Connective Recovery in Social Networks After the Death of a Friend

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Most individuals have few close friends, leading to potential isolation after a friend's death. Do social networks heal to fill the space left by the loss? We conduct such a study of self-healing and resilience in social networks. We compared de-identified, aggregate counts of monthly interactions in approximately 15,000 Facebook networks in which someone had died to similar friendship networks of living Facebook users. As expected, a substantial amount of social interaction was lost with the death of a friend. However, friends of the decedent immediately increased interactions with each other and maintained these added interactions for years after the loss. Through this, the social networks recovered approximately the same number of active connections that had been lost. Interactions between close friends of the decedent peaked immediately after the death and then reached stable levels after a year. Interactions between close friends of the decedent and acquaintances of the decedent stabilized sooner, within a few months. Networks of young adults, ages 18 to 24, were more likely to recover than all other age groups, but unexpected deaths resulted in larger increases in social interactions that did not differ by friends' ages. Suicides were associated with reduced social network recovery.

Most individuals have few close friends [1–3] and close friends are major sources of support [4]. After the death of a friend, close friend networks could dissolve or experience long-term impairment. While theoretical models suggest that networks are often globally robust to random losses [5, 6], we have limited empirical foundation for models of resilience in human networks. There are currently no large-scale studies that evaluate recovery and resilience after deaths in friend groups.

A friend group could compensate for a loss by strengthening or building new friendships within-network, potentially even returning to similar levels of connectivity and function after a death. Studies on crises document increases in social interactions [7–10] and increases in support are thought to reduce the negative effects of the crises [7, 11]. Similarly, many bereaved spouses increase contact with children and grandchildren [12] and, especially after long periods of caregiving over which social contact declined, increase social activity and participation in community groups [13, 14]. However, small studies also record that social support networks can collapse [15] or, compared to control groups, show no significant change in social support [16] in the months and years after a death. Notably, longitudinal studies on the effects of deaths on social interactions are rare because pre-bereavement data is uncommon [16], especially among non-elderly samples. With time, most bereaved individuals appear to exhibit resilient psychological responses to grief and trauma [17, 18], but average, precise, and long term patterns of social support after a death are less well established.

Recent research on social networks during crises have found that friend groups react in three distinct ways: 1) quickly forming temporary bonds that dissolve, (2) slowly forming longer-term, in-group bonds, or (3) dissolving and never healing. These responses to crises predict a broad range of average responses to a death, covering the spectrum from full connective recovery to collapse. For example, strong connections develop for information sharing and support in the midst of a crisis, but the connections are not long lasting [8]. College students have responded to natural disasters by gradually increasing local network clustering – that is, forming relationships with friends-of-friends instead of outsiders [10]. Some networks never recover from the loss of a central individual: academic collaboration networks are more likely to dissolve after the death of an important member [19].

Here, to evaluate the resilience of social networks after a death, we measure how quickly friend networks recover connectivity, how completely they do so, and whether this connective recovery persists beyond the acute grieving period. We used data from the online social network Facebook to measure online social network connectivity in the months and years before and after a loss. Past research has shown that online social interactions closely correspond to offline interactions [20–22], as well as important health outcomes such as subjective well-being [23] and longevity [24]. Although online interactions do not fully reflect social support provided offline, mundane chat is thought to play an important role in well-being [25]. Furthermore, social media is increasingly used to keep up with close friends, with 40% of Facebook users friending all of their closest offline confidants [20]. Thus, online conversations are a reasonable proxy for overall social network health.

To measure social network responses to loss, we studied the adaptations of 15,129 de-identified social networks on Facebook between 2011 through 2015 in which the central individual died between January 2012 and December 2013, compared to 30,258 similar networks that did not experience a death. We focused on the close friends of the decedent, examining changes in close friends' numbers of interactions over a four-year window, analyzing how their communication patterns changed (1) with other close friends of the decedent, (2) with the decedent's acquaintances (encompassing the close friends' existing and new friends), and (3) with individuals who did not know the friend who died (again, existing and new friends of the decedent's close friends). Figure 1 illustrates the effects. We limit our focus to social connections, but we hope that these findings and future research lead to explanations of changes in functional outcomes.

Our focus in all models is interactions between the decedent's close friends and others in the decedent's social network. Interactions are measured as the number of friendships that were "activated" in a social network each month, based on post, comment, or photo tag ties in the network (see Materials and Methods). The measure is the total number of interaction partners in a month in each network, weighted by the number of interaction modes (post, comment, photo). We focus on "activated" friendships rather than total volume of communication to avoid biasing findings toward pairs that communicate extremely heavily. We do not distinguish between newly formed and strengthened friendships because we do not know when two people first met. The interactions we measure online can include conversations between two people have not talked to each other in many years or former acquaintances who have suddenly become close friends.

We used quasi-Poisson generalized estimating equations to mea-

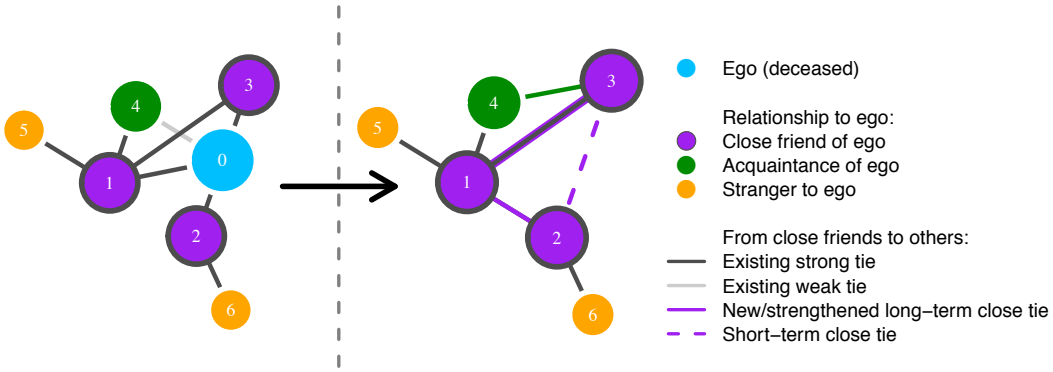

Fig. 1. *Connective recovery.* After a person dies (node 0), his or her close friends (nodes 1, 2, and 3) will begin to interact more with each other and with acquaintances of the decedent (node 4), even if they were not previously friends. These new social interactions may be temporary or long-lasting. They will not interact more with individuals who were not friends of the decedent (nodes 5 and 6).

sure changes in the number of interactions between the decedent's close friends and other members of the decedent's local social network. These count models estimated changes in social interactions relative to a pre-death baseline and relative to the control networks, weighted by the control networks' likelihood of experiencing a death (see Materials and Methods). In this control group setup, the models estimate the numbers of interactions in the bereaved networks compared to how many interactions we would have expected without the loss. The difference-in-difference estimates from these models are ratios for the numbers of interactions in the bereaved group compared to the control group and pre-death baseline, so that the findings control for pre-existing differences in levels of online activity. Thus, if we see larger increases in activity among younger people, it is not simply because younger people were more active than older people on social media in the first place. The estimates reported in the text and in Figure 3 are from models that exclude the month of death, as well as the month before the death and the month after it, so that the estimates for longer-term effects are not skewed by peaks in activity immediately around the death and funeral.

We first estimate changes in numbers of interactions among close friends of the individuals who died. The purple line in Figure 2 displays the monthly changes in close friend interactions before and after the death of a friend. Interactions increase sharply at the death and slowly fade as time goes on (log months from death slope -0.026, CI -0.032 to -0.020). On average, there were 4.5% (95% CI 3.4-5.7%) more interactions in close friend networks nine months after losing a mutual friend than otherwise.

The green line in Figure 2 displays the monthly changes in interactions from the decedent's close friends to the decedent's acquaintances. There were 2.6% (95% CI 1.5%-3.6%) more interactions with acquaintances two years after the death than before. These interactions were significantly less likely to fade over time than the close-friend-to-close-friend interactions (slope -0.008, 95% CI -0.015 to -0.001). That is, the networks displayed long-lasting effects, with close friends and acquaintances strengthening and developing new connections that persisted for multiple years and that stabilized at levels similar to the increase in social interactions among close friends.

Finally, the orange line in Figure 2 shows that there was no overall change in social interactions directed from close friends of the decedent toward individuals who did not know the person who died ($p = 0.37$), suggesting that interactions formed in the short and longer term were highly localized. In other words, close friends did not increase their online social interactions in general.

Because the increases in close friends' interactions happen after loss of potential interactions from the death of a friend, we estimate how many interactions were "recovered" through compensation. This comparison between how much social interaction was lost and how much was gained allows us to better interpret the magnitude of potential social support provided after a death. While we do not know how much online social support individuals need or would like after the death of a close friend, the resulting "recovery" in social connections suggests that friends of the deceased provided compensatory support to each other, reducing potential isolation.

The right side of Panel A of Figure 3 shows that in networks of individuals age 25 or over the increase in interactions nearly to fully compensated for the loss of the interactions that the deceased individuals had contributed. The gray dots in the left side of Panel A estimate the absence of the ego (i.e. the decedent) without compensation (e.g., the interactions lost after the subject's death) and the turquoise dots in the right side of the panel with compensation (e.g., the lost interactions plus the new/strengthened interactions to other close friends and acquaintances of the decedent). In networks where the subject was under 25, the surrounding friends actually increased the number of interactions in the local network.

