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Tracking the temporal flows of mobile communication in daily life

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Abstract

Prior theoretical perspectives assert that mobile media and communication accelerate time perception. To test this hypothesis, we coupled mobile app logs and experience sampling to capture social app use and time perception in daily life. Participants ($N = 132$) provided self-reports of time perception ($n = 9{,}081$) and recordings of social app use ($n = 2{,}193{,}655$). Although people perceived time as relatively fast on average, results did not support an overall link between social app use and accelerated time perception. Conversely, social media use—but not messaging use—was associated with decelerated time perception. In addition, observed relationships between social app use and time perception were consistent across individuals. We conclude by considering how future mobile communication research will be challenged to measure and model how temporal flows are interwoven with mobile connection in the background of daily life.

Keywords

Acceleration, ecological validity, experience sampling method, log data, mobile communication, mobile media, social connection, temporal flows, time perception

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One of the first things that appears when people unlock their phones is the time. This simple fact—that there are digital clocks in the corner of our eyes throughout everyday life—is one of the taken-for-granted marvels of mobile communication. Mechanical timekeeping has been embedded in society for centuries (Ling, 2012). However, with phones almost always on hand, people no longer need to rely on an array of clocks, watches, ovens, or other time-keeping devices, which are often right only twice a day. The taken-for-granted nature of mobile communication and mechanical timekeeping fuse, such that people expect others to know the time because they expect them to have access to a smartphone (Ling, 2012). Indeed, thanks to the constant oscillation of cesium atoms, people can know exactly what time it is with a phone swipe, helping to synchronize the clocks of individuals and societies (Mulvin, 2017).

Yet mobile media do not necessarily synchronize how people *perceive* time. As the march toward ever faster communication continues (Farman, 2018; Frith, 2015)—currently on display with advertisements for the purported lightning-fast speeds of 5G (Campbell et al., 2021)—objective time recedes in importance and perceived time takes center stage (Ling and Lai, 2016; Ling and Ytrri, 2002). Although two individuals may agree that one took an hour to respond to the other's message, the original sender may view that response as slow while the responder does not. Without delays due to lost mail carriers or wayward passenger pigeons (Farman, 2018; Feenberg, 1989), the sender can reasonably expect an immediate reply (Ling, 2012). As people exchange messages with numerous individuals and groups in daily life, time perception is potentially shaped by patterns of mobile communication.

This study is situated at this intersection of social connection and time perception. Specifically, we couple mobile app logs with experience sampling to examine the relationship between social connection and temporal perception in daily life, providing empirical groundwork for research on mobile media and time. In doing so, we examine whether mobile media use is speeding up perceptions of time, and offer insights into the temporal cognition that underlies how people weave the threads of social connection and time perception.

Acceleration and mobile media

Theoretical work on media and time often foregrounds the concept of acceleration. Acceleration can take several forms. Here, we focus on technological acceleration, which refers to "the speeding up of intentional, goal-directed processes of transport, communication, and production" (Rosa, 2003: 6), and acceleration of the pace of life, which involves "the speed and compression of actions and experiences in everyday life" (Rosa, 2003: 8–9). Simply put, the core idea is that technological acceleration (i.e. progress) leads to the acceleration of the pace of life (Rosa, 2003). The acceleration of the pace of life can be considered along objective and subjective lines. New technologies create the potential for quicker and simultaneous actions with fewer breaks (Bittman et al., 2009; Rosa, 2015), imbuing each moment with myriad possibilities (Görland, 2019); this can be considered objective acceleration of the pace of life (Rosa, 2003). As more activities are packed into smaller folds of everyday life (Fortunati, 2002), the corresponding outcome is *accelerated time perception*—that is, subjective acceleration of the pace of life,

or the sense that perceived time is outpacing objective time. Accelerated time perception is marked by time pressure (Wajcman, 2015) and a sense of lost time (Virilio, 2006). From this view, we increasingly believe that we do not have enough time on our hands.

Mobile media—a manifestation of technological acceleration—can go hand in hand with acceleration of the pace of life. They can contribute to objective acceleration of the pace of life, which entails accelerated time perception. Mobile media allow for actions to be completed more quickly and simultaneously with fewer breaks (Rosa, 2003). People flit between screens at a rapid pace for information, communication, and entertainment (Reeves et al., 2021). Mobile media often accompany other activities through multitasking (Prommer, 2019). Finally, people check their phones in the smallest folds of life because they can uniquely be used throughout the day (Campbell, 2013; Fortunati, 2002). In sum, there are reasons to expect that mobile media facilitate objective and subjective acceleration of the pace of life.

Notably, scholarship on mobile media and time highlights the important role of social connection as an undercurrent of time perception. Our sense of time is sharply molded by the expectations of others. Ling (2012) argued that mobile communication (as well as mechanical timekeeping) became embedded in society when people expected others to use and abide by it. Burchell (2015) coined the term "networked time" to encapsulate this phenomenon, referring to the sense of time that emerges between an individual and their always-available network. To the extent that our sense of time is shaped by others' expectations for our time, mobile communication can impinge upon "people's everyday routines and experiences in time and space" (Thulin et al., 2019: 1). A now-classic example of this trend is micro-coordination: As people coordinate arrangements on-the-fly, the hands of the clock cede importance to the hands texting to coordinate one's arrival (Ling and Ytrri, 2002). A glance at a calendar is replaced with a flurry of social connection, resulting in accelerated time perception.

Overall, mobile media can be viewed as a manifestation of technological acceleration, which in turn accelerates our perceptions of the pace of life. Mobile communication via social apps further accelerates time perception by becoming embedded in society and engendering reciprocal expectations for social connection (Ling, 2012). In this study, we conceptualize mobile communication via apps in two ways: (a) social media app use and (b) messaging app use. We focus on these two app categories given that they are primarily used for social connection. Our hypothesis draws from theorizing at the societal level (Rosa, 2003) to predict that social app use will lead to accelerated time perception on average across individuals:

Hypothesis 1 (H1). Social app use will be associated with accelerated time perception.

