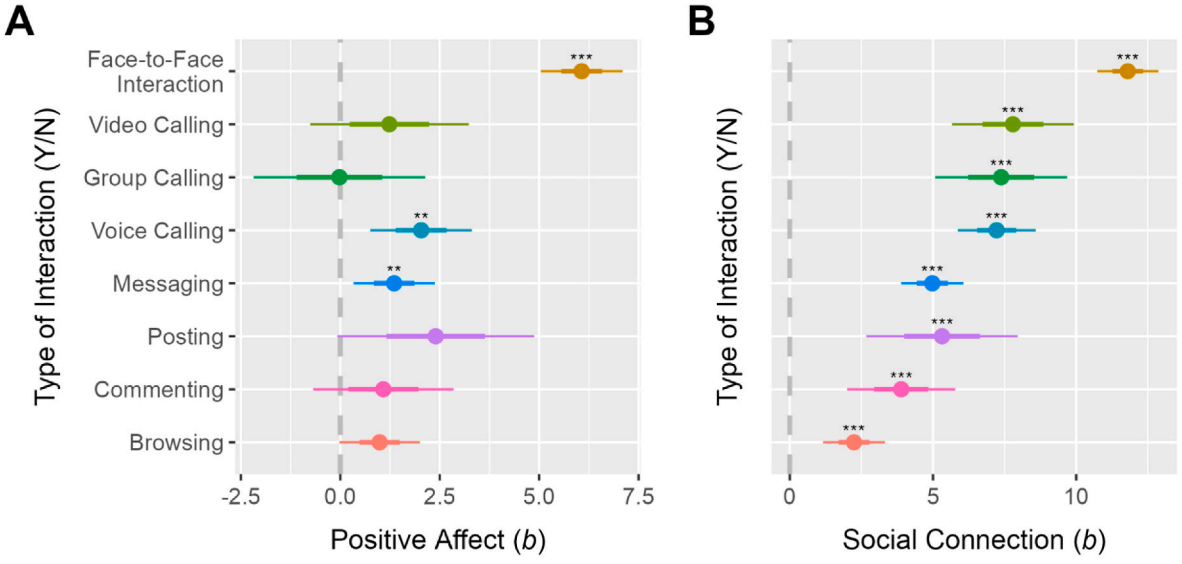

Fig. 3. Positive Affect and Social Connection Predicted by Face-to-Face and Virtual Interaction. Fig. 3 (A) Face-to-face interaction was related to significantly higher momentary positive affect. Voice calling and online messaging/texting also significantly predicted higher positive affect. (B) All modes of interaction significantly predicted higher momentary social connection, with face-to-face interaction as the strongest predictor. **$p < 0.01$, ***$p < 0.001$.

showed that face-to-face interaction ($b = 11.77$, $SE = 0.53$, $t(6809) = 22.04$, $p < 0.001$) within the past hour was related to significantly higher momentary feelings of social connection (Fig. 3B).

Additionally, several forms of virtual interaction predicted increased feelings of social connection. Specifically, as with positive affect, voice calling ($b = 7.23$, $SE = 0.68$, $t(6870) = 10.65$, $p < 0.001$), online messaging/texting ($b = 5.00$, $SE = 0.54$, $t(6865) = 9.24$, $p < 0.001$), and browsing social media ($b = 2.23$, $SE = 0.54$, $t(6885) = 4.12$, $p < 0.001$) all related to increases in social connection. Video calling ($b = 7.85$, $SE = 1.06$, $t(6839) = 7.41$, $p < 0.001$), group calling ($b = 7.39$, $SE = 1.15$, $t(6826) = 6.41$, $p < 0.001$), commenting on social media ($b = 3.89$, $SE = 0.94$, $t(6863) = 4.13$, $p < 0.001$), and posting to social media ($b = 5.32$, $SE = 1.32$, $t(6807) = 4.03$, $p < 0.001$) likewise predicted increases in social connection (Fig. 3B). As such, all interaction modes significantly related to increased feelings of social connection (Table 4). Exploratory analyses confirmed that voice calling, video calling, group calling, online messaging/texting, posting to social media, and face-to-face interactions remained robust predictors even when controlling for all other virtual interactions and face-to-face interactions within the same model and for household size (see Supplement F).

