

Echoes From the Past: How Technology Mediated Reflection Improves Well-Being

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ABSTRACT

As people document more of their lives online, some recent systems are encouraging people to later revisit those recordings, a practice we're calling *technology-mediated reflection* (TMR). Since we know that unmediated reflection benefits psychological well-being, we explored whether and how TMR affects well-being. We built Echo, a smartphone application for recording everyday experiences and reflecting on them later. We conducted three system deployments with 44 users who generated over 12,000 recordings and reflections. We found that TMR improves well-being as assessed by four psychological metrics. By analyzing the content of these entries we discovered two mechanisms that explain this improvement. We also report benefits of very long-term TMR.

Author Keywords

Memory; well-being; reflection; recording; technology mediated reflection.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design

INTRODUCTION

With the widespread adoption of social media, people are increasingly capturing their daily activities and sharing them with others by posting photos and status updates to social media websites. Some recent technologies are now encouraging people to *reflect* on these previously captured experiences by returning the recordings after time has passed [4,14,16]. These systems make it possible to revisit veridical accounts of our pasts in ways that were not previously possible. With the exception of [18], however, there have been few systematic studies of the effects of digital reflection, whereby people revisit and re-evaluate their pasts through such recordings.

Prior research has shown that reflecting on our pasts has

important benefits for psychological well-being and personal growth [2,11]. Even reflecting on negative experiences brings health benefits [19]. Reflecting also affects broader aspects of life: active reminiscers are more effective at school and job-seeking [19]. People do not accurately remember their pasts but instead have *adaptive biases*, remembering more positive events and forgetting or editing negative ones [15,25]. As a result, people become more positive about their pasts and more quickly overcome negative events. This raises important questions in a world where technology mediated reflection is prevalent. Does exposure to veridical digital records of forgotten *negative* events *interfere* with adaptive unmediated reflection that would have edited such events? Alternatively, could repeated digital reminders about forgotten past *positive* events *improve* well-being?

In this study, we examined fundamental processes of *technology-mediated reflection* (TMR) to understand how it differs from simply recording one's experiences without reflection. To explore these issues, we built a smartphone application called Echo that supports active reflection on personal memories (see Fig 1). It affords logging of everyday activities using pictures, text descriptions, and ratings of emotional state. It also prompts users to explicitly reflect on such previously recorded events and to repeatedly revisit those reflections, so users can observe patterns in their reactions to events over time.

We used Echo to systematically explore theoretical and practical aspects of TMR. We conducted three system



Fig. 1: Reflecting with Echo. UI showing initial post and three reflections about an event that happened 3 years ago. Each reflection is shown as a stacked card with time and smiley happiness rating.

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deployments in which 44 users generated over 12,000 recordings and reflections. Two short-term deployments were for one-month periods involving 43 participants. The third long-term deployment involved one of the authors and has lasted nearly four years. We present qualitative and quantitative data addressing:

- the *nature* of TMR and how it compares with simply recording events without reflection,
- the well-being *benefits* of using TMR,
- the *mechanisms* by which TMR affects well-being.

RELATED WORK

Technology to Support Health. There has been huge recent interest in technology to improve *physical* health, e.g. addressing obesity using online tools to monitor food intake and motivate exercise [6,8,24]. These technologies encourage behavior change by showing people visualizations of their exercise, diet, or sleep patterns, prompting them to set specific goals, and connecting them with others for motivational support. This work has led to design principles for such systems [6,13]. There has been less research into systems to support *psychological* health and well-being, although research is emerging. Some commercial systems implement online Cognitive Behavioral Therapy regimes [3]. However, these systems address depression rather than well-being in normal populations, our aim here.

Recording Systems. Lifelogging systems [22] automatically create rich records associated with a person's everyday activities, which has been shown to improve memory and self-efficacy in Alzheimer's patients [1]. Some commercial tools such as MemoLane, MorningPics Timehop, and Everyday.me capture entries from social media sites and send them back after time has passed. However, unlike TMR, those systems simply *remind* users about past events, rather than providing explicit support for evaluating and repeatedly reflecting on one's changing reactions to those events. Finally, many studies examine daily recording of experiences using the Experience Sampling Method (ESM) [10], documenting happiness depending on many factors (location, social setting, time of day, etc). However, ESM does not examine how participants *reflect* on such ratings.

Reminiscence Systems. Other dedicated memory tools have been designed to support *social reminiscence*, often focused around digital photos or physical objects. Stevens et. al [23] designed a 'memory box' that held mementos accompanied by explanatory recorded narratives. PosiPost Me [9] lets people share positive posts with their friends to improve well-being. MobiMood [5] visualizes physiological data about emotions, which are then shared with friends, and eMoto [7] allows sharing of emotions between friends. Three Good Things [17] encourages people to engage in positive psychology techniques, which increases happiness and reduces depressive symptoms [21]. Perhaps most similar to Echo, Pensieve [18] presents users with prior Facebook status posts or general prompts about

their pasts and asks them to write their reactions to those earlier events. People both enjoyed such reflection and reported that it improved their mood. AffectAura [12] takes a similar approach, including visualizations of physiological data.