Decoupling social connection and accelerated time perception

Some perspectives on acceleration can be critiqued for their degree of technological determinism. Keightley (2013) writes, "Time is not reducible to the temporal logics of

technologies as their temporal affordances have to be translated into experienced time" (p. 68). While the acceleration of the pace of life may manifest at the societal level, how individuals actually experience such acceleration in their lives is an open question (Wajcman, 2015). Moreover, the disconnection between "the temporal logics of technologies" and "experienced time" (Keightley, 2013: 68) may be especially true for mobile media. Earlier media (e.g. television) were typically limited to particular times of day. The argument that technology could structure temporal routines was more tenable when the hip new program was only on at 7:00 p.m. (Neverla, 1992; cited in Prommer, 2019). However, mobile media enable that same program to be watched at almost any time. Therefore, while mobile media can be directly implicated in the acceleration of everyday life (as outlined above), they may also afford users the agency to weave mobile communication into their own personalized temporal flows (see Lomborg et al., 2018; cf., Ytre-Arne et al., 2020).

These personalized flows may manifest because time perception is entrained in social networks (Bayer et al., 2016; Burchell, 2015). These networks require different expectations of availability and individuals maintain different expectations to be available to others (Trieu et al., 2019), leading to variation in the extent to which social (dis)connection is (in)voluntary (Campbell and Ross, 2021; Syvertsen, 2020). For people in demanding networks, social connection may correspond with accelerated time perception. For others, this link may be weaker; social connection may emerge simply based on a desire to connect, rather than a sense that one is shirking the expectations of others.

These complexities sync with qualitative and critical cultural scholarship on time, which often criticizes acceleration theorists for overlooking how acceleration of the pace of life is unevenly distributed across individuals (Green, 2002; Sharma, 2013). Race, gender, economic status, and other categories of identities likely shape this uneven distribution, as the weight of acceleration is borne on those with less power (Gregg, 2018; Sharma, 2014). A crucial through line here is social roles, which are uniquely linked to communication and disentangled from time and place due to mobile media (Green, 2002; Vanden Abeele et al., 2018). For example, the social role of "mother" may be activated if a woman receives a text from a sick child, even if they are still at work (Wajcman, 2008). Individuals with different social roles are likely embedded in different social networks with different availability expectations, and certain social roles encourage an acceleratory focus on the present (Rosa, 2003).

Taken together, the link between social connection and accelerated time perception may depend on competing factors. Different social networks, different availability expectations, and different social roles suggest that the relationship between mobile media and time perception is conditioned on individual differences in temporal cognition (i.e. how the mind cognitively processes time; see Droit-Volet and Wearden, 2016; Kruglanski et al., 2015).[1] In other words, mobile communication may be embedded at the societal level (Ling, 2012), but it may also become embedded at the individual level in unique ways (see Bayer et al., 2016; Vanden Abeele et al., 2018). To explore whether the link between social app use and time perception differs across individuals, we ask the following research question:

Research Question 1 (RQ1). To what extent does the relationship between social app use and time perception differ across individuals?

The current study

To test H1 and RQ1, this study couples experience sampling with mobile log data. Experience sampling method (ESM) involves short surveys in naturalistic settings, readily enabled by the widespread diffusion of mobile media such as smartphones (Schnauber-Stockmann and Karnowski, 2020). Mobile log data captures social app use on individuals' mobile devices (Boase, 2016; Callegaro and Yang, 2018), circumventing concerns about the accuracy of self-reported mobile media use (Boase and Ling, 2013). Our approach follows the trajectory of social science researchers combining these methods, blending the benefits of subjective self-reports with more objective data sources (Rhee et al., 2020). In sum, this study prioritizes ecological validity by recording social app use and gauging time perception *in vivo* to understand their relationship amid everyday life.

Method

Participants

This study was conducted as part of a broader project on mobile technology and daily mobility.[2] A total of 465 participants completed all phases of the project from May 2019 to December 2019. Participants were randomly split into three experience sampling groups, one of which served as the basis for this study ($n = 173$). Forty-one participants were excluded due to problems with data transmission ($n = 32$) and low experience sampling survey completion ($n = 9$). Thus, our final sample used for analysis consisted of $N = 132$ participants who completed 9,081 experience sampling surveys (~69 per participant) and contributed logs of their smartphone app use over the two-week study period ($n = 8{,}876{,}821$ instances of app use; $n = 2{,}193{,}655$ instances of social app use). Participants were 34.3 years old on average ($SD = 10.2$). Thirty-one were recruited through a large Midwestern university in the United States and 101 were recruited on Facebook or Instagram. Seventy-nine identified as female and 53 identified as male. Please see the OSF page of the broader project for more information about recruitment.

Procedure

The study was reviewed and approved by the institutional review board (IRB) at the first author's institution. After taking a pre-screen survey to confirm their eligibility and completing a baseline survey, participants were provided with instructions to download the study application developed for the project. Over the next 2 weeks, participants used the study application to complete six brief surveys per day. Surveys were sent at random times within six equal time intervals. These intervals were created based on the wake and sleep times that participants configured in the study application. Up to three surveys per day were triggered by movement (e.g. logged walking) in place of the random surveys due to broader project objectives (~10% of total surveys).[3] Concurrently, the study application logged the app in the foreground of the screen up to every 10 seconds (regardless of whether the screen was on or off). After 2 weeks, participants completed an endpoint survey. Please see the OSF page of the broader project for more information about the overall method.

Mobile log validation

In the endpoint survey, participants self-reported the eight apps that they used most during the study period. We linked these self-reports to the app packages recorded in the log data and the corresponding apps in the Google Play Store. By doing so, we both ensured the validity of the mobile log data and focused on apps that participants perceived to be central to their daily lives. Of participants' 1,023 self-reports of their top eight apps over the study period, 95.6% were successfully cross-validated, for a total of 302 unique apps. Please see Supplemental Materials for details about our validation procedure.

Measures

Social app use. We selected messaging and social media apps from our list of validated apps. These apps were initially identified as those categorized in the Google Play Store as "social" or "communication" apps. We then excluded voice call, dating, email, and web browser apps. We excluded voice call apps because they were less frequently used by participants, and they are less central to moment-to-moment time perception; synchronous calls often involve longer communication episodes that are less readily interwoven into daily life than asynchronous app use. We excluded other apps because they are not primarily used for non-romantic social connection. Social media and messaging apps were operationalized as the remaining apps categorized in the Google Play Store as "social" and "communication," respectively. Table 1 displays the 28 social media and messaging apps identified in this study.

Based on these social media and messaging apps, we calculated binary measures of social app use. *Social media* [*messaging*] *use* consisted of whether at least one social media [messaging] app was recorded in the foreground of participants' screens in the 10 or 60 minutes before experience sampling surveys. The screen was allowed to be on or off. These measures were strongly correlated between time scales and weakly-to-moderately correlated between social media and messaging use. Please see Supplemental Materials for more information about these measures.