Using estimates from the count models to simulate the percent of social interactions recovered among close friends of the decedent and from close friends to acquaintances of the decedent, we estimate that recovery across all age groups was 99% (simulated 95% CI 77% to 126%). Considering only compensation from close friends of the decedent to other close friends, compensation was 78% (simulated 95% CI 63% to 96%). We show estimates for recovery within close friend groups by age in the Supplementary Information (SI).

In the results described above, we considered the effect of the age of the deceased friend on connective recovery in their social network. To test whether younger or older individuals compensated for the loss of a friend differently, we stratified our estimates based on the ages of close friends. We also distinguished text-based interactions (wall posts and comments) from photo-based interactions (photo tags) to evaluate to what extent recovery might be limited to online interactions and not extend to offline ones. Past research found that photo tags were more likely to reflect offline interactions [22] (see SI for a principal component analysis supporting this distinction between

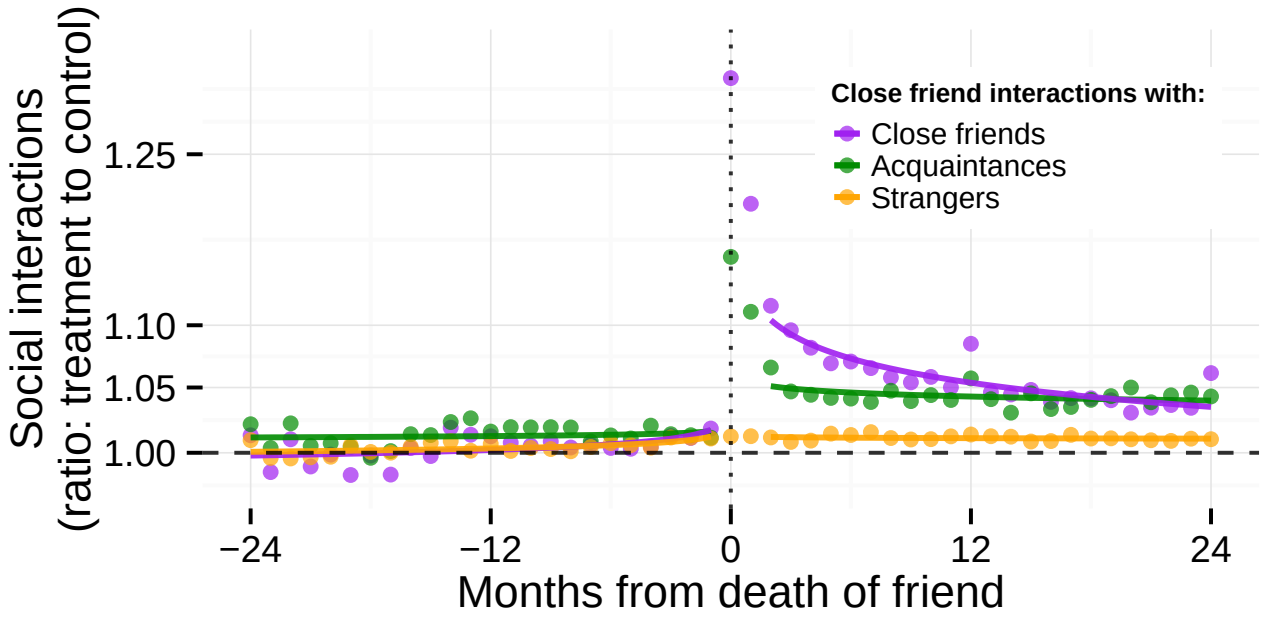

Fig. 2. *Short and long-term interaction changes after the death of a friend.* Communications increase from close friends of the deceased to other close friends (purple) and to acquaintances (green) of the deceased after the death. Interactions peak in the first few months, but continue to be higher two years later. Each point represents one month. The y-axis is the rate ratio from a quasi-Poisson model of social interactions in the bereaved networks relative to corresponding social interactions in control networks, so that the findings do not reflect pre-existing differences in levels of online activity. Close friends do not significantly increase their online social interactions in general after loss (orange).

text and photos).

In Panel B of Figure 3 we show that increases in social interaction vary by the age of a deceased individual's friends. We observe smaller compensation effects among older friends: older adults engage in fewer new social interactions with other friends of the decedent. However, we show in Panels D and E of Figure 3 that this decline can be explained by both the ego and close friend ages, as well as cause of mortality. When a young person dies unexpectedly (that is, from an unintentional injury – similar to previous work [12], we exclude suicides and homicides from the 'unexpected' loss category), new interactions are high regardless of close friends' ages. After the unexpected death of a young person, friends aged 18 to 24 increased mutual friend interactions 8.7% (95% CI 2.8% to 14.7%) while friends aged 25 to 64 increased mutual friend interactions 12.9% (95% CI 8.2% to 17.6%). In Panel B, we see no difference in mutual friend interactions by interaction type at young ages, suggesting that support is happening both online (e.g. exchanging supportive wall posts and comments) and offline (getting together in person and being photographed). However, older individuals increase interactions with the decedent's mutual friends through posts and comments without a corresponding increase in photo tags.

In Panel C, we show that photo-based interactions with people who did not share the loss of a friend (i.e., strangers to the decedent) decrease among older people. At ages 55 to 64, photo-based interactions with individuals who did not know the friend who died were only 93% (point-wise 95% CI 88% to 99%) of, or approximately 7% lower than, their expected level. We did not observe this effect among younger people, suggesting that a decrease in photo-based interactions may be specific to older populations.

Finally, in Panel D, we describe variation in these effects by cause of death. In the panel, cause-specific estimates are from separate models, each of which were stratified by the age of death as in Panel A. The red line at 1.0 is the average change in interactions after a death for all causes other than the one shown, and the estimates are changes in interactions above or below that average increase in interactions after a death for the specific cause. Some causes of death are linked to stronger changes in close friends' social interactions; close friends of individuals who die suddenly and unexpectedly, such as from an unintentional injury, interact more with each other. Friends of suicide victims, however, are less likely than friends of people who died of other causes to strengthen or form new interactions with the decedent's other friends. Friends of people who die from drug overdoses exhibit a similar pattern, though not at a statistically significant level. We show in the SI that other causes of death associated with substance abuse [26] and stigma [27], deaths from liver disease and sexually transmitted diseases, were also associated with reduced recovery.

This large-scale, longitudinal study documents social network adaptations to structural trauma. We found that, on average, social networks fully recovered the volume of social interactions lost from a death. Healing occurred through connective recovery and friends were more closely connected to each other years after the shared loss. These effects were highly localized and, by and large, the increase in interactions did not extend beyond the immediate social network.

While we observed some age variation in close friends' adaptations to a death, these differences appeared to be limited to close friends ages 18-24 and, after age 24, could be explained by cause of mortality and the age of the person who died. In other words, the youngest people in these networks – conceivably those with the most fluid lives and ties – tended to contribute a disproportionate amount to connective recovery, but individuals of all ages adapted and greatly contributed to recovery when a young person died unexpectedly from an unintentional injury. These differences were not due to different