Reflection about Positive Events. Positive reflection is a fundamental aspect of unmediated human memory. People reminisce about past relationships, events, and achievements on a daily basis [2]. This has benefits for well-being [11]. Positive reflection improves mood and ability to enjoy life. It helps people maintain relationships, work through past events, and develop self-identity [11]. It increases self-esteem and social efficacy [21]. It is often invoked as an adaptive response to loneliness or current negative moods [2]. Reflection has been extensively explored in positive psychology, showing that people benefit from learning to evaluate past life events positively [11, 21].

Reflection about Negative Events. Reflection has also been used extensively to help people deal with *negative* past events. In the *emotional writing* (EW) paradigm [19] people are encouraged to write about past negative events repeatedly, transforming their feelings about those experiences with positive health consequences. People who engage in EW have better college grades, more success in job seeking, reduced work absenteeism, and improved mood [19]. The procedure works better for men than women, and for people who are more 'mindful.' Feelings about past negative events become more positive over time via *redemption narratives* in which experiencers see themselves as more resilient by overcoming adversity [19].

Unmediated Human Memory and Reflection. People do not accurately recall their pasts, but have adaptive biases. Overall they remember more positive than negative events (*Positivity Bias*) [25]. The strength of emotional reactions to events also attenuates over time, with negative reactions fading faster than positive ones (*Fading Affect Bias*). One explanation for this bias is the '*Rosy View*' hypothesis where negative *aspects* of situations are systematically forgotten (long lines at Disneyland) as events recede, making event perception more positive over time [15].

THE ECHO APPLICATION

To learn how technology might affect reflection and well-being we built Echo and studied its use. Echo is an Android app designed for *recording* and systematically *reflecting* on one's daily activities. Recording an event (Fig 2a) consists of writing a subject line, rating one's happiness at that moment, and optionally adding a description, photos, videos, and/or audio recordings. The happiness rating scale goes from 1 (low) to 9 (high) and is accompanied by smiley faces that correspond with each rating.

Unlike applications that simply remind users about prior posts [4,14,16], Echo encourages users to *reflect* on prior posts. To reflect, users view the initial post and any subsequent reflections on that post (Fig 1). They then go to

a Reflect Screen (Fig 2b) where they re-rate their current happiness about the event and enter their current reactions. They may also add new photos, audios, or video (Fig 2b). In Fig 1, the user has reflected 3 times about the initial post from 3 years ago, with reflective posts from 8 months, 1 year, and 2 years later, each shown on “cards” that stack to suggest receding into the past. The cards show the smiley and rating from each prior rating in the upper right corner, revealing longer-term affective patterns.

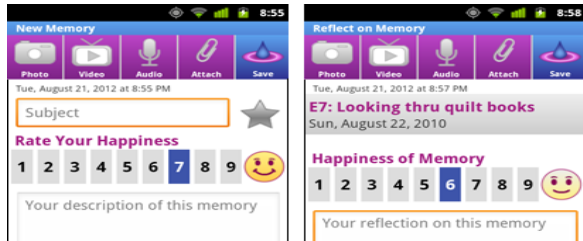


Figure 2a (left): New Memory Screen for recording initial events. Figure 2b (right): Reflect Screen for reflecting on earlier events.

Each day, Echo presents up to three prior posts from different time periods for reflection (e.g. 1 day ago, 1 week ago, 1 month ago, 2+ months ago, 1 year ago, and 2+ years ago), prioritizing older posts over newer ones as the person uses the system longer. If there is more than one post from the same time period, the system randomly chooses one. Echo also generates *reminders* delivered through Android’s notification feature, prompting people to reflect on earlier posts. Echo also allows the user to see a list of all their prior posts. They can select any post for reflection in addition to, or instead of, the one chosen by the system.

EXPLORATORY STUDY

We deployed Echo in a month-long pilot to determine how people used the system, addressing: (a) *how they used TMR* and (b) the *experience* of reflection and *benefits* it provided.

We recruited 10 participants (5 women, 5 men) aged 18-24 who owned an Android smartphone. After they had installed the software, we gave them a brief tutorial on Echo’s functions for recording and reflection. We asked them to record several events per day and to reflect on those events when they wanted to, over a period of 4 weeks. Echo sent notifications to reflect on posts from 1 day, 1 week, and 1 month ago. Participants could also spontaneously reflect on prior posts at any time. Of course, participants initially could reflect on only a few recent events because there was only a small pool of prior posts, but as the study progressed they reflected on a larger set of events.

To ensure participants were internally consistent in their happiness ratings, they created a personalized reference scale. Each point in the scale corresponded to an event in their life, from highly positive to very negative: e.g. 9=whale watching in Hawaii, 5=had meeting, 2=failed college application. Participants were asked to remember the scale and keep it accessible for consultation. We logged

each participant’s ratings and the number of initial posts and reflections. After 28 days we conducted semi-structured interviews to determine perceived usage and benefits.

Modes of Usage: Journaling and Analysis

On average each person made about 64 total posts: 39 recordings and 25 reflections. Overall, confirming prior work [18,25], their average emotional rating was positive at 5.64 (with 5 being neutral). Initial posts were rated 5.57 on average, with reflections a bit higher at 5.82.

Participants were highly positive about TMR, describing many benefits. They told us they recorded many types of events from the mundane (*getting coffee*) to the profound (*relationship/life issues*), in both social and private settings. Based on the interviews, we learned that people used TMR in two main ways: *journaling* (6 participants) and *analysis* (4 participants), each with different benefits. Participants who used Echo for *journaling* used it both to savor positive experiences and to stop obsessing about negative feelings by writing them down. In contrast, people who used Echo for *analysis* used their posts to work through their reactions to prior events, reconsidering their feelings, reflecting on their habits, and *drawing lessons* from their experiences.