We also calculated overall measures of social app use. *Raw* measures of overall social media [messaging] use referred to the number of instances when social media [messaging] apps were recorded in the foreground of participants' screens during the two-week study period. *Proportional* measures of overall social media [messaging] use divided the raw measures of social media [messaging] by the total number of instances when apps were recorded in the foreground of participants' screens during the two-week study period.

Time perception. We measured time perception with two items in every experience sampling survey. The first item measured *time passage* (Droit-Volet and Wearden, 2016). Participants were asked, "Before seeing the survey notification, how was time passing for you compared to the time on the clock?" Participants rated their time perception on a five-point scale from "Much slower" (1) to "Much faster" (5). The second item measured *time efficiency* (see Kruglanski et al., 2015). Participants were asked, "Right now, do you

Table 1. Overview and prevalence of messaging and social media apps.

App name	App package	Recordings	Self-report
Social media			
Facebook	com.facebook.katana	747,387	90
Instagram	com.instagram.android	221,908	60
Snapchat	com.snapchat.android	149,852	30
Twitter	com.twitter.android	81,036	22
Reddit	com.reddit.frontpage	39,785	9
Boost for Reddit	com.rubenmayayo.reddit	16,886	1
Facebook Lite	com.facebook.lite	12,328	2
TikTok	com.zhiliaoapp.musically	11,777	3
Sync for Reddit (Pro)	com.laurencedawson.reddit_sync.pro	9006	1
Tumblr	com.tumblr	8757	3
Parler	com.parler.parler	4911	1
Joey for Reddit	o.o.joey	1907	1
Messaging			
Facebook Messenger	com.facebook.orca	283,520	21
Samsung Messages	com.samsung.android.messaging	222,233	17
Messages by Google	com.google.android.apps.messaging	134,487	9
WhatsApp Messenger	com.whatsapp	110,932	8
Verizon Messages	com.verizon.messaging.vzmsgs	105,023	4
Android Messages	com.android.mms	45,928	2
Discord	com.discord	30,799	6
GroupMe	com.groupme.android	25,136	5
Signal Private Messenger	org.thoughtcrime.securesms	18,853	1
Textra SMS	com.textra	16,146	1
Handcent Next SMS	com.handcent.app.nextsms	9634	1
Telegram	org.telegram.messenger	7101	1
WeChat	com.tencent.mm	6835	1
Kik	kik.android	2726	1
Pulse SMS	xyz.klinker.messenger	2267	1
BOTIM	im.thebot.messenger	1246	1

App names were pulled from Google Play Store when possible. *Recordings* refers to the number of recordings of a given app in the foreground of participants' screens during the study period. *Self-report* refers to the number of times that participants self-reported a given app as among the top eight that they use most in daily life. Two apps were self-reported but not recorded (and were thus excluded).

have too much or too little time on your hands?" Participants rated their time efficiency on a five-point scale from "Too little time" (1) to "Too much time" (5). We reverse-coded time efficiency so that higher values of time passage and time efficiency indicated accelerated time perception. In other words, *higher* values of time efficiency correspond with *less* time on one's hands and thus *higher* acceleration. They were strongly correlated between-persons, $r = .53$, $p < .001$, and weakly-to-moderately correlated within-persons, $r = .24$, $p < .001$.

Analysis plan

Due the hierarchal nature of the data, we used R (R Core Team, 2019) and lme4 (Bates et al., 2015) to perform linear mixed effects analyses of the relationship between social app use and time perception. We specified multilevel linear mixed effects models, in which observations were nested within participants. Each model was initially run as a random intercepts model. In subsequent models, social app use was added as random slopes to mitigate Type I errors as well as test heterogeneity. Separate models were specified for the two independent variables (social media and messaging use) at both time scales (10 and 60 minutes) and for the two dependent variables (time passage and time efficiency). All models used REML estimation method. All predictors were person-mean-centered in order to provide standardized within-person coefficients (Schuurman et al., 2016).

Postregistration

This study was postregistered following recommendations for registering secondary data analysis by Weston et al. (2019). The postregistration was intended to provide transparency and guidance for our exploratory analysis of previously collected data. As such, we occasionally deviated from our postregistration when we believed this would improve our model specification and robustness. We clarify these deviations here. All de-identifiable data and scripts are available on our OSF page, enabling the verification of all results presented in the main manuscript and Supplemental Materials.

For our primary analyses, in the postregistration, we specified multiple conceptualizations (frequency, recency) and operationalizations (binary, continuous, ordinal) of social app use in the 2, 10, 30, and 60 minutes prior to experience sampling surveys. In the main manuscript, we only report the binary measures of frequent social app use in the 10 and 60 minutes before experience sampling surveys. We chose this operationalization because its results were representative of the results of other measures of social app use and presented fewer convergence issues. Analyses with alternative conceptualizations, operationalizations, and time scales are presented in Supplemental Materials. We additionally expected time perception to predict subsequent social app use. These analyses exceeded the scope of this article and are reported in Supplemental Materials.

We also postregistered secondary analyses that ensured robustness of our results to temporal, device, and demographic covariates; used a personalized measure of social app use (i.e. only including each participant's most frequently used or self-reported social apps); included an autoregressive predictor term; and explored personality and situational moderators of our findings. In general, our primary findings persisted across these secondary models. Additional findings were deemed to be outside of the scope of this article. The results of these secondary analyses are reported in Supplemental Materials. In all analyses, we did not nest observations within study days after encountering increased convergence issues.