3.6. Discussion

Results from Study 2 replicate findings from Study 1 that engagement in face-to-face interaction is the best way to connect with others and achieve greater well-being relative to other interaction modes. In our sample, face-to-face interaction predicted the highest reports of momentary positive affect and social connection (Fig. 4). That said, nearly all forms of virtual interactions were associated with improved well-being. Similar to findings from Study 1, here we see that voice calling and texting were the most effective forms of virtual interaction, significantly predicting increased well-being as measured by both feelings of positive affect and social connection. Video calling, group calling, browsing social media, commenting and posting on social media offered the next best alternatives, predicting increased feelings of social connection. While this study supports prior work suggesting that face-to-face interaction most effectively engenders well-being, these findings also underscore the potential benefits of engaging in virtual interactions during periods of social isolation.

4. General discussion

Virtual interaction—video calls, instant messaging, and especially social media—represents a novelty of the modern age. And yet, we know startlingly little about the impacts of widespread, enduring virtual interaction. Here, we collected both longitudinal (Study 1) and in-situ (Study 2) data to assess the effects of virtual interaction on affect and social connection during the pandemic. We find that voice calls, group calls, and online messaging generally predict increased feelings of well-being. However, the benefits associated with face-to-face interactions reliably eclipsed all virtual surrogates under investigation.

Our results are situated within the longstanding debate concerning whether virtual interaction is *beneficial* or *harmful* for well-being. Those of the former persuasion cite increased satisfaction with life (Kang & Jung, 2014; Rotondi et al., 2017) and feelings of social support and connection (Ling, 2010; Walsh et al., 2009). In contrast, opponents adduce evidence of decreased relationship quality and satisfaction (Turkle, 2016) and subjective well-being (Twenge et al., 2018). Our findings advocate a cautiously optimistic stance: while the association between virtual interaction and positive affect and social connection fail to match those of face-to-face communication, several common modes of virtual interaction *do* successfully improve participants' well-being—most notably voice calling and texting. These options may even appreciate further in value when opportunities for face-to-face interaction are limited. Virtual interaction *can* act as useful means for increasing connection and affect especially during difficult and inherently unnatural experiences of social isolation.

While demonstrating an overall positive impact of virtual interactions on well-being, these findings also provide a more nuanced understanding of this relationship. In particular, our results align with Media Richness Theory (Daft & Lengel, 1986), such that the mode of engagement matters when assessing how virtual social interactions impact well-being. While both of our studies reliably underscore the value of face-to-face interaction, we also find that relatively richer media—voice calling and online messaging/texting—more reliably improve well-being, whereas less rich media—such as commenting on and posting to social media—exhibit the least reliable effects. These findings support previous investigations framing active engagement with others through virtual interactions as the most beneficial (Burke & Kraut, 2016; Chan, 2015, 2018; Goodman-Deane et al., 2016). Thus, richer forms of media reliably catalyze higher well-being—and the face-to-face modality remains the most well endowed.

Our results join a growing body of work investigating the relationships between types of virtual engagements and well-being during the COVID-19 pandemic. In particular, the current results complement findings from a recent daily diary study investigating how people's emotions vary across different kinds of digital and in-person interactions (Petrova & Schulz, 2022). Researchers find a link between type of interaction and emotional experiences that is reliant on how life-like the interaction was. Similar to our findings, in-person interactions predicted the most positive outcomes. Additionally, in another study conducted during the pandemic, researchers similarly found that media imbued with less of a social presence, such as email and social media, relate to lower social connectedness, while media on the opposing end of the spectrum, such as voice and video calls, do not (Nguyen et al., 2021).

Our findings align less well with several other prior findings. For example, video-based interactions have been found to predict more positive and less negative emotional experiences than phone- and text-based interactions—a pattern we do not necessarily observe here (Petrova & Schulz, 2022). In another study, researchers looked at how in-person and virtual social interaction impacted college students' well-being early on during lockdowns in response to COVID-19 (Towner et al., 2022): they found no significant effect of any form of virtual social interaction (messaging/texting, voice-only calls, video calls, posting on social media, liking or responding to posts on social media, etc.) on depression, loneliness, or happiness (Towner et al., 2022). The current investigation supports some prior findings, while it contradicts others, thus highlighting the complexity of the relationship between different types of virtual engagement and affective experiences and feelings of social connection.