Journaling. Journaling involved documenting an event and expressing current feelings about it. Several Journalers mentioned the benefit of having a detailed photojournal record of positive experiences they might otherwise forget: “[It’s] nice to remember small details of your days in the past... having reminders of certain things with a picture there with it.” These Journalers simply wanted to be reminded about things, but did not want to *analyze* them.

The act of journaling sometimes deepened the experience of positive events. One participant explained: “*The cool thing that I really enjoyed was, it’s the Kurt Vonnegut quote ‘If you’re ever feeling good, please just stop and think or murmur or exclaim, ‘If this isn’t good, what is?’ This project nailed that, because I would sit there and take a picture and then think ‘Hey, this is pretty nice.’*” Journaling also *cemented* unmediated memory for events.

Most Journalers recorded positive events, but some recorded upsetting events where expressing their feelings allowed them to stop obsessing. “*It made me tune in and listen to how I felt... Get it off my chest and off my mind.*” This was particularly useful when it was difficult to find a confidant. Because Echo was private, people could explore emotions without feeling judged by others: “*This affects me very deeply. I can’t really talk about it easily with my mom or my sister or my guy friend... With Echo I could use it to freely put ‘here’s what I feel. Here’s how I think about it’ and not have to worry about getting someone’s response or being judged.*” To avoid perseveration they often chose not to reflect on these events.

Analysis. Analyzers went beyond recording events and feelings, focusing on gaining insight from their initial and changing reactions to events. They were not concerned

about being reminded about negative experiences and instead embraced the idea of learning by reflecting on them.

Analyzers all said TMR supported *problem solving*. They analyzed negative situations to develop methods for dealing with personal problems and how to approach them. They also reframed negative events, putting them into context better. Reflection also offered perspective on past negative events, allowing people to move on: “*The situation with my mom, I originally felt really bad about it. ...I rated it a ‘1’ I felt stuck, frustrated, angry, depressed. And the rating for it changed because my situation changed. I was no longer in that position and I felt a little better.*”

Another benefit of analysis was that it helped people understand and sometimes *modify emotional habits* by gaining insight into behavioral patterns: “*It made me take my time. Not everything is so drastic. Like calm down, how do I feel...Calm down with my responses.*” One participant captured this by referring to Echo as his “*pocket therapist.*”

Those who used Echo extensively for analysis gained insight into how their reactions changed over time. Consistent with the literature, they described *fading affect*, where initially strong reactions attenuated over time [25], allowing them to gain control. “*The [other event] I rated a 1, that's ...still a 1. That's still a really crappy situation. But reflecting on it, I gave it a 3. I'm cooling down now. I don't feel as mad about it, I'm still mad.*”

Overall, for both modes of usage, participants said they benefitted from using Echo because it deepened experiences and allowed emotional expression. It also distanced them from initial reactions, which gave participants insight and control over their emotions.

RECORDING VS. REFLECTING STUDY

While our initial study generated insights into TMR and provided subjective data about its benefits, it nonetheless had several limitations. The study was *small scale* using just 10 participants, and we did not *systematically measure* the effects of usage on well-being. It also did not compare TMR with recording without reflection and so could not isolate the *mechanism* by which TMR had its effects.

We addressed these limitations in a follow-up deployment that involved over 30 participants and systematically measured TMR effects based on four standardized well-being scales. To examine the mechanism by which TMR had its effects, we implemented two versions of Echo to compare technology-mediated reflection with simple recording of experiences without reflection. In the *Reflection* version, participants generated event recordings and reflected in the usual way. However in the *Recording* version, we disabled both the ability to review past records and the reminders, so the system was simply a way to record an event and one's emotional reaction to it, much like a digital journal.

The Exploratory Study showed the benefits of journaling in allowing people to savor reactions to current activities and work through negative feelings [11]. So we anticipated that Recording would increase well-being. However, we expected the benefits to be greater for Reflection, as it facilitates analysis and perspective-taking. It also enables people to learn from patterns in their behavior, and allows for redemption narratives regarding negative events [11,21].

Participants

We recruited 38 participants via personal connections, Craigslist, Facebook and by posting to Quantified Self forums. Two were removed because of technical issues with phones and 3 withdrew from the study. This left 33 participants: 17 women and 16 men aged 20 to 60 ($M=28.7$, $SD=9.9$).

Procedure

The procedure was identical to the Exploratory Study. Participants were given a tutorial on Echo's functions, they constructed their personal emotion ranking scale, and they were asked to use Echo for 28 days.

Participants were randomly assigned to either the Recording or Reflecting group, with each group receiving a different version of Echo. The 17 Recording group participants were simply asked to record and emotionally rate 3 events per day. They could view or edit those posts only until the end of the day; after that, posts were no longer visible. The 16 Reflection participants were asked to record 3 new entries per day and also to reflect on an additional 3 prior posts. Echo prompted the Reflection group to reflect on previously recorded events from 1 day, 1 week, and 1 month ago. This group could also spontaneously reflect on any prior recording. We checked in with participants weekly to see if there were technical problems and ensure they were following the procedure.