Results

Social app use accounted for almost a quarter (24.8%) of app use, with approximately 16,494 ($SD = 9{,}655$) recordings per participant. Among social app use, 55.8% was social

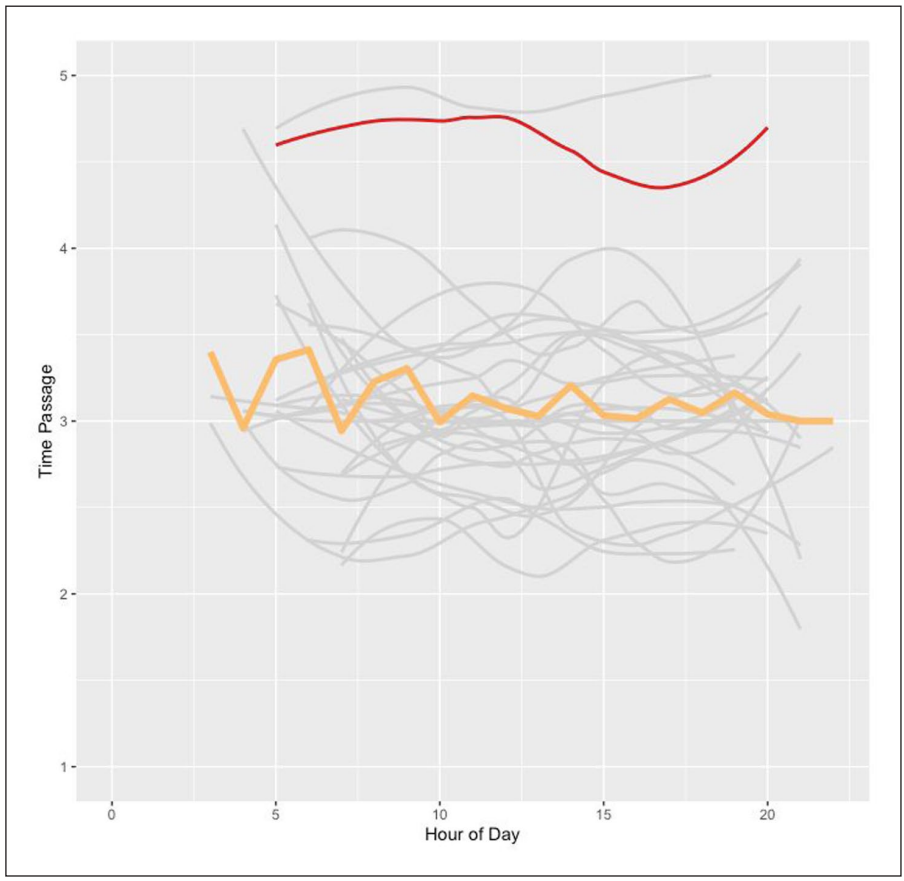

Figure 1. Daily time passage by participant.
A random quarter of participants are shown. Self-reports of time passage during a given hour of the day over the course of the study were averaged for each participant and plotted using the geom_smooth function in ggplot2 (Wickham, 2016). The mean is represented by the thick orange line. An example participant, who experienced heightened acceleration in the morning and late evening, is highlighted in red.

media use and 44.2% was messaging use. On average, social media apps were recorded 26.6% (51.7%) of the time in the 10 (60) minutes prior to experience sampling surveys, and messaging apps were recorded 28.9% (55.5%) of the time in the 10 (60) minutes prior to experience sampling surveys. In terms of time perception, participants perceived time to be moving slightly faster than the hands on the clock ($M = 3.17$, $SD = 0.90$) and thought that they did not have enough time on their hands ($M = 3.45$, $SD = 0.89$) on average, with both values differing significantly from the scale midpoint (p's $< .001$). Figures 1 and 2 show the variation in daily time passage and time efficiency, and Figures 3 and 4 show the variation in daily social media and messaging use, for a random subset of participants.

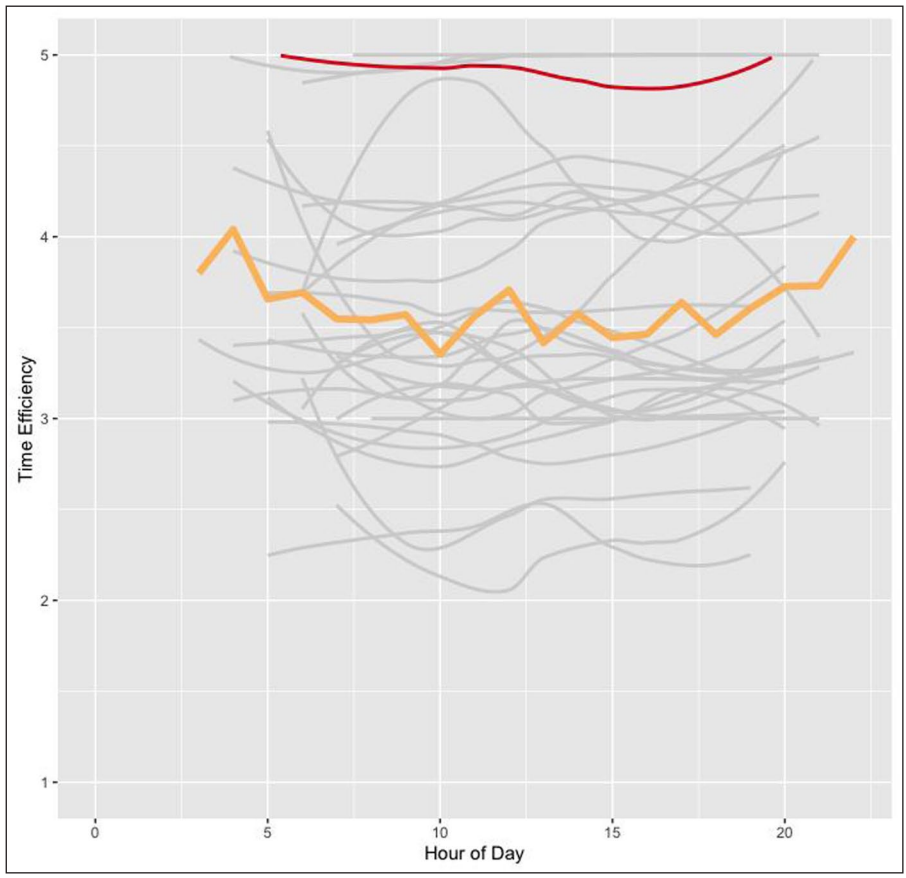

Figure 2. Daily time efficiency by participant.
A random quarter of participants are shown. Self-reports of time efficiency during a given hour of the day over the course of the study were averaged for each participant and plotted using the geom_smooth function in ggplot2 (Wickham, 2016). The mean is represented by the thick orange line. An example participant, who experienced heightened acceleration throughout the day, is highlighted in red.

Between- and within-person correlations

Table 2 displays between- and within-person correlations between social app use and time perception. A majority of between-person correlations between overall social app use and time perception were insignificant. However, participants who used messaging apps as a greater proportion of their app use perceived that time was going faster for them than the time on the clock, and participants who used social media apps more and as a greater proportion of their app use perceived that they had more time on their hands.