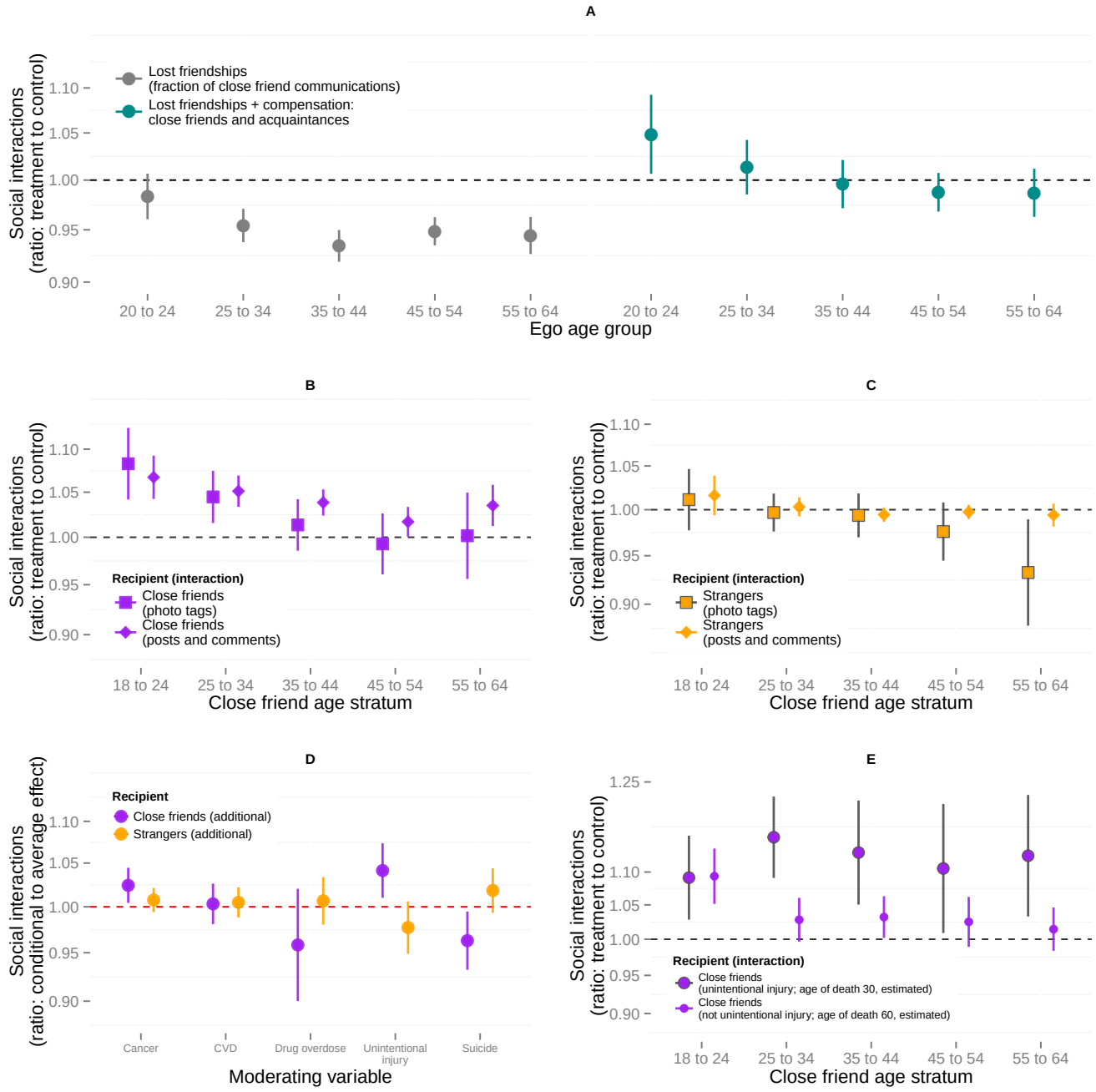

Fig. 3. *Variation in connective recovery by subject age, close friend age, interaction type, and cause of mortality.* This figure displays variation in compensatory social interactions in networks that experienced a death. Panel A shows difference-in-difference estimates of the number of interactions lost due to the death of a friend (left side), and that, on average, most networks regain their lost interactions (right side). Panel B and C separate the effects by interaction type and partner, and Panel D shows the moderating effect of cause of death (see SI). Panel E shows that responses were nearly equivalent when we control for the age of the deceased friend and whether the death was unexpected. 95% confidence intervals are point-wise and calculated with robust standard errors clustered at the ego network level.

overall levels of online activity by age. The difference-in-difference design and the multiplicative model, which estimated ratios of activity rather than absolute changes, facilitated comparisons of effect sizes between younger and older groups with different baseline levels of activity.

We leave many questions unanswered. It is likely that networks do not always adapt to a loss and network-level recovery might not translate into recovery at the individual level – notably, we were not able to evaluate both connective recovery and the subjective experience of loss here. Evidence on recovery among widows, for example, suggests that social support from friends does not often compensate for the loss of a spouse [28] and that recovery may depend on a shared loss, as widowed individuals fare better when they live close to others who have experienced the death of a spouse [29]. Furthermore,

the apparently smooth trajectories of network recovery seen here might correspond to noisier oscillations in recovery at the individual level [30]. Even with full connective recovery, the networks might have a changed "personality" and function differently than before. The strengthened and newly active friendships did not replace the deceased; while levels of connectivity were the same, the networks restructured to accomplish it.

Although we establish that online social networks recovered lost social connections after a death, it is difficult to further evaluate whether the effect sizes identified here are large or small. As a reference, the subjects sent an average of thirteen wall posts and messages and were tagged in three photos in the six-month 2011 impanel period [24]. For comparison, another large-scale Facebook study demonstrated that receiving approximately twice as many comments from close friends, compared to the average number received in the study, was linked to increases in perceived social support comparable to a major life event, such as having a baby [31]. Here, after accounting for baseline differences in activity between the two studies, increased interaction for the month of death was approximately sixty percent of that size among young adults ages 18 to 24 and thirty percent among all adults, while the long-term increase in interaction was approximately one twentieth that size. Further, these increases in interaction occurred for over twenty (median 27) close friends in the bereaved networks. This very rough comparison suggests that even small increases in online social network activity, such as the effects seen here, have the potential to be meaningful. However, as we note above, we are not able to measure the subjective experience of loss and recovery at the individual level.

Because we do not have data on offline interactions, we cannot say for certain that social support online reflected increased offline interactions. While past studies have documented similarities between online and offline interactions [20–22], there are few comparisons between online and offline interactions during grieving – ours is currently the only large-scale quantitative study of social interactions before and after a death, online or offline. Existing, largely qualitative studies on grieving document basic similarities in interactions in online social contexts compared to offline contexts, but suggest that online interactions, particularly the public and noticeable interactions with a deceased individual's social media profile, may positively or negatively alter the social support and grieving process [32–34]. It is possible, for example, that highly visible interactions online in the immediate aftermath of the loss, including posts seen on and promoted by Facebook's personalized news feed, led to more interactions than would have otherwise occurred. It is not clear whether this happened (in observational studies, the effects of the news feed are often not readily distinguishable from organic changes) or whether this phenomenon would lead to increased social support offline as well. Similarly, it's possible that young adults ages 18 to 24 grieve more publicly on social media than all other age groups, including adults aged 25 to 34, and interact after a death at levels greatly disproportionate to their pre-existing differences in online activity. In other words, young adults could 'recover' on social media more than other age groups, despite recovering offline no differently. Furthermore, our sample is drawn from a California-based sample that was active on social media in 2011 and online social support patterns could differ by region and time period.

A practical implication of these findings is that the typical social response to loss appears to happen faster than psychological diagnosis periods. While psychological maladaptation to a loss is diagnosed at fourteen months after a death [35], the findings here suggest that social interventions might take place substantially earlier. Though we don't know whether this increased connectivity translates to immediate perceptions of closeness, it suggests that the precursors to new or strengthened close friendships manifest immediately after a loss. The potential for age differences in recovery merits further study, particularly in the context of modern, aging populations.

We note two possible explanations for the quick and nearly complete recovery of social interactions that we observed. First, the compensation effects might be driven by a lower bound on individuals' level of social connection. Since individuals might have a carrying capacity in their social activity [36], we might expect them to be driven to replace lost friendships more quickly than they are driven to establish friendships in general. Importantly, however, we rule out a Facebook-specific compensation effect by showing that we do not observe a similar compensatory increase in social interaction among friends of a living individual who simply deactivated their account on Facebook (see SI).

Second, compensatory social interactions could result from bonding during crisis. The extent of recovery observed here would imply that grief responses tend to produce a level of increased social interaction that compensates for the loss of a single individual.

Finally, recovery dynamics here did not correspond to the hypothesized "five stages of loss" [37]. Instead, they were similar to patterns seen in resilient psychological responses to grief and trauma [17]. These responses to loss mathematically resemble responses to shock in small-scale biological networks. As a quantitative analog for the patterns of social recovery we observed, we highlight in Figure 5 in the SI that the dynamics here resemble patterns observed in synaptic potentiation – the set of processes that underlie learning and memory in the brain [38].

We hope that these findings spur greater interest in how social networks adapt to trauma and crisis. Better understanding of social network adaptations could help us identify why social networks succeed or fail in recovery – and how social network failures might be prevented. The findings here, we believe, are an important first step in this direction.

Materials and Methods. To conduct this study, we used Facebook data as well as public vital records from the State of California. Our study protocol was approved by four bodies: the Institutional Review Board at the University of California, San Diego; the State of California Committee for the Protection of Human Subjects; and the Vital Statistics Advisory Committee at the California Department of Public Health, and Facebook's internal review group. The UCSD institutional review board approved a waiver of informed consent for analysis of existing data. We have created an aggregate dataset that preserves data privacy, and we will make this data and replication code available to researchers who request them from the corresponding author.

The analysis is restricted to the social networks of Facebook users in California who met basic, pre-analysis criteria: They had a 'real' first and last name, birthdate between 1945 and 1989 (see SI), and at least two 'close friends' (defined below). 12,689,047 profiles fit the eligibility criteria. Once we identified the eligible population, we matched profile information (first name or nickname, last name, and date of birth) to California Department of Public Health vital records for 2012 and 2013 to ascertain whether the individual was still living, and if not, his or her cause of death. In 15,129 cases, the vital records indicated that the person died between January 2012 and December 2013. To preserve privacy, after automatically matching to public records, all analyses were performed on de-identified, aggregate data. All data were observational; no one's experience on the site was different from usual.

The focus of the study is on the close friends of deceased individuals—how their friendship connections and communication patterns changed after the death of a friend (referred to as the subject or the decedent throughout). We characterized types of friends of the subject based on their communication during an impanel period, January through June 2011. Close friends were defined as people who communicated with the subject using Facebook comments, posts, or photo tags, or if they appeared in a photo with the subject during this six-month window. We use the term "close friends" loosely to represent individuals who interacted with the subject; this likely includes both the subject's closest confidants [20, 22] as well as other less important communication partners.