Data Collected

We logged the number of posts and their ratings, and we asked participants to share the *content* of their posts (after first browsing posts to remove any they didn't want to share). All but 4 gave us access to their logs. Again we interviewed people about their experiences with Echo. At the end of the study we asked participants whether they wanted to continue using the application.

To measure well-being we asked participants to complete 4 well-being scales before and after their month using Echo:

- *Subjective Happiness Scale* (SHS): 4 item survey that assesses happiness of self, and self relative to others.
- *Satisfaction with Life Scale* (SWLS): 5 item survey that assesses overall life satisfaction.
- *Psychological General Well-Being Index* (PGWBI): 22 item survey that measures self-representations of affective and emotional states.
- *Mindfulness Attention Awareness Scale* (MAAS): 15 item survey that measures attentiveness to what is occurring in the present.

All scales are widely used and have demonstrated high discriminant and convergent validity and test-retest reliability with a wide range of populations.

Findings

We first discuss the nature of posts, determining whether people were focused on positive events, as prior work would suggest. Next we describe results showing that using Echo enhanced well-being for both the Recording and Reflecting groups, although it did so through different mechanisms.

Overall Event Ratings Tended to be Positive

Overall, those participants who provided their data generated an average of 90 posts, or 3.2 per day: 2.5 for Recorders and 4.3 for Reflectors (made up of 2.4 initial posts and 1.9 reflection posts per day). The length of Recorders' posts (22.9 words) and Reflectors' initial posts (13.6) were not statistically significant, nor were Reflector's initial posts (13.6) and their later reflection posts (10.9).

As predicted by prior work [18,25], happiness ratings of posts tended to be *positive*, averaging 5.9 on the 1-9 scale. The two groups' ratings were not statistically different. To profile the linguistic content of posts, we also ran LIWC [20], a linguistic analysis tool that calculates usage of word categories, including references to positive or negative emotions, self, causal words, verbs, present, past, and future, etc. Overall, 5.3% of words generated by both groups were positive and 2.7% were negative. These are higher than the baselines of 2.7% positive and 2.6% negative provided in Pennebaker's personal writing corpus [19].

Echo Use Improved Well-Being

Next we examined the effects of TMR on well-being. Table 1 shows overall increases in perceived well-being after using Echo for a month. To test these effects, we ran a MANOVA with one between-subjects factor Condition (Recording vs. Reflecting) and one within-subjects factor Time (pretest vs. posttest). The dependent variables were the combined four well-being scales.

Scale	Recorders		Reflectors	
	Pre-test	Post-test	Pre-test	Post-test
SHS	4.81	5.12	4.97	5.17
SWLS	24.53	26.18	22.94	23.44
PGWBI	61.55	67.22	63.92	66.08
MAAS	4.22	4.10	3.97	4.00

Table 1: Mean well-being scores before and after using Echo. Both Reflectors and Recorders show improved well-being for combined well-being scores.

Using Pillai's trace, the main effect for pretest vs. posttest was significant, $V=.31$, $F(4,28)=3.09$, $p=.03$. As we expected, both groups improved on combined well-being measures with a large effect size ($\eta_p^2=.31$). Although we expected Reflection to induce greater improvements than

Recording alone, the interaction effect of Time by Condition was not significant, $V=.11$, $F(4,28)=.90$, $p=.48$, indicating that neither group improved significantly more. The finding that Echo improved well-being is also supported by the fact that 8 months later, 6 participants are continuing to use Echo.

Recording and Reflecting Are Different Emotional Processes

Our prediction that Reflectors (RF) would experience greater improvement than Recorders (RC) was not supported. To understand the reasons for this, we did two content analyses of participants' posts, one of *overall posts* and the other analyzing the *words used within the post*. We found that both groups used Echo for intense self-analysis, but they did so in different ways. Reflectors generally gained insight into their behavior when they revisited prior posts. After reflecting they were happier and *gained perspective* on events they had initially judged negatively:

RF1:[Happiness rating 2] *My Boyfriend's not texting me often enough :(I really wish he would text me more often.*

1 day later:[Happiness rating 6] *You know, I guess I'm not that angry... I'm sure I can, at times, be that crazy girlfriend who texts too much and is overbearing, so I'm sure he can get annoyed too.*

Recorders, however, gained benefits from *expressing* their emotions. This participant vents and self-coaches:

RC13:[6] *Feeling pretty good today all told. The shipment is not going to schedule BUT: a) I don't personally care, so I should not stress; b) it is not my fault shit's late; and c) it is [R's] fault for not planning better.*

Differences in Emotional Depth for Recording and Reflecting.

To systematically analyze how Echo was operating, we hand-coded 996 randomly selected posts representing 40% of each person's posts, 462 from Recorders and 534 from Reflectors (317 initial posts and 217 reflections). We rated each post for its *emotional depth* based on these mutually exclusive categories:

Report: No emotional content. (*Have a bunch of homework to type up.*)

Mention: Mention or suggestion of an emotional response. (*Chilled with friends. It was nice to relax.*)

Express: Description or expression of an emotion. (*Stressed about finding a house. Still doing a lot of work. Being busy feels good, but the stress is killing me.*)

Analyze: Rich explanation or analysis of an emotion, self-coaching on how to behave or feel (*A lot of fear, can't just avoid issue but feel like I can't face it head on. Feel like god isn't there and I am like a codependent little kid.*)

We defined each coding category through a description, several examples, and a list of typical terms. One person coded the entire sample while a second coded 20% of the posts, achieving 78% agreement. The results for *initial posts* are shown in Fig 3, indicating that while both groups were equally likely to simply Report events, Recorders

more often engaged in Expression and Analysis of emotions, whereas Reflectors were more likely to simply Mention emotions ($\chi^2(3) = 32.17, p < 0.0001$).