Participants who used social media apps more during the prespecified time periods (i.e. 10 or 60 minutes) before experience sampling surveys exhibited slower time

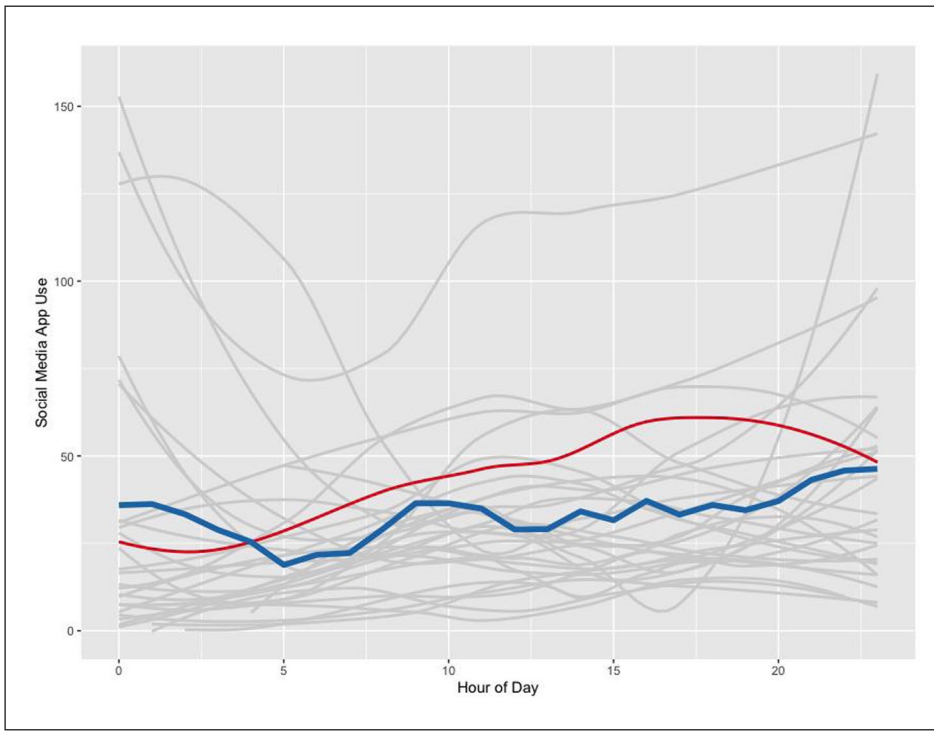

Figure 3. Daily social media app use by participant.
A random quarter of participants are shown. The number of recordings of social media app use during a given hour of the day over the course of the study were averaged for each participant and plotted using the geom_smooth function in ggplot2 (Wickham, 2016). The mean is represented by the thick blue line. An example participant, whose social media app use peaked around midafternoon and gradually tapered off before and after, is highlighted in red.

perception, whereas participants who used messaging apps more or less during the time periods (i.e. 10 or 60 minutes) before experience sampling surveys exhibited similar time perception. Within-person correlations between social app use and time perception reinforced this pattern. However, they revealed considerably smaller effect sizes and the relationship between social media use and time passage at the 60-minute time scale was insignificant.

Multilevel models

We conducted a series of multilevel models to test the relationship between social app use and time perception. For each model, we first specified social app use as a fixed effect and included random intercepts to account for nesting within individuals (H1). Next, we ran a separate model in which we added social app use as a random slope and compared the two models to determine if significant heterogeneity existed for the

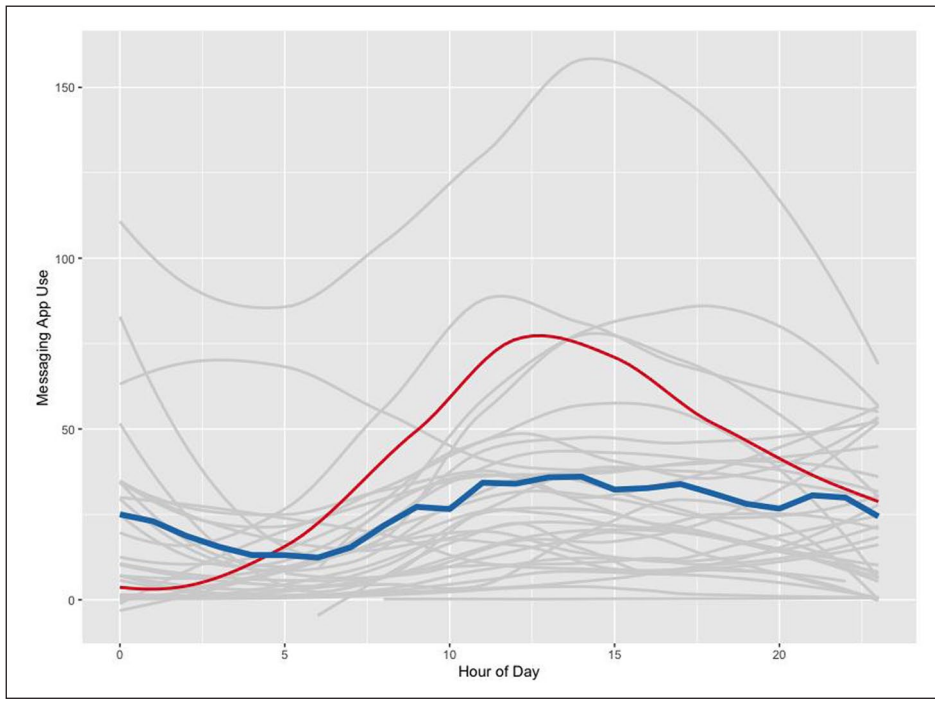

Figure 4. Daily messaging app use by participant.
A random quarter of participants are shown. The number of recordings of messaging app use during a given hour of the day over the course of the study were averaged for each participant and plotted using the geom_smooth function in ggplot2 (Wickham, 2016). The mean is represented by the thick blue line. An example participant, whose messaging app use peaked around midday and gradually tapered off before and after, is highlighted in red.

relationship between social app use and time perception (RQ1). Tables 3 and 4 present our results, which are summarized in the following sections.

Social media use

Time passage

10-minute time scale. Model 1A specified social media use as a fixed effect predicting time passage. Social media use was associated with decreased time passage, $B = -.06$, $p = .01$. When participants checked social media apps in the 10 minutes prior to a survey (relative to their individual mean), they perceived that time was going slower for them than the time on the clock. Model 1B additionally specified social media use as a random slope to evaluate heterogeneity, but the model did not converge.