We contrast these close friends with acquaintances, Facebook friends who did not communicate with the subject during the impanel period, and strangers, individuals who were not Facebook friends with the subject and did not communicate with or appear in any photos with the subject. Within the analysis sample (see Methods), the median number of close friends was 27 (25-75th percentiles: 10-69) and acquaintances (Facebook friends excluding close friends) was 64 (30 - 138). These numbers are lower than those for all Facebook users, but social connections and social media activity are typically lower in older populations. All Facebook users not in the close friend and acquaintance groups were counted as strangers (i.e. any Facebook user at two degrees of separation from the decedent). For computational reasons, we measured wall posts, comments, and photo tags of close friends who were also based in California, but *recipients* of interactions were not constrained to California.

We then counted how many different people the subject's close friends communicated with each month who were (a) other close friends of the decedent, (b) acquaintances of the decedent, and (c) strangers to the decedent. We separately counted text wall posts, comments, and photo tags, counting the number of people each of the subject's close friends directed each of those actions toward during the month. To avoid counting a small number individuals extremely heavily in our outcome measure, we did not count multiple interactions of the same type between the same two people (though, including them did not alter our results).

For each action type (wall post, comment, photo tag) and recipient type (close friend, acquaintance, stranger), we summed these monthly social interactions for all close friends in the networks. To combine the three action types of differing scales without making assumptions about their importance, we then used the geometric average of the wall post, comment, and photo tag edge sums in each network with an adjustment to account for zeroes. Per network in the analysis sample, there was a cumulative median of 113 of these monthly interactions between close friends and other close friends of the decedent (25-75th percentiles: 16-463), 87 (22-261) between close friends and acquaintances of the decedent, and 4,049 (1,117-12,041) between close friends and strangers of the decedent. Figure 6 in the SI displays the distributions of counts of close friends and acquaintances, as well as interactions between close friends and the decedents' other close friends, acquaintances, and strangers.

To ensure age and gender covariate balance in our analyses, we compared the deceased individuals to a stratified random sample of non-deceased individuals. This comparison sample contained two networks matched on age, gender, and name validation (see SI) for each network that had experienced a death. These comparison networks were randomly paired, given same age, gender, and name validation, to networks in which the central individual died. The comparison networks were assigned counterfactual dates of "death" from the paired networks. There were 30,258 social networks in this comparison sample, referred to as the "control" group to be consistent with other studies, and 15,129 networks in which the central individual died, referred to here as the "treatment" group. In total, there were 2,020,493 close friends and acquaintances in this sample, and 771,034 who experienced the death of a friend.

To further reduce confounding and ensure parallel trends in the treatment and control groups, especially unmeasured confounders related to social values, culture, and socioeconomic status, we used stabilized inverse probability regression weights. The propensity scores were estimated using a penalized regression on subject and friend characteristics (counts of subject Facebook activity, counts of close friend Facebook activity, Facebook friend self-reported education, self-reported marital status, whether they used a smartphone, and a set of 'like' space derived latent social characteristics, which we describe in the SI). This propensity score method was previously validated using an experimental baseline [39].

We used quasi-Poisson generalized estimating equations with independent working correlation to measure changes in the number of interactions between the decedent's close friends and other members of the decedent's local social network. We used a diagnostic plot of the variance to mean relationship in our data to choose quasi-Poisson over negative binomial and chose these models over Poisson due to over-dispersion in the data. The mean and variance of the treatment and control groups did not differ before the deaths. In the quasi-Poisson models, the treatment estimate was the difference-in-difference interaction between (1) whether the network includes a deceased individual, and (2) whether the time period is before or after the death. The standard errors were clustered at the ego network level. We included controls for interactions among close friends during the six-month impanel period to account for differences in network clustering at baseline, along with a control for Facebook activity outside of the local network (i.e. interactions with strangers) in models that measured interactions within the local social network (close friend interactions with other close friends and acquaintances). This online sociality control slightly attenuated the effect sizes, but helped account for changes in overall Facebook activity over time. To estimate the number of communication interactions "lost" by the death of the central subjects, we added close friends' communications sent to the central subjects' for the control group only. This allowed us to estimate the potential interactions lost in the treated compared to the control networks. We do not include wall posts, comments, and photo tags to the deceased individual's account in these models. All statistical tests are two-sided. We did not adjust for multiple comparisons in Figure 3. The tests were conducted for causes of death that were unexpected (unintentional injury) [12] and that past works have found to be strongly associated with low levels of social support (drug overdose and suicide) [24, 40–42]. With a Bonferonni correction for multiple comparisons, the p-value for the suicide estimate was 0.11. The unintentional injury estimates were robust to the Bonferroni correction.

For each of the month-by-month figures, we ran the same models, substituting a continuous variable (months from death – included as fixed effects) for the binary (pre/post death) variable. This paired sampling and model setup is very similar to the coarsened exact matching approach used by Azoulay et al. [19].

Competing Interests. William Hobbs was a Facebook research intern in 2013. Moira Burke is a Facebook employee.

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Connective Recovery in Social Networks After the Death of a Friend

William R. Hobbs, Moira K. Burke

1. Supplementary Notes

Data.

Eligible population and linking. Prior analyses of social media usage have typically restricted their focus to relatively active users (e.g. active on a specific day [1]) and/or self-reports of activity [2]. Rather than selecting on activity levels closely related to our outcome of interest, we required only that individuals 1) communicated with two or more people on the site between January and June 2011; and 2) listed a first name (or, based on a publicly available database, associated nickname) and last name independently present in the California voter record (e.g. we included users named 'Jenny' if anyone in the California voter record was named 'Jenny' or 'Jennifer'). To further confirm that users listed real names, we segmented our analyses based on whether individuals listed a combined first name (or nickname), last name, and date of birth on Facebook that was also present in the California voter record, and we omitted users who listed a January 1st birthday because this is the default value when signing up for the site. 12,689,047 profiles fit these criteria (the 'full' population), of whom 4,011,852 were present in the California voter record (the 'validated' subpopulation). This match rate of 32% is similar to the match rate reported in previous analyses of California Facebook users [1] and is consistent with the observations that 1) younger people are less likely to be registered to vote, and 2) California has the 2nd lowest voter registration rate in the United States because of its large non-citizen population. Public voting records were only used for this sample validation step; no information related to voting was part of the study.

Once we identified the eligible population, we compared first name or nickname, last name, and date of birth to California Department of Public Health vital records for 2012 and 2013 to ascertain mortality status and cause of mortality. We then linked users who were living in January 2012 to their aggregated Facebook usage (see below) for the six-month impanel period January 2011 through June 2011, as well as basic demographic information: year of birth, gender, date signed up on Facebook, highest education listed on profile, marital status listed on profile, and type of device used to access Facebook, along with the same information for all Facebook friends of the subjects. We excluded deaths that occurred in the six months prior to the impanel period so that the impanel period was less likely to include acute periods of illness and disability. All data were de-identified and aggregated after linking, and no individual activity was viewed by the researchers.

We categorized underlying causes of mortality in 17 specific categories, as well as 5 broader categories (cancer, cardiovascular disease, drug overdose, suicide, unintentional injuries), based on codes of the *International Classification of Diseases, Tenth Revision* [3]. Cause of death categorizations differ from standard categorizations seen in prior works [4] only in that there are fewer old age categories (e.g. no dedicated prostate cancer category) and more young age categories (e.g. distinguishing between drug overdoses and unintentional injuries).

Variable summaries and categorizations. In our analysis sample, the average age as of January 2011 was 49 (sd 12) and 43% listed female gender. Of those who made any social action on the website for January 2011 through June 2011, 27% used smartphone applications on iOS, Android, or Blackberry operating systems (for comparison, others have reported that 35% of Americans owned a smartphone in 2011 [5]).

The median number of close friends (including those co-tagged in a photo with the subject) was 27 (25th percentile 10, 75th percentile 69; mean 56, sd 87) and Facebook friends 64 (25th percentile 30, 75th percentile 138; mean 127, sd 232). These numbers are lower than those for all Facebook users, but note that social connections and social media activity are typically lower in older

populations.

After taking geometric means of posts, comments, and photo tags, there were a median of 113 (25th percentile 16, third quartile 463; mean 498, sd 1249) total monthly interactions between close friends and other close friends, 87 (25th percentile 22, third quartile 261; mean 278, sd 711) to acquaintances, and 4,049 (25th percentile 1,117, third quartile 12,041; mean 10,593, sd 19,041) to strangers per network. A median of 15 (25th percentile 3, 75th percentile 50; mean 35, sd 50) close friend interactions were sent to the comparison egos over the full panel.

We linked these individuals (the 'egos') to aggregate counts of the Facebook activity of their close friends (anyone who interacted with the individual using Facebook comments, wall posts, or photo tags), and separated these interactions by communication type (comment, post, photo tag), as well as whether the communications were sent to other close friends, Facebook friends who had not interacted with the egos, and strangers who were not Facebook friends and had not interacted with the egos. For technical reasons (related to our IRB approvals), we counted all interactions by month and time from death for each monthly count by days from the middle of that month. In the fixed effects models, we run fixed effects for monthly aggregates of the approximate days from death.