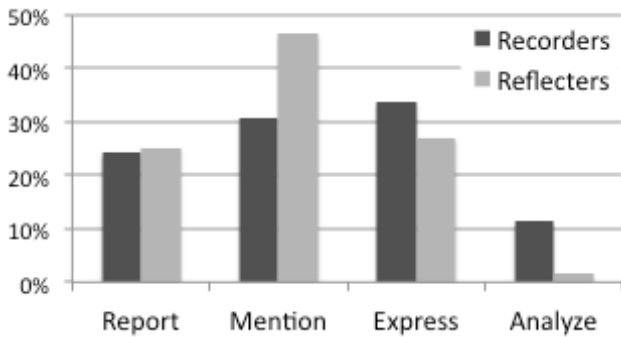


Figure 3. Percent distribution of emotional depth of Recorders' posts and Reflectors' initial posts. Shows that Recorders expressed more emotional depth in their posts.

However, Reflectors conveyed deeper emotions in their reflections. Compared with their initial posts, their reflections were more likely to Express and Analyze, and less likely to Report and Mention emotion (see Fig 4). An analysis confirmed that while the combined number of cursory emotions (Reports and Mention categories) decreased from initial posts to reflections, explicit discussion of emotions (Express and Analyze categories) increased ($\chi^2(1) = 25.27, p < 0.0001$). It therefore seems that Reflectors are deferring detailed emotional analysis until they revisit posts. We explore these differences further by looking at whether Recorders and Reflectors use different words in their posts.

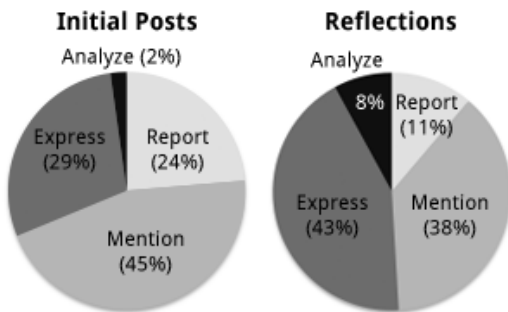


Figure 4. Percentage of posts with different levels of emotional depth in initial posts compared with reflections. Reflections show more emotional depth than initial posts for Reflectors.

Linguistic Differences between Recording and Reflecting. We used LIWC to quantitatively compare the linguistic properties of all posts for Recorders and Reflectors and confirmed that the emotional quality of their posts was different. Reflectors tended to be more positive about the emotions they described, ($t(27)=3.25, p=.003$, Record: $M=4.6, SD=1.44$, Reflect: $M=7.17, SD=2.79$). They also had more assent as assessed by words like 'ok', 'yes' and 'agree', ($t(14.55)= 4.93, p<.001$ using Levene's

correction for heterogeneity of variance). (Note that we used this correction for all t-tests with unequal variance.)

Why did Reflectors express more positive emotions? Our content analysis of posts suggested this might be because Reflectors, who did less analysis in their initial posts, later drew positive lessons from both positive and negative events. For positive events, they seemed to use TMR both to savor them as they were occurring and to generalize positive lessons from them later. If, like Recorders, they had simply recorded the initial event they would have had less opportunity to see its general positive benefit.

RF4:[8] *Glee!: Watching glee at Sam's house!*
 1 week later:[7] *I love spending time with my coworkers outside of work and looking back glad I can spend moments like these with them.*

More importantly, however, Reflectors also used TMR to see positive aspects of initially negative experiences, later perceiving benefits to events they had first found upsetting. Benefits could be simple lessons drawn from negative circumstances, but they also took the form of redemption narratives [19] whereby people draw personal affirmation and increased self-esteem from having triumphed in difficult circumstances.

RF7:[5] *Crazy amount of work: So my econ thing is due tomorrow! And the Monterey place asked me a bunch of technical questions because they're actually interested in me. And I still have the prototype for 80k due tomorrow and 162 and CE12 to take care of! Aaaaahhhhhhhhh!*
 3 days later:[6] *That shit was crazy, but it was worth it. I feel pretty accomplished and some people seem impressed with it.*

To explore this further, we analyzed changes in event ratings after reflection. Consistent with prior work showing adaptive bias in unmediated memory [25], initially negative events were evaluated more positively upon reflection. Moreover reflection ratings of initially very negative posts showed greater positive change than events that were mildly negative. Extremely negative initial ratings of 2 or 3 (no events were rated as 1) improved more on reflection than those with a mildly negative initial rating of 4, ($t(13.2)=2.40, p=.032$. Mean changes of 2s and 3s=1.59, $SD=.93$, Mean changes of 4s= .86, $SD=.38$).

TMR was different for Recorders. Because they only registered events once, even when they analyzed deeply they may have been less able to take a perspective on the situation and see possible positive benefits from upsetting current experiences.