60-minute time scale. The fixed effect of social media use on time passage was insignificant at the 60-minute time scale, and the model comparison revealed insignificant heterogeneity in this relationship (Models 2A and 2B).

Table 2. Between- and within-person correlations between social app use and time perception.

		Time passage		Time efficiency	
		Between-person	Within-person	Between-person	Within-person
Social media use	10 minutes	–.17*	–.03*	–.23**	–.04***
	60 minutes	–.18*	–.01	–.27**	–.02*
	2 weeks (raw)	–.15	N/A	–.21*	N/A
	2 weeks (proportion)	–.08	N/A	–.22*	N/A
Messaging app use	10 minutes	.15	.02	.07	.00
	60 minutes	.09	.01	.06	.00
	2 weeks (raw)	.16	N/A	.10	N/A
	2 weeks (proportion)	.23**	N/A	.14	N/A

Correlations were conducted using the statsBy function in the *psych* (Revelle, 2020) package in R.
*$p < .05$, **$p < .01$, ***$p < .001$.

Time efficiency

10-minute time scale. Model 3A specified social media use as a fixed effect predicting time efficiency. Social media use was associated with decreased time efficiency, $B = –.06$, $p < .001$. When participants checked social media apps in the 10 minutes prior to a survey (relative to their individual mean), they perceived that they had more time on their hands. Model 3B additionally specified social media use as a random slope, but the model comparison was insignificant, $\chi^2(2) = 2.64$, $p = .26$, indicating a lack of heterogeneity.

60-minute time scale. Model 4A specified social media use as a fixed effect predicting time efficiency. Social media use was again related to decreased time efficiency, $B = –.03$, $p = .04$. When participants checked social media apps in the 60 minutes prior to a survey (relative to their individual mean), they perceived that they had more time on their hands. Model 4B additionally specified social media use as a random slope, but the model comparison was insignificant, $\chi^2(2) = 0.07$, $p = .97$, indicating a lack of heterogeneity.

In sum, people who used social media prior to experience sampling surveys perceived less acceleration, especially at the 10-minute time scale. There was no evidence that the link between social media use and time perception differed across individuals.

Messaging use

The fixed effects of messaging use on time passage and time efficiency were insignificant at the 10- and 60-minute time scales, and model comparisons revealed insignificant heterogeneity in these relationships (Models 5A and 5B; Models 6A and 6B; Models 7A and 7B; Models 8A and 8B). Messaging use prior to experience sampling was not related to subsequent time perception. There was no evidence that the link between social media use and time perception differed across individuals.

Table 3. Multilevel models for social media use predicting time perception.

	Time passage				Time efficiency			
	10 minutes		60 minutes		10 minutes		60 minutes	
	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B	Model 4A	Model 4B
	Random intercepts	Random slopes	Random intercepts	Random slopes	Random intercepts	Random slopes	Random intercepts	Random slopes
	B (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)
Intercept	3.17 (.04)	N/A	3.17(.04)	3.17(.04)	3.47 (.06)	3.47 (.06)	3.47 (.06)	3.47 (.06)
Social media use	–.06* (.02)	N/A	–.02 (.02)	–.02 (.02)	–.06*** (.02)	–.06** (.02)	–.03* (.02)	–.03* (.02)
Model fit								
Deviance	21,508	N/A	21,893	21,892	17,094	17,092	17,458	17,458
AIC	21,516	N/A	21,901	21,904	17,102	17,104	17,466	17,470
BIC	21,545	N/A	21,929	21,946	17,130	17,146	17,494	17,512
χ^2 (*df*)	N/A		1.37 (2)		2.64 (2)		0.07 (2)	
Variance (p)	.161	N/A	.159	.159	.398	.398	.399	.399
Variance (residual)	.662	N/A	.666	.664	.393	.393	.397	.397
Variance (random)	N/A		.008		.002		.000	
Pseudo R^2	.205	N/A	.203	.206	.506	.507	.504	.504

AIC: Akaike information criterion; BIC: Bayesian information criterion.
All intercepts were significant at $p < .001$. Model 1B did not converge. Model 4B exhibited singularity. The ICC for time passage was .194 and the ICC for time efficiency was .501.
*$p < .05$, **$p < .01$, ***$p < .001$.

Table 4. Multilevel models for messaging use predicting time perception.

	Time passage				Time efficiency			
	10 minutes		60 minutes		10 minutes		60 minutes	
	Model 5A	Model 5B	Model 6A	Model 6B	Model 7A	Model 7B	Model 8A	Model 8B
	Random intercepts	Random slopes	Random intercepts	Random slopes	Random intercepts	Random slopes	Random intercepts	Random slopes
	B (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)	*B* (SE)
Intercept	3.17 (.04)	3.17 (.04)	3.17 (.04)	3.17 (.04)	3.47 (.06)	3.47 (.06)	3.47 (.06)	3.47 (.06)
Messaging app use	.03 (.02)	.03 (.02)	.02 (.02)	.02 (.02)	.00 (.02)	.00 (.02)	.00 (.01)	.00 (.01)
Model fit								
Deviance	21,514	21,513	21,893	21,889	17,107	17,105	17,462	17,460
AIC	21,522	21,525	21,901	21,901	17,115	17,117	17,470	17,472
BIC	21,550	21,567	21,929	21,943	17,143	17,159	17,498	17,515
χ^2 (*df*)	1.08 (2)		4.53 (2)		1.77 (2)		1.58 (2)	
Variance (p)	.161	.161	.159	.159	.398	.398	.399	.399
Variance (residual)	.663	.662	.666	.663	.394	.393	.398	.397
Variance (random)	.006		.012		.003		.005	
Pseudo R^2	.205	.207	.203	.208	.505	.507	.504	.506

AIC: Akaike information criterion; BIC: Bayesian information criterion.
All intercepts were significant at $p < .001$. The ICC for time passage was .194 and the ICC for time efficiency was .501.

Discussion

This study grounded theoretical perspectives on media and time in mobile sensing and experience sampling, revealing nuanced relationships between social connection and temporal perception in everyday life. We found evidence that social app use was not directly linked to accelerated time perception. In fact, we showed that social media use—but not messaging use—was often related to decelerated time perception. Moreover, the observed effects exhibited homogeneity, as individuals experienced similar relationships between social app use and time perception. Our study thus affirms the importance of coupling objective and subjective data for insights into mobile communication and temporal cognition.