The counts of interactions were sums of directed indicators for whether one individual interacted with another individual in a social network in a given month (i.e. total directed edges in a network). We summed the unique close friend $\rightarrow$ close friend/acquaintance/stranger pairs in each network in a given month per interaction type. To combine different Facebook interactions while making few assumptions about their importance, we used the geometric averages of post, comment, and photo tag interactions per month as our outcome variables. To account for zeroes, we added one to each count before taking the geometric mean and subtracted one again after taking the average.

We distinguished text-based interactions (wall posts and comments) from photo-based interactions (photo tags). The photo tags were more likely to reflect strong ties [6] and, because they are based on photos, offline interactions. This categorization correspond to loadings on major variance dimensions in a principal component analysis [7] of subject Facebook activities in the observation period. Loadings (i.e. transformation coefficients) in Figure 7 are the eigenvectors of our sample's Facebook activity covariance matrix and they can be multiplied by the original activity counts to produce a transformation of the data which preserves correlated information in a smaller number of composite, orthogonal variables. The eigenvector corresponding to the leading eigenvalue contains each variable's contribution to the matrix's largest variance component (and the eigenvector correponding to the nth largest eigenvalue is each variable's contribution to the nth largest variance component). In the principal component analysis here, we $log(x+1)$ and scale each variable by its standard deviation and then center at zero.

The first component (i.e. the largest variance component, accounting for 70% of the proportion of variance explained) in this principal component analysis is overall activity (not shown because it is similar for all activity variables), the second is undirected/outgoing activity versus incoming activity (including network size – this component explains 7% of the variance), and the third is text-based versus photo-based activity (5% of the variance). In other words, it appears that users vary primarily in their level of activity, the extent to which the send or receive interactions, and the extent to which they use photos or text to interact with others on the site.

2. Supplementary Methods

Matching and controls. The general Facebook population was younger than the population of individuals who died. Therefore, we created a comparison dataset matched on year of birth, gender, and name validation (full name and date of birth present in the California voter record) so that our full sample was composed of two California Facebook users for each deceased California Facebook user and was perfectly balanced on these covariates.

Propensity scores. Propensity scores were estimated using an logit link elastic net penalized regression [8] on network characteristics (counts of subject Facebook activity, counts of close friend Facebook activity, Facebook friend self-reported education, self-reported marital status, whether they used a smartphone, and a set of 'like' space derived latent social characteristics) with α set to 0.99 (i.e. very close to LASSO) and λ set by cross-validation. Penalized regression avoids over-fitting in models including many independent variables.

This propensity score method was validated using an experimental baseline by Eckles and Bakshy [9]. Ours differs from their approach by using a penalty close to the l1 norm, including like behaviors of friends, and by reducing the dimensions of the network average 'like' space prior to inclusion in the model, thus reducing the number of like-based predictors from 1,556 to 100 variables. This pre-processed dimensionality reduction is similar to a ridge regression [10] on the full 'like' variables, as implemented by Eckles and Bakshy, but allows us to describe the major variance components of the input variables. We note that while Eckles and Bakshy stratified their models on the propensity scores (so that their estimates depended on only prediction rank), the treatment and control groups here, after sampling to balance on age and gender, are much less imbalanced than their sample.

Subject networks received stabilized weights of $(P(treated))/(p_i(treated))$ and the stabilized weights for controls were $(1-P(treated))/(1-p_i(treated)))$, where $P(treated)$ is the overall probability of a death in our sample and $p_i(treated)$ is an individual's predicted probability. Figure 8 shows estimates with and without these weights.

Comparison networks were randomly paired, given same age, gender, and name validation, to networks in which the central individual died. The comparison networks were assigned counterfactual dates of "death" from the paired networks.

Like space dimensions. To construct our 'like' space measure of latent social characteristics, we decomposed an affiliation matrix of likes of popular Facebook page content. We selected the top 1,000 pages for each month January through June 2011 and used the likes of all California based Facebook users over this period to construct the affiliation matrix. To reduce skew in our matrix, we applied a count normalization (the square root) prior to normalizing to the Laplacian matrix. This additional normalization produced interpretable dimensions and slightly improved predictions in the propensity score models. We ran a singular value decomposition on a normalized Laplacian of this affiliation matrix to estimate 'ideal points' in the Facebook like space, and then took the average of these ideal points per individual. Once we obtained these like space ideal points per individual, we then further averaged the ideal points of Facebook friends for each subject in our study.

The singular value decomposition of the matrix normalized Laplacian returned dimensions corresponding to major sources of homophily and distance in social networks. The first dimension of this decomposition was the eigenvector centrality of a Facebook page (34% variance) and the subsequent dimensions described like polarization by language (15%), age (8% variance), social values (7% variance), race/ethnicity (5% variance), and gender (4% variance). A similar scaling method on political page likes (producing a liberal-conservative dimension highly correlated with our 'social values' dimension) was validated by Bond and Messing [11].

Imputation. Because a small number (4.6%) of social networks contained no individuals who had liked pages, we imputed missing values using multivariate imputations by chained equations [12]. Because the imputation was used only for the propensity score estimation, we used single imputation and used all variables in the imputation models that would be later used in constructing the propensity scores.

Statistical models. We used quasi-Poisson generalized estimating equations with independent working correlation. Our estimating equation relates counts of interactions in the ego social network i at month t from our observation period:

$$E[y_{it}|X_{it}] = exp[\beta_0 + \beta_1 ln(y_{it_0}) + \beta_2 ln(t) + \beta_3 post_t + \beta_4 D_i + \beta_5 post_t * D_i],$$

where y_{it} is the number of interactions in the local social network (a geometric average if the outcome is a composite of different types of Facebook interactions), $ln(y_{it_0})$ is the monthly average count of interactions in the observation period, t is the number of months from the observation period, $post_t$ is an indicator variable indicating post-treatment period (regardless of treatment status), and D_i is an indicator for treatment status (both before and after treatment). Because comparison networks were assigned a counterfactual date of death, our treatment estimate is the interaction $post_t * D_i$ (estimate β_5).

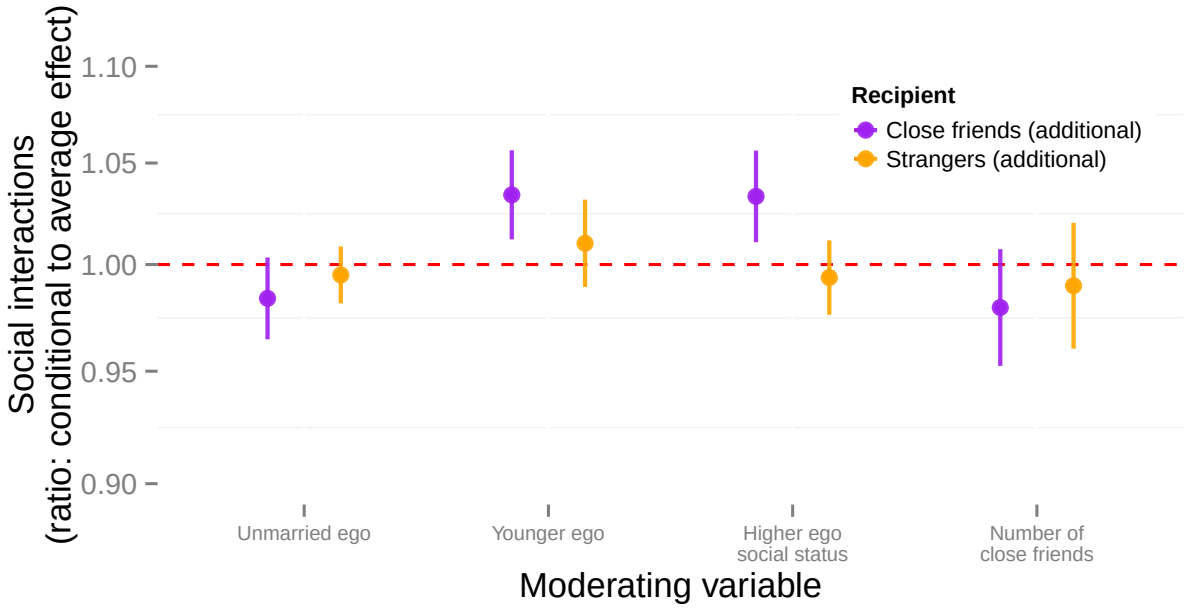
For models measuring the counts of interactions from close friends to close friends and close friends to acquaintances, we added controls for counts of interactions sent from close friends to others outside the network:

$$E[y_{it}|X_{it}] = exp[... + \beta_6 ln(s_{it_0}) + \beta_7 ln(s_{it})...],$$

This added control slightly attenuated our effect sizes, but increased the precision of our compensation estimates. Figure 8 shows estimates with and without this control. In our moderation analyses, we stratified our estimates based on the age of close friends. These stratified analyses measure social network responses of close friends by age regardless of the age of the recipients of their interactions. In cause-by-cause analyses, we stratified our models based on the age of death of the central individuals, using the age of death groups presented in our main results.