These studies lay the groundwork for future investigations of the relationships between virtual interaction and well-being. For example, we identify voice calling as one of the most positive forms of virtual communication. Why might this modality, one which lacks rich visual stimuli, have such a strong impact on social connection? Given prior work suggesting that the human voice is one of the most compelling cues of sociality (Schroeder et al., 2017), perhaps voice calling offers a unique social signal. In contrast, social media may, because of its detachment

Table 4
Individual LMEMs with virtual and face-to-face interactions each predicting social connection.

Predictor	*b*	*SE*	*t*	*p*
Face-to-Face Interaction	11.77	0.53	22.04	< **0.001*****
Video Calling	7.85	1.06	7.41	< **0.001*****
Group Calling	7.39	1.15	6.41	< **0.001*****
Voice Calling	7.23	0.68	10.65	< **0.001*****
Online Messaging	5.00	0.54	9.24	< **0.001*****
Posting on Social Media	5.32	1.32	4.03	< **0.001*****
Commenting on Social Media	3.89	0.94	4.13	< **0.001*****
Browsing Social Media	2.23	0.54	4.12	< **0.001*****

Note. Only fixed effects are listed. ***$p < 0.001$.

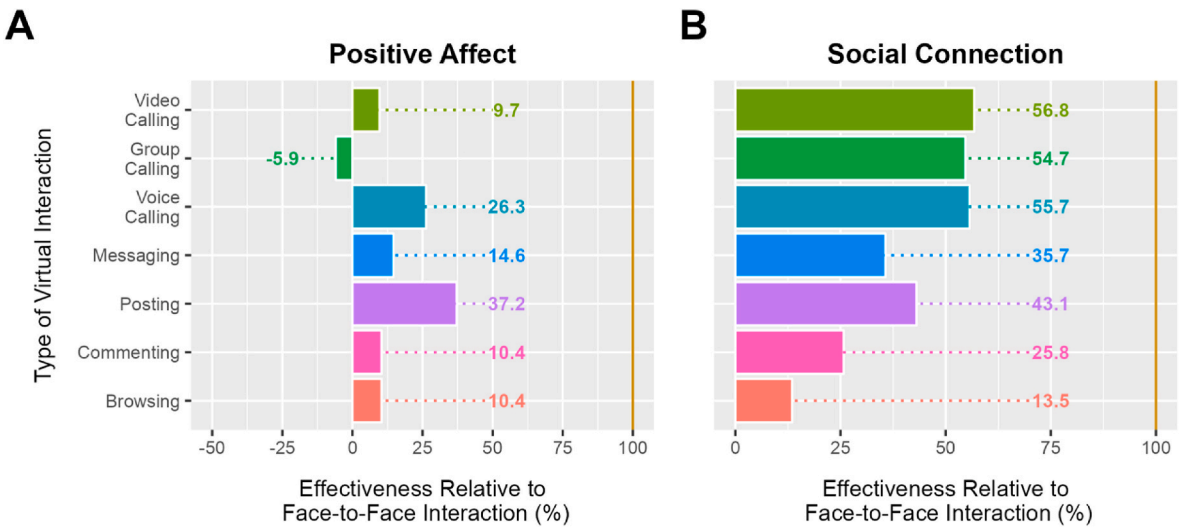

Fig. 4. Effectiveness of Virtual Interactions on Positive Affect and Social Connection Controlling for Face-to-Face Interaction. Fig. 4. Controlling for face-to-face interaction, (A) posting on social media and voice calling were the strongest predictors of momentary positive affect, and (B) video calling, group calling, voice calling, and posting on social media were the strongest predictors of momentary social connection.

from natural vocal stimuli, offer a particularly weak signal of sociality and thus fail to increase positive affect and social connection. However, we do find it puzzling that video and group calling fail to match the success of voice calling in facilitating well-being despite, in most cases, inherently including voice as one of multiple streams of information. Work by Schroeder et al. (2017) shows that combining visual cues with voice content did not systematically improve perceptions of a partner's mental capacities above and beyond simply voice communication. Yet, the researchers do observe that the audiovisual combination outperforms text-based alternatives. Do these additional streams of information inadvertently dampen the positive effects of voice-only communication? Future studies should attempt to account for these apparent discrepancies.