RC7:[5] *Why is it that on some days I am scared to death to go to work but on others I am fine? Is it the people I work with, is it me, is it just that I might be a little bit psycho? I really do not know what to say other than I need to breath relax and everything will be fine. Work is hard enough but*

more so if I stress myself out. I love my job, i really do but sometimes it really scares the crap out of me!

Since Recorders didn't have the opportunity to reflect, they had to do their analysis in the moment. Reflecters, on the other hand, could have analyzed initially, but did so less often, perhaps knowing they would have the opportunity later when they had perspective. To understand how the different patterns led to well-being benefits for both groups, we again looked at the content of their posts using LIWC.

How Recording and Reflection Improve Well-Being Reflecters Improved By Talking About Actions and Drawing Lessons for Future Behavior. We used LIWC to examine how the language used in posts correlated with responses to specific well-being scales. For Reflecters, increases in subjective happiness were positively correlated with specific characteristics of initial posts including: a greater use of all verbs, $r(10)=.61$, $p=.036$, and auxiliary verbs (should, can, will, ought), $r(10)=.59$, $p=.045$, along with more discussion of the present, $r(10)=.79$, $p=.002$, and the future, $r(10)=.60$, $p=.038$. This suggests that for Reflecters, it was adaptive to focus on actions (as indicated by verb use) and prescribe future lessons derived from present understanding (as indicated by tense usage and auxiliary verbs), or to draw those lessons in their later reflections.

We saw many examples of Reflecters following this pattern: reflecting on initial posts and proposing future-based resolutions for improved habits.

RF10:[3] *Parents left a note saying food in the fridge. They left me the smallest piece of meat. Fuck they make me angry. I know it my fault for not being present for dinner. But still my parents suck a little.*

2 days later: [5] *It's cool. I shouldn't act like such a spoiled brat. I knew that I'd feel this way later when I reflected on the anger I felt that night. Poop. This too shall pass.*

Similarly, the LIWC analysis of Reflecters' posts supported our earlier finding that reflections were more complex than initial posts: reflections included more cognitive process (cause, know, ought) ($t(22)= 2.16$, $p=.042$ Reflections: $M=17.07$, $SD=1.88$, Recordings: $M=15.03$, $SD=2.68$) and insight words (think, know, consider) ($t(14.06)= 3.19$, $p=.007$, Reflections: $M=3.33$, $SD=1.50$, Recordings: $M=1.85$, $SD=.56$). For example, this participant gained insight into her course performance from an initially negative experience, leading her to make a resolution not to stress so much.

RF1:[6] *We had a lab assignment this past Thursday .. I'm kinda getting worried about it, because there are some questions/items on there that I don't know how to do/answer, so I'm afraid I won't get full credit on it :(ugh*
2 weeks later: [6] *So, I'm starting to realize as long as we do a decent job on the assignments, we will get full credit... so I don't feel like I should stress SO much. I should just make sure that I know what I'm doing, but relax a bit.*

Interestingly, the LIWC content analysis also indicated that other types of posts did *not* improve Reflecters' subjective happiness. Initial posts that talked about biological functions and eating/drinking were associated with *decreases* in happiness ($r(10)= -.58$, $p=.048$ and $r(10)= -.70$, $p=.012$ respectively). How can we explain this? It may be that writing about one's body (health or food issues) confronted people with evidence of their failed intentions to work out and eat better:

RF1:[6] *Starbucks for the 3rd time today*
10 days later:[3] *Yuck, I should NOT be drinking anymore of that fatty, sugary food! :(*

Recorders Improved Well-being by Discussing Relationships. For Recorders, the LIWC analysis showed different factors improving well-being. Their increases in subjective happiness were positively correlated with use of he/she, $r(15)=.54$, $p=.026$, talk about people, $r(15)=.49$, $p=.048$, sex, $r(15)=.53$, $p=.028$, and using quotes, $r(15)=.48$, $p=.049$, suggesting that those who discussed relationships benefited more. Some Recorders benefited from simply expressing positive outcomes in relationships.

RC6:[7] *Just had the best most spiritually connected conversation with [M] after sitting in sun in union square. So grateful that i can be so grateful with [M] about everything and feel so understood. Starting to just be me and do things despite what I think people will think.*

Recording also allowed people to fully express negative emotions about relationships and not obsess about them. Because there was no reflection, people knew they would never see these outpourings again, which may have allowed them to express themselves more freely:

RC2:[3] *Can't stand him. Or guys in general for that matter. I don't get it. Do they have to be so childish? I don't understand men. I don't know what they want. If I'm being honest, then I hurt their feelings. If I'm being nice, they take me for granted. If I try to be adaptive, they think I'm flaky. Maybe I'm just hard to get along with. Whatever. There is nothing wrong with me. Fuck men.*

It appears, then, that Recorders were choosing to take on more interpersonal topics in their posts, and that expressing strong feelings improved well-being. Reflecters were less inclined to probe emotional issues initially, but reflecting on their earlier posts encouraged them to gain insight, even from less emotionally expressive posts. The final interviews helped confirm this difference.