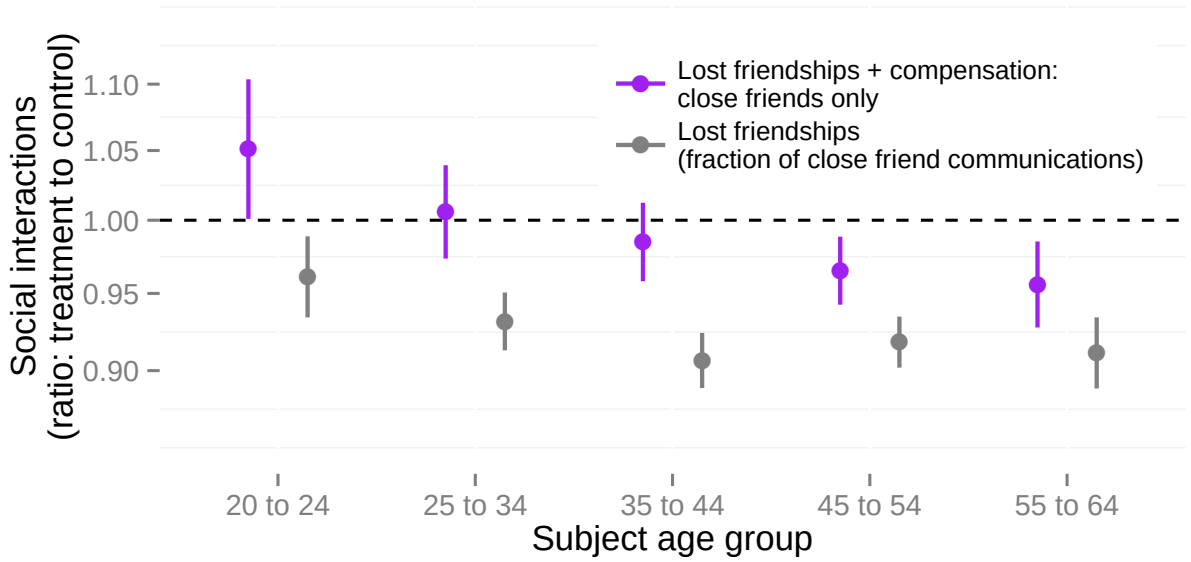
3. Supplementary Figures

Moderating variables (other).



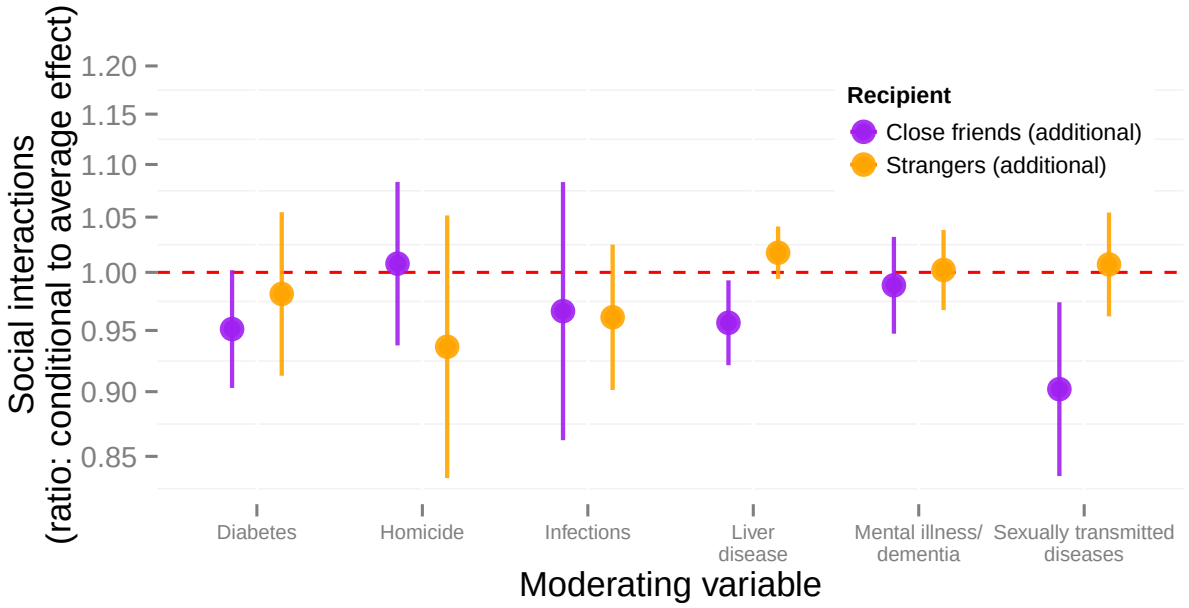
Supplementary Figure 1. *Variation by marital status, age, social status, and number of close friends.* This figure displays variation in social interaction effects by marital status, age, our measure of social status (number of sent and accepted Facebook friendships minus number of received and accepted Facebook friends), and number of close friends. We estimate this variation by interacting moderating variables with the difference in difference variable Deceased:After death. The model included interactions for causes of death considered in the main text (cancer, cardiovascular disease, drug overdose, suicide, and unintentional injury).

Compensation within close friend network.



Supplementary Figure 2. *Compensation effect, close friend network only.* Percent friendships recovered is the lost friendship coefficient divided by the compensation coefficient. Shown here, this is the purple (lost + compensation) estimate minus black (lost) estimate divided by black (lost) estimate.

Compensation effects – additional causes of death.

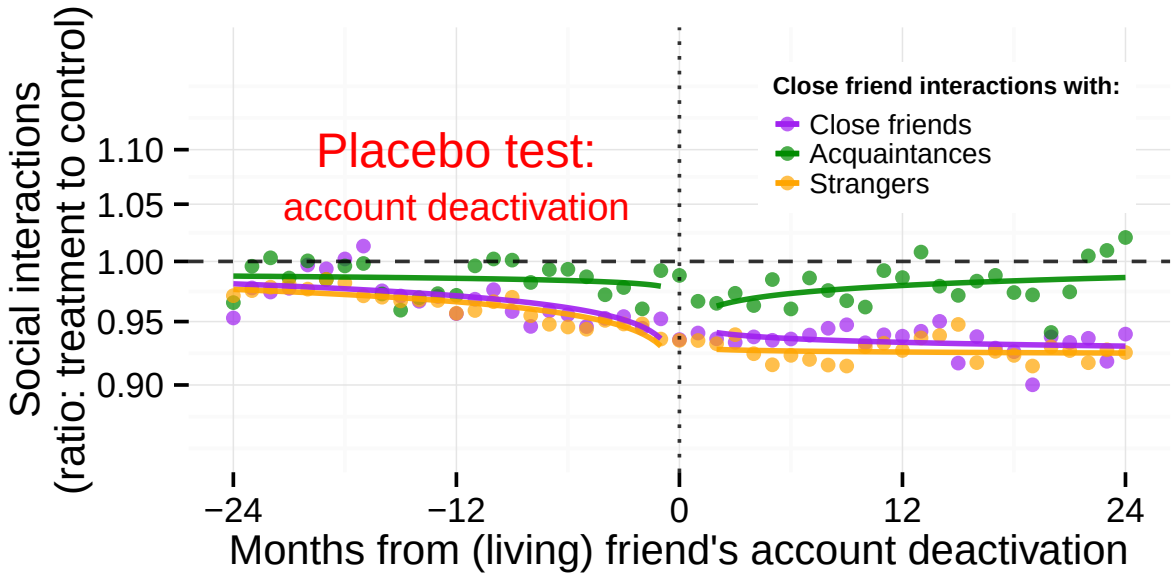


Supplementary Figure 3. *Compensation effects – additional causes of death.* This figure displays additional effects (on top of the average compensation) for moderating cause of death variables in interaction models.

Association between user account deactivation and close friends' social activity. To evaluate whether the increase in social interactions among the friends of a deceased Facebook user were driven by people simply maintaining a constant level of Facebook use, we tested whether we observe the same compensatory increase in social interactions after a living user deactivated his or her account.

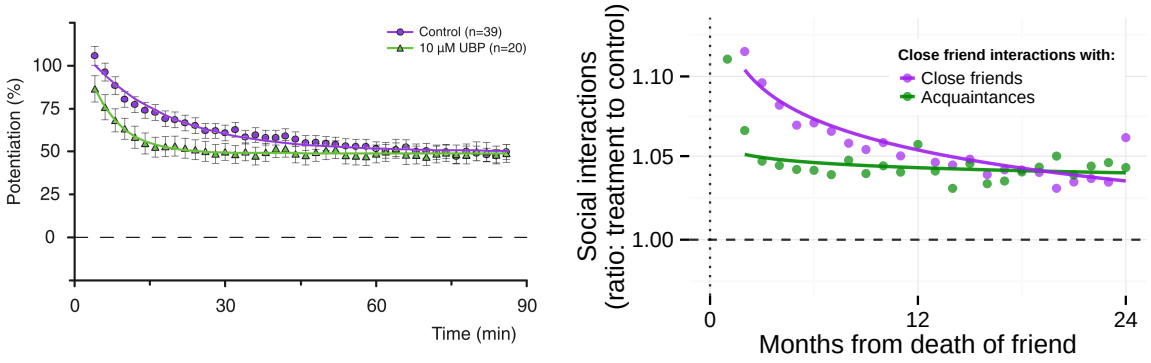
For this account deactivation test, the central individuals in the treatment networks were presumably still a part of their offline social networks. If Facebook use simply reflects offline activity (or if the compensation effects are driven by a grief response), then we should see no increase in the interaction volume in an online social network surrounding a deactivated account. For this analysis, we used the same methods as used in our main tests, replacing "deceased" with "deactivated account", as well as "date of death" with "date of deactivation", in all of our models.