Our study also offers rich descriptive data on time perception and social app use in daily life. Figure 1 shows that participants perceived that time was passing slightly fast, consistent with past experience sampling work (Droit-Volet and Wearden, 2016). Such perceptions are not new, but have persisted and may have reached new heights in recent years (Rosa, 2003). Participants' average time efficiency was even further from the midpoint (Figure 2), as participants felt that they did not have enough time. Further, there was considerable variability in both time perception and social app use among individuals over the course of the day (see also Figures 3 and 4). Although the average level of social app use likely reveals participants' typical waking hours (Hintze et al., 2017), disaggregating the data highlights that people weave social connection into their lives in unique ways. Interestingly, a comparison of the trendlines for social media and messaging apps reveals that social media slightly grows during the evening hours while messaging use somewhat declines. Altogether, the descriptive data—useful for quantitative and qualitative mobile scholars alike—affirm the intra- and inter-individual complexity of time perception and pave the way for future research on mobile communication.

Correlations between social app use and time perception unveiled two different pictures for messaging and social media use, neither of which support a clear-cut connection between technological acceleration (mobile communication) and acceleration in the pace of life (accelerated time perception). In terms of overall social app use during the two-week study period, individuals who used social media apps (a) more often and (b) as a greater proportion of their app use thought that they had more time on their hands, indicating decelerated time efficiency. In contrast, messaging use was linked to neither deceleration nor acceleration, with one exception: Individuals who used messaging apps as a greater proportion of their app use during the two-week study period perceived *accelerated* time passage.

Between- and within-person correlations for the 10- and 60-minute periods before experience sampling surveys show a similar pattern. Individuals who checked social media apps before surveys reported decelerated time perception in terms of both time efficiency and passage, whereas individuals who checked messaging apps before surveys reported neither accelerated nor decelerated time perception. Within-person correlations generally corroborated these findings, with the exception that social media use was unrelated to time passage at the 60-minute time scale.

Together, these correlations suggest a stark demarcation between social media and messaging app use. Both social media and messaging were conceptualized as offering social connection. However, in addition to enabling direct messaging capabilities, many

social media platforms encompass public-facing elements like live news feeds, streams, and/or stories (Bayer et al., 2020). These key spaces within social platforms may produce connection expectations besides those discussed in the introduction. For example, users may feel expectations to be aware of content shared in social media streams (Lu and Hampton, 2017). The value of streamed information may decay more rapidly than messaged content; messaged content will likely remain relevant to the receiver after a delay, whereas streamed information may quickly lose its relevance to the current online conversation (Atchley and Warden, 2012). Crucially, these facets of social media use (vs messaging use) may be both time-sensitive and intensive, such that people can only keep up if they have adequate time to do so.

Our multilevel models corroborate this divide between social media and messaging use (H1). We largely found insignificant relationships between messaging use and time perception. Participants who used messaging apps prior to experience sampling surveys did not report accelerated time perception. This result held across multiple time scales of social app use (i.e. 10 and 60 minutes) and conceptualizations of time perception (time passage and efficiency). Furthermore, as reported in the Supplementary Materials, these analyses were robust to additional time scales (i.e. 2 and 30 minutes) and operationalizations (i.e. continuous and ordinal) for messaging use. We anticipated that a link between messaging use and acceleration would reflect societal embedding (Ling, 2012). However, the lack of such a link may suggest that taken-for-granted mobile communication is so embedded that, in aggregate, it does not alter perceptions of acceleration.

By contrast, our findings for social media use go *against* the acceleration hypothesis. Negative associations emerged between social media use and time passage at the 10-minute time scale, as well as for social media use and time efficiency at both the 10- and 60-minute scales. The fact that this finding primarily occurred in the 10-minute models lends credence toward situation-level explanations. It may indicate people scrolling through social media feeds during downtime (Ytre-Arne et al., 2020). Checking social media may indicate that participants had time to spare during the given time period—or perhaps felt more efficient after catching up with missed posts and messages (Barley et al., 2011).

In addition, our multilevel models provided evidence that the above results are consistent across individuals (RQ1). We did not find evidence of significant heterogeneity in our models. This indicates less heterogeneity than related studies of mobile communication. For example, Beyens et al. (2020) examined self-reported mobile social media use and affective well-being, finding that 46% of participants displayed a positive relationship and 10% exhibited a negative relationship. Thus, the high degree of homogeneity of the current findings is noteworthy and important to unpack in future research, especially considering how time perception is presumed to vary from individual to individual (Hammond, 2012; Wittmann, 2016). Mobile communication research—and quantitative social scientific research more broadly—typically focuses on the strength of bivariate relationships averaged across individuals, taking a between-person rather than a within-person perspective. This work suggests that this approach can be justified in domains where there is clear homogeneity. Indeed, our findings may reflect how the societal embedding of mobile communication (Ling, 2012) can manifest consistently at the individual level (cf. Bayer et al., 2016; Vanden Abeele et al., 2018). Our findings may

preview a theoretical shift in future mobile communication research, toward the examination of whether and how societal trends emerge consistently for individuals.

Taken together, these findings suggest that the relationships between social app use and accelerated time perception in daily life are highly complex. Leveraging descriptive data, between- and within-person correlations, and multilevel models, we revealed a highly conditional view of the relationship between social app use and acceleration. Our findings were contingent on our conceptualization and measurement of social apps (social media vs messaging; raw vs proportional), time perception (passage vs efficiency), time scale (10 minutes before surveys vs 60 minutes before surveys vs two-week study period). Yet, this complexity coalesced into consistent opposition to the acceleration hypothesis.

Our findings have implications for theorizing on time and media use. Technological acceleration may indeed entail accelerated time perception, but this process may stem more from the *potential* to use technology rather than *actual* use (Campbell, 2013). People may experience accelerated time perception if they know they can receive messages in an instant—and that they are expected to respond (Bayer et al., 2016; Ling, 2012). For example, other people may reach out to micro-coordinate a rendezvous (Ling and Ytrri, 2002). Being aware of one's constant availability may accelerate perceived time, even as objective time chugs along (Burchell, 2015). Future work could relate time perception to *in vivo* measures that capture the potential for use (e.g. awareness expectations; Lu and Hampton, 2017). Overall, acceleration may not be grounded in objective social connection captured in this study, as suggested by some acceleration perspectives. Instead, perceptions of social connection—including when mobile media is not in use—may be more impactful.