4.1. Limitations and future directions

The current investigation offers evidence that different forms of interactions can differentially improve or undermine well-being. However, because this was an observational study, we are limited in our ability to make causal inferences about the direction of the effects. On one hand, it is possible that interacting face-to-face promotes social connection and positive affect. On the other, individuals who feel more positively and socially connected may simply be more motivated to engage in face-to-face interactions or may find themselves in environments that afford more opportunities for face-to-face interactions. Future research should leverage experimental manipulations to test for causal patterns between interaction modes and well-being. For instance, individuals could be prompted to engage in different modes of interaction to investigate whether those interactions influence momentary well-being. In addition, future research could examine fluctuations in well-being by using pre-pandemic baselines or measuring the cross-lagged effects of different interaction types on well-being over time.

Another limitation of the current study is that our methods do not allow for direct comparison between face-to-face interaction and virtual interactions. Ideally, we could run well-powered statistical interaction models isolating the relevance of possible differences between the presence or absence of engagement in face-to-face interaction and the difference between presence or absence of engaging in each type of virtual interaction. This would enable us to ascertain whether one kind of interaction is a significantly stronger predictor of each measure of well-being than another. With the current data, we can only say that we observed the effects of face-to-face interaction on well-being to be greater in magnitude than those of our virtual interactions. Experimental manipulations can be used to distinguish differences between virtual and face-to-face interaction. Future work could also adopt a Bayesian approach by estimating the posterior distribution of differences in virtual and face-to-face interactions' predicted effect sizes and calculate the Bayes Factor as an alternative.

4.2. Implications

Our current research has important ramifications in the mental health domain. A review paper assessing mental health during the COVID-19 pandemic suggests that OCD, anxiety, depression, and general distress symptoms tended to increase from pre-to peri-pandemic (Robinson et al., 2022). How can we help combat these negative well-being outcomes observed amidst mandated social distancing? Our work suggests that future mental health interventions could incorporate virtual interactions accounting for the *mode* of communication to improve well-being, and our data specifically indicate that voice calling and texting may prove the most beneficial for bolstering positive affect and social connection. Further, newer technology for artificial intelligence may enhance the impact of texting between existing friends (Narain et al., 2020) or expand the availability of social interaction with artificial agents on well-being (Li, Zhang, Lee, & Mohr, 2023).

While we have identified voice calling and texting as strong predictors of increased affect and social connection, we acknowledge that these modes of virtual communion may still not suffice in the absence of face-to-face interaction. As such, despite the short-term praise being readily heaped upon emerging digital innovations for remote interaction, declines in mental health observed during the pandemic may suggest an altogether less optimistic story: currently, our best efforts at revolutionizing human socialization through virtual means still cannot match the status quo of meeting face-to-face.

4.3. Conclusions

A healthy social life is richly populated with a fulfilling variety of face-to-face interactions. Unfortunately, a global pandemic saw the sacrifice of this everyday luxury. In a world turned upside down, we were provided an evidence-based view of the transitory and enduring psychological effects of virtual interaction. Although this study was conducted during the COVID-19 pandemic, our findings apply all the same to a post-pandemic world. Digital devices remain dominant in our

everyday lives as people are constantly sharing, communicating, and interacting with others through their phones, tablets, and computers. In sum, our work suggests that certain virtual interactions may improve positive affect and social connection. Nevertheless, no popularly available option can yet parallel the time-tested route of face-to-face interaction in facilitating these outcomes.

CRediT authorship contribution statement

Nathan Liang: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Samantha J. Grayson:** Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mia A. Kussman:** Writing – review & editing. **Judith N. Mildner:** Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Diana I. Tamir:** Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to the data in the manuscript at the Attach Files step.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2024.100455.

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