We show in Figure 4 that we observe no sudden increase in social interactions among the friends of a person who has deactivated their Facebook account. Instead, we see that account deactivation tends to correspond to declining levels of Facebook use in a social network.



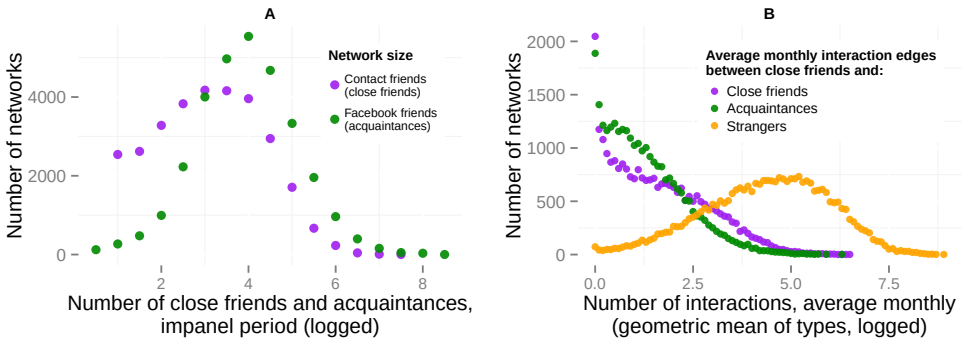
Supplementary Figure 4. *Effect of account deactivation on social interactions in surrounding friend network.*

Comparison of Social Network Adaptation and Neuronal Plasticity.

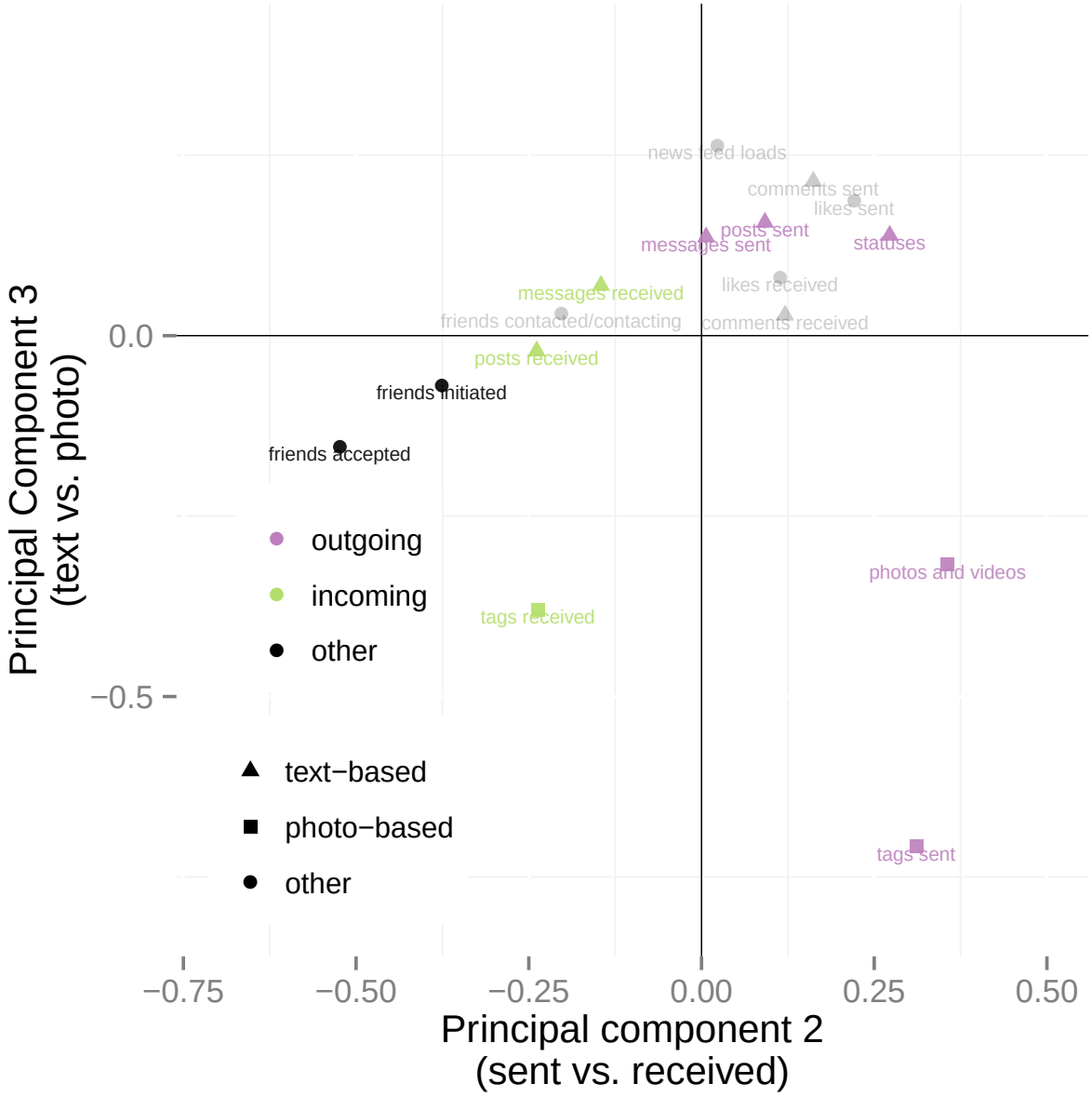


Supplementary Figure 5. *Comparison of synaptic potentiation and social network "plasticity effects".* Human network recovery was not reflected in a single, exponential decline of social interaction over the grieving period (commonly observed in network responses to crisis) or in a five-stage process of emotional recovery. Instead, we observed a separable, two pattern decline in social interaction, one pattern declines rapidly in the first few months after a death and another declines over the first year, on top of a stable increase in social interaction. These responses mathematically resemble patterns of synaptic potentiation in the brain. Panel A displays short-term potentiation and long- term potentiation in hippocampus synapses, the set of processes thought to underlie learning and memory [13]. The green line displays potentiation without the slow decline present in the purple line. This figure is adapted, with permission, from Volianskis et al. [14] / CC BY 4.0. Panel B displays the three pattern response in our study. The purple displays all patterns of recovery, while the green line exhibits only the first rapid decline (more visible in Figure 2) and the long-term increase in interaction.

Variable summaries and categorizations.

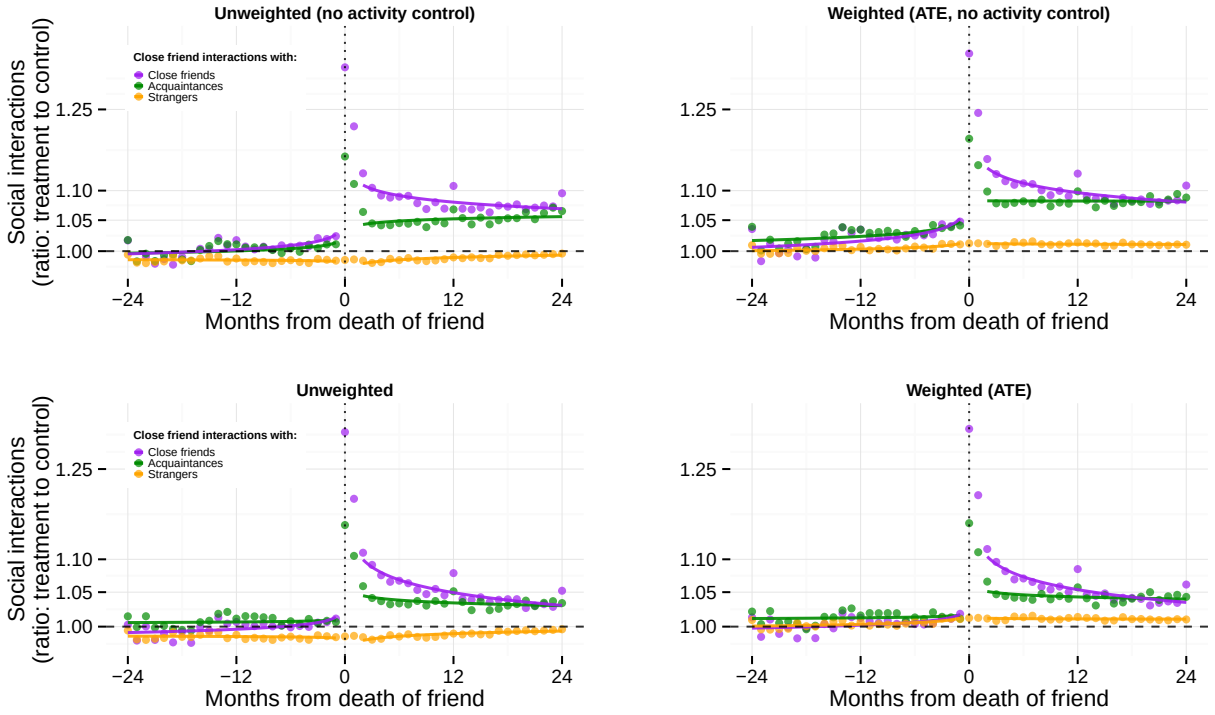


Supplementary Figure 6. *Distributions of network sizes and average monthly "activated" ties.*



Supplementary Figure 7. *Principal component analysis of common Facebook activities.* This figure shows the second and third components of a principal component analysis on major Facebook activities. The first component (not shown) is the overall level of activity, and the activities of interest do not clearly differ on it (see 12). The second component corresponds to sent versus received messages, and the third component corresponds to text versus photo activities.