Summary of Final Interviews

The final interviews showed that the two groups perceived different benefits from using Echo. Much like the Journalers from the Exploratory Study, some Recorders explained that simply writing down their thoughts helped them *explore* and *understand* their feelings. One person commented that recording "*generally helped me solidify my emotions about something and put it in perspective.*" Even

writing about the trivial made them appreciate the activity more: “For example, if I was doing something as simple as taking out the garbage Sunday night ... recording it would make me feel like I was helping my parents ... It made me feel better about myself even if it was something not so important.” Recording was also helpful in negative situations, allowing participants to express negative feelings as if to a ‘digital confidant.’ “it allowed me to talk about it a little bit I guess, sort of just get it out of my head.”

Reflecters, on the other hand, said they benefited from seeing longer-term patterns in their behavior or drawing lessons from the outcome of earlier events, which they could use in future experiences. One said, “It was useful in that I got to separate what happened at the time from what happened after... So, it showed me that I didn’t have to feel bad about stuff which I couldn’t control, which was useful.” Another noted, “I think it improved my well-being because it sort of forced me to think of these negative things as problems to be solved, revisit them, and think of them as a continuing process rather than some isolated, negative event. It was sort of empowering, I guess.”

LONG TERM EFFECTS

The data presented so far describe studies conducted over a month. While we find it remarkable that people found value and increased well-being in recording and reflecting over a relatively short period, we are especially interested in the long-term impact of TMR. To this end, one of us (Isaacs) has been recording and reflecting on her life for nearly four years. While this represents a single individual, it is unusual to have any data over such a long period of time. We discuss her experience with long-term TMR, suggesting potential benefits to be explored in future long-term studies.

Since November, 2008 Isaacs has generated 5,324 recordings and 4,093 reflections, averaging 3.8 posts per day (ranging from 1 to 12 posts per day). She has reflected on 2.9 posts per day, chosen at random from 1 week, 1 month, 1 year, 2 years, or 3 years ago. While some posts have never returned for reflection, others have as many as 7 reflections, with an average of 0.8 reflections per post.

Reflection Improves Event Perception

One defining aspect of reflection in everyday unmediated memory is *fading affect bias* [25], in which strong negative emotions fade more quickly than strong positive ones. FAB allows people to adaptively recover from negative events by changing their perception of those events. Since Isaacs had many chances to reflect on her initial posts, we wanted to see if she would exhibit fading affect bias.

The long-term ratings data show she did (see Fig 5). There was a net adaptive bias towards reflecting on events more positively. We analyzed changes in event ratings after reflection finding that negative ratings (1, 2, or 3) moved to the mean more than positive ones (7, 8, or 9), $t(60.13)=6.88, p<.001, d=1.15$. Further, very negative ratings (1s or 2s) improved more after reflection than

moderately negative ones (3s or 4s), $t(213)=3.61, p<.001, d=.91$ and extremely positive ratings (8s or 9s) faded more than moderately positive ones (6s or 7s), $t(2086)=10.26, p<.001, d=.84$.

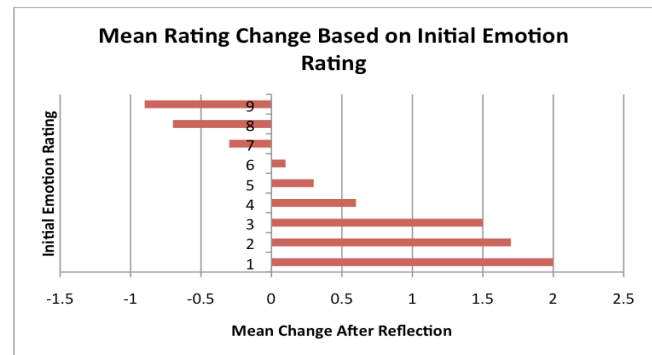


Figure 5. Fading affect bias: Changes in rating between initial post and reflection as a function of original rating. Extreme initial posts change more than moderate ones, with highly negative initial posts improving most.

Although Isaacs’ reflection patterns are similar to those of the study participants, we note several outcomes that are the cumulative effect of practicing long-term reflection.

Longer-term Behavior Change Based Around Perceiving Patterns in Emotional Habits

Isaacs started using TMR to reduce anxiety about events she initially perceived negatively. With repeated use of Echo, she noticed that these events usually turned out better than she had anticipated. At first she deliberately applied this lesson to new situations, as in this Echo reflection: “I’ll use my Echo learning and not stress, figure it will all work out.” Eventually, this mindset became automatic, as shown by this initial post about a project that was going off track: “In one way, I’m concerned that this could blow up and the project will go where none of us wants it to go, and in another way, I’m still liking the team and the work, so I have faith it’ll be okay.”

Another change occurred from analyzing repeated reflections on the same events. Several years ago, Isaacs felt her work was having little impact. Upon seeing a post on one such project she reflected: “A typical example of how little of the work I do amounts to anything.” But as these reflections returned, she saw how they only reinforced her negative feelings. Instead, she started to focus on the personal benefit gained from the activity. A later reflection: “This wasn’t used but it was good for the development of my own thinking.” Here, the learning came from seeing the pattern in her reflections on the original posts. These reflections reveal that she was developing improved habits, i.e., imagining potential positive outcomes to worrisome situations and seeing positive aspects of negative situations.