Alternatively, accelerated time perception could be viewed as a byproduct of a shift in cultural values toward speed and efficiency, rather than a direct result of technological acceleration (Wajcman, 2015). Relatedly, Rosa (2003) views acceleration of the pace of life as additionally stemming from a "cultural motor," which perpetuates the promise of acceleration. From this view, social app use would be related to accelerated time perception to the extent that it indexes cultural values such as efficiency. The null and even negative associations between the two might therefore suggest that social app use may facilitate but also inhibit perceptions of efficiency. Social app use represents a quick way to connect, but may interrupt efficiency in other domains (e.g. work; Prommer, 2019). Future work could capture situational perceptions of these cultural values and relate them to social app use and time perception.

Yet whether or not media is the culprit behind perceptions of acceleration, researchers are still left with the challenging task of measuring societal-level change over time (see Gergen, 1973). Technological and cultural change covary with a wide variety of factors that are not readily captured. Crucially, these changes can shift the meaning of the construct of interest. In the same way that the notion of "friends" has likely changed with the advent of social media (Beer, 2008), our understandings of time may have shifted with the advent of timekeeping tools that function as social alarm clocks (Ling, 2012).

Rather than comparing to past eras, this study instead elected to compare people to a more accurate and proximal baseline: themselves. To that end, our study design enabled a $N=1$ approach by capturing a large sample of perceptions from each individual. This approach has been increasingly advocated for communication researchers to examine the

heterogeneity and complexity of media effects (Valkenburg et al., 2021). Our coupling of ESM and log data therefore showcases a promising methodological paradigm for future research on mobile communication.

Limitations

Overall, future work will be challenged to address the limitations of this study in gauging time perception, social app use, and their bidirectional relationships. With regard to time perception, measuring time passage and efficiency six times per day may not adequately capture the dynamic nature of time perception. Time perception—and its link to mobile communication—may fluctuate even more than other psychological states measured in experience sampling studies (e.g. mood). Variability may emerge within rather than between persons, as individual networks, availability expectations, and social roles fluctuate in daily life. People develop different temporal expectations for different partners (Licoppe, 2004) and our time perception is synced with how our communication partners perceive time (Rettie, 2009). As a result, overall time perception may shift as a function of the salience of these different conversations and roles (and their associated thoughts). Mobile media add an important wrinkle by providing a constant reminder of objective time, yet also allowing one's time to be dictated by others (Burchell, 2015). Additional surveys may also inflate participants' awareness of time. This points to the challenges of experience sampling more broadly. We implemented "mixed" ESM, with surveys generally sent at random during intervals and sometimes triggered by mobility. Although the results of this study were robust to mobility triggers, future research could use event-contingent designs to capture time perception at other theory-driven moments (e.g. after social app use) (Schnauber-Stockmann and Karnowski, 2020; Bayer et al., 2018).

Turning to social app use, this study used log data as an ecologically valid and accurate representation of participants' mobile media use (Boase and Ling, 2013). Yet, we only captured the app in the foreground of participants' screens. This decision protected participant privacy, but complicated our ability to parse out some of the situation-level mechanisms elaborated above. We created multiple measures of social app use, but alternative measures (e.g. burstiness; Jo et al., 2012) may be more predictive of accelerated time perception. Further, social app use represents only a subset of social connection; how participants engage in other forms of social connection (e.g. face-to-face, video calling) during and between checks of social apps is also crucial to overall perceptions of time (see Prommer, 2019). Future research can adopt complementary methodological approaches to untangle these processes. ESM studies could probe participants' other social interactions in combination with social app use (Merolla et al., 2021). Other log data approaches could provide more detailed information about app use while maintaining user privacy (Reeves et al., 2021). Qualitative methods could deepen these insights by interviewing participants about their temporal flows (Ytre-Arne et al., 2020), perhaps while displaying and referencing their log data or message transcripts (Mannell, 2019).

Finally, time and media theorists note the bidirectionality of accelerated time perception and media use. Feelings of lost time (Virilio, 2006) and time pressure (Wajcman, 2015) encourage people to continue to engage with technology in an attempt to save time (Rosa, 2003). Such bidirectionality is also embedded in socio-cognitive perspectives on

mobile communication. Drawing on Mead (1934), Bayer et al. (2016) argue that people have "a baseline temporal expectation for checking the 'mystery inbox' [i.e. phone] in order to be available to society" (p. 139). When one feels a temporal lapse—a sense that too much time has passed, consistent with accelerated time perception—the salience of this connection norm increases. In turn, connection norms can cue non-conscious checks of one's mobile device. Concurrently, this framework also acknowledges that slower time perception can increase checks of one's mobile device. Individuals who are bored (Turkle, 2016) or waiting (Farman, 2018) may have more cognitive resources at hand to perceive social norms or follow other impulses to check their phones. Consequently, we postregistered analyses that predict social app use based on time perception. In Supplemental Materials, we report the results of these analyses, finding some evidence that decelerated time perception promotes social media (but not messaging) use in the hour after experience sampling surveys. This corroborates explanations of the current findings, which suggest that social media use increases during downtime. However, future research should examine and model bidirectionality directly, perhaps leveraging dynamic structural equation or time series modeling to parse the complexity of temporal cognition.

Conclusion

Advances in mobile communication place our social networks in our pockets, allowing others to impinge on our moment-to-moment experiences of time. Our study combined mobile log data and experience sampling to show how the relationship between social app use and time perception is not marked by overall acceleration. Rather, we find consistent effects that perceptions of acceleration are largely unrelated to messaging use and negatively related to social media use. These nuanced findings provide theoretical and methodological direction for future research in mobile communication. Theoretically, we reframe Ling's (2012) notion of taken-for-grantedness to the individual level, exploring how time perception and mobile communication are embedded and, at times, synchronized in daily life. Methodologically, we demonstrate the value of coupling experience sampling and mobile sensing to examine how mobile media and time perception are intricately interwoven in the real world. Together, we unveil the complexity of our temporal relationships with mobile devices, which silently display the objective time while also mediating how perceived time is negotiated on-the-fly.

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Notes

1. Although this article frames temporal cognition as socially constructed, to the extent that it is pinned to networks, expectations, and social roles, we also acknowledge that individuals likely hold innate predispositions toward time.

2. See https://osf.io/6d9my/ for the OSF page of this study and https://osf.io/6yb9h/ for the OSF page for the broader project.
3. Our analyses were robust to including mobility triggers as a covariate (see Supplemental Materials).

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