Mental Time Travel Allows Real-time Nostalgia

Not all long-term effects were about correcting flaws or problems. Isaacs also reports the profound experience of living life both *in the moment* and *retrospectively*, savoring

how precious a moment is (or will be) and by anticipating how it will feel when she reflects on it later. In an interview, she said, “*I had the feeling of appreciating the day from a nostalgic standpoint, like these are the good days of our lives, they're special and what make our life worth living.*” In an Echo initial post she described an enjoyable activity: “*It felt like living a happy memory.*” Another unexpected long-term outcome was both *re-anticipating and re-experiencing* enjoyable activities, such as vacations. As Isaacs sees recordings of plans and preparations for previous years’ vacations, she begins to anticipate “going on the vacation” again. As the vacation unfolds, she re-experiences it each day as her descriptions and images of those days return.

The Downside: Desire to Repress the Negative

Not all long-term TMR is positive. Sometimes unpleasant events come back that don’t lend themselves to personal growth. Other times, Isaacs preferred to forget the details of a negative event. She underwent a house remodel that turned out well, although her relationship with the builder soured by the end. She would prefer to savor living in the new home and not remember the specifics of their disagreements, since these can no longer be addressed.

DISCUSSION AND CONCLUSIONS

Understanding How TMR Improves Well-Being

Our results extend our understanding of how new mediated memory systems work in both research [5,7,18] and commercial domains [4,14,16]. We demonstrate that using Echo produced *measurable improvements* in well-being. This is a striking result, as our participants had only been using Echo for a month. For our one very long-term user, TMR led to adaptive changes in her behavior and emotional responses that she experienced as profound.

Improvements occurred both when participants simply *recorded* events and when they *reflected* on prior events. One could interpret this result to suggest that reflection is not necessary, since recording alone improves well-being, but we found that the two groups benefitted through different mechanisms. People who only recorded events benefitted by savoring positive emotions and by analyzing their negative emotions (often about relationships) rather than bottling them up [19]. People who both recorded and reflected benefitted by generalizing from positive experiences and by drawing positive lessons from negative events. They also identified recurring patterns and habits, noting plans to change unwanted behaviors. This suggests that TMR may be most appropriate in cases when it is helpful to see patterns of behavior and to extract lessons after the outcome of events is known. It may also be a catalyst for *behavior change*, as suggested by the Reflecters’ usage patterns and by the long-term use results.

TMR Does Not Disrupt Adaptive Memory Biases

We also found evidence that TMR’s underlying properties and biases were similar to those of unmediated memory [25]. We saw typical autobiographical unmediated memory

phenomena such as the *redemption narrative* [19]. As with classic unmediated memory, Echo users also tended to record more positive than negative events [2,15], and they exhibited the characteristic fading affect bias [25] over long-term use, whereby extremely negative events show the most improvement. This result clarifies underlying relationships between unmediated memory and emotion. For example, the Rosy View [15] argues that people subconsciously edit negative aspects of prior events, but we found that people came to feel less extreme about events *even when they read in their own words how they initially felt about those events*. This suggests that fading affect bias occurs not because people edit extremes from memory, but rather because they change their stance on those events once they know the outcome.

More generally, our results argue against the *adaptive forgetting* view. One concern was that Echo’s presentation of actual posts might undermine adaptive positivity biases in unmediated memory, perhaps by reminding people of negative things they wanted to forget. But we found that being reminded about what one *actually felt* as opposed to what one *remembers feeling* also led to measurable improvements in well-being. People were able to re-evaluate even negative events with increased feelings of control and perspective. We saw the opposite behavior with Recorders however: they sometimes vented strong emotions to avoid obsessing about them.

Potential for Providing Novel Physical Health Benefits

There is great interest in using mobile applications to help people to improve *physical* health by encouraging users to set reachable goals and record their progress. This study is one of the first systematic demonstrations that mobile tools can improve *psychological* well-being through TMR. Unexpectedly, our data hinted that TMR might even help people improve their *physical* health, albeit more indirectly than current approaches. Reflecters frequently wrote about health-related behaviors: eating, exercise, sleep, stress, smoking, and drinking. Without necessarily setting goals for themselves, people sometimes felt motivated to change when they saw their posts after suffering the consequences of their earlier behavior. Our data showed that being reminded of eating habits and body issues negatively affected well-being after one month. It’s possible, however, that over time, reflection would motivate people to change, and we saw some examples of this. In an interview, one participant said, “*When I saw the event I actually felt worse because I just made the same mistake again. But [Echo] has actually helped me not to do that, to reflect on it. See? I don’t have any more entries like that.*” Perhaps a general tool for analyzing habits such as TMR might help people change their physical behavior, as an alternative to current wellness approaches.

Design implications

Our finding that recording and reflecting improves well-being also opens up questions about how we might

optimize our *intervention technique* to increase psychological health. For example, several participants suggested that we make Echo *adaptive*: if users report a sequence of negative events, we might try to elevate their mood by selecting an earlier positive memory for reflection. Or we might apply the emotional writing approach [19], encouraging participants to repeatedly reflect on upsetting events until they have a more positive perspective. For people who want to vent about events without being reminded of them, we might implement a ‘repression feature.’ Or we might offer ratings of different *types* of emotions, not just happiness. We also want to explore longer-term interventions to determine whether the benefits by our single long-term user would generalize to others.

These are just some of the new systems, interventions, and theories that our work suggests. Our study not only demonstrates the positive well-being effects of a relatively new class of system, but it also suggests novel ways that technology mediated memory systems might be deployed to improve physical health.

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