Propensity scores.



Supplementary Figure 8. *Changes in social interactions following the death of a friend, showing weighted and unweighted data.* Most balance improvement occurred in the pre-sampling stage, where treatment and control networks were matched exactly on age, gender, and name validation. After this pre-sampling, inverse stabilized weights using high-dimensional propensity scores decreased pre-death differences between treatment and control groups primarily in overall social interactions on Facebook (orange line). Controlling for overall activity, there was little difference between unweighted and weighted estimates of crisis response and compensation effects (purple and green lines).

4. Supplementary Tables

Overall estimates.

	Close friends	Acquaintances	Strangers
(Intercept)	1.149	0.831	4.362
	(0.005)	(0.004)	(0.005)
	0.000	*0.000*	*0.000*
Close friend interactions (impanel)	1.282		
	(0.008)		
	0.000		
Stranger interactions (impanel)	-1.406	-1.290	1.678
	(0.016)	(0.015)	(0.005)
	0.000	*0.000*	*0.000*
Stranger interactions	1.724	1.611	
	(0.018)	(0.015)	
	0.000	*0.000*	
Deceased	0.004	0.013	0.004
	(0.005)	(0.005)	(0.004)
	0.417	*0.016*	*0.320*
After death	-0.232	-0.197	-0.069
	(0.003)	(0.003)	(0.003)
	0.000	*0.000*	*0.000*
Deceased:After death	0.045	0.026	0.005
	(0.006)	(0.005)	(0.006)
	0.000	*0.000*	*0.369*
Acquaintance interactions (impanel)		1.058	
		(0.004)	
		0.000	
Observations	2,043,837	2,043,837	2,043,837

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 1. Overall estimates

Crisis-response slope models.

	Close friends	Acquaintances	Close friends, control acquaintances
(Intercept)	1.204	0.880	1.248
	(0.006)	(0.005)	(0.005)
	0.000	*0.000*	*0.000*
Close friend interactions (impanel)	1.282		1.460
	(0.008)		(0.005)
	0.000		*0.000*
Stranger interactions (impanel)	-1.419	-1.298	
	(0.016)	(0.015)	
	0.000	*0.000*	
Stranger interactions	1.737	1.619	
	(0.018)	(0.015)	
	0.000	*0.000*	
Deceased	0.001	0.010	0.001
	(0.006)	(0.007)	(0.007)
	0.904	*0.154*	*0.853*
After death	-0.339	-0.291	-0.192
	(0.005)	(0.005)	(0.006)
	0.000	*0.000*	*0.000*
Months from death (centered at 18)	0.060	0.053	0.046
	(0.002)	(0.002)	(0.002)
	0.000	*0.000*	*0.000*
Deceased:After death	0.032	0.024	0.022
	(0.009)	(0.009)	(0.009)
	0.000	*0.011*	*0.020*
Deceased:Months from death	-0.004	-0.004	-0.003
	(0.004)	(0.004)	(0.004)
	0.230	*0.298*	*0.447*
After death:Months from death	-0.146	-0.128	-0.067
	(0.003)	(0.003)	(0.003)
	0.000	*0.000*	*0.000*
Deceased:After death:Months from death	-0.022	-0.005	-0.019
	(0.005)	(0.006)	(0.006)
	0.000	*0.432*	*0.001*
Acquaintance interactions (impanel)		1.058	-0.725
		(0.004)	(0.008)
		0.000	*0.000*
Acquaintance interactions			0.685
			(0.008)
			0.000
Observations	2,043,837	2,043,837	2,043,837

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 2. Crisis-response slope models

Models included in Figure 3.

	20 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	2.755	2.488	2.168	1.738	1.342
	(0.013)	(0.010)	(0.008)	(0.006)	(0.007)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Close friend, acquaintance, and subject interactions (impanel)	1.369	1.333	1.312	1.239	1.166
	(0.025)	(0.019)	(0.016)	(0.015)	(0.012)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions (impanel)	-1.845	-1.528	-1.228	-1.087	-0.959
	(0.041)	(0.039)	(0.039)	(0.031)	(0.026)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions	2.082	1.742	1.533	1.367	1.200
	(0.032)	(0.041)	(0.045)	(0.042)	(0.029)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased	-0.017	-0.047	-0.068	-0.053	-0.057
	(0.012)	(0.009)	(0.008)	(0.007)	(0.010)
	0.161	*0.000*	*0.000*	*0.000*	*0.000*
After death	-0.272	-0.262	-0.233	-0.206	-0.185
	(0.012)	(0.008)	(0.006)	(0.005)	(0.005)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased:After death	0.064	0.060	0.064	0.040	0.044
	(0.018)	(0.013)	(0.010)	(0.009)	(0.010)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Observations	79,572	218,586	324,804	596,844	761,904

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 3. Figure 3, Panel A

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	-0.375	0.023	-0.267	-0.711	-1.492
	(0.011)	(0.009)	(0.010)	(0.012)	(0.023)
	0.000	*0.014*	*0.000*	*0.000*	*0.000*
Close friend interactions 18 to 24 (tags, impanel)	0.675				
	(0.011)				
	0.000				
Stranger interactions 18 to 24 (tags, impanel)	-0.526				
	(0.013)				
	0.000				
Stranger interactions 18 to 24 (tags)	0.988				
	(0.009)				
	0.000				
Deceased	-0.004	0.006	0.013	0.015	-0.018
	(0.017)	(0.011)	(0.014)	(0.020)	(0.037)
	0.827	*0.574*	*0.360*	*0.445*	*0.623*
After death	-0.368	-0.227	-0.135	-0.086	-0.062
	(0.011)	(0.008)	(0.007)	(0.008)	(0.013)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased:After death	0.080	0.044	0.013	-0.007	0.002
	(0.020)	(0.014)	(0.014)	(0.017)	(0.024)
	0.000	*0.002*	*0.349*	*0.669*	*0.945*
Close friend interactions 25 to 34 (tags, impanel)		0.761			
		(0.010)			
		0.000			
Stranger interactions 25 to 34 (tags, impanel)		-0.534			
		(0.011)			
		0.000			
Stranger interactions 25 to 34 (tags)		0.943			
		(0.008)			
		0.000			
Close friend interactions 35 to 44 (tags, impanel)			0.691		
			(0.010)		
			0.000		
Stranger interactions 35 to 44 (tags, impanel)			-0.481		
			(0.012)		
			0.000		
Stranger interactions 35 to 44 (tags)			0.971		
			(0.010)		
			0.000		
Close friend interactions 45 to 54 (tags, impanel)				0.623	
				(0.010)	
				0.000	
Stranger interactions 45 to 54 (tags, impanel)				-0.465	
				(0.014)	
				0.000	
Stranger interactions 45 to 54 (tags)				0.982	
				(0.010)	
				0.000	
Close friend interactions 55 to 64 (tags, impanel)					0.457
					(0.016)
					0.000
Stranger interactions 55 to 64 (tags, impanel)					-0.418
					(0.016)
					0.000
Stranger interactions 55 to 64 (tags)					0.936
					(0.010)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 4. Figure 3, Panel B

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	0.323	0.864	0.878	0.824	0.477
	(0.009)	(0.006)	(0.005)	(0.009)	(0.017)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Close friend interactions 18 to 24 (posts and comments, impanel)	1.065				
	(0.009)				
	0.000				
Stranger interactions 18 to 24 (posts and comments, impanel)	-1.073				
	(0.016)				
	0.000				
Stranger interactions 18 to 24 (posts and comments)	1.387				
	(0.018)				
	0.000				
Deceased	0.008	0.006	-0.003	-0.009	-0.026
	(0.008)	(0.007)	(0.007)	(0.009)	(0.020)
	0.310	*0.399*	*0.629*	*0.359*	*0.176*
After death	-0.337	-0.299	-0.232	-0.183	-0.159
	(0.008)	(0.004)	(0.004)	(0.004)	(0.005)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased:After death	0.065	0.050	0.038	0.017	0.034
	(0.012)	(0.009)	(0.007)	(0.008)	(0.011)
	0.000	*0.000*	*0.000*	*0.041*	*0.003*
Close friend interactions 25 to 34 (posts and comments, impanel)		1.141			
		(0.007)			
		0.000			
Stranger interactions 25 to 34 (posts and comments, impanel)		-0.933			
		(0.012)			
		0.000			
Stranger interactions 25 to 34 (posts and comments)		1.148			
		(0.013)			
		0.000			
Close friend interactions 35 to 44 (posts and comments, impanel)			1.094		
			(0.006)		
			0.000		
Stranger interactions 35 to 44 (posts and comments, impanel)			-0.741		
			(0.010)		
			0.000		
Stranger interactions 35 to 44 (posts and comments)			0.984		
			(0.010)		
			0.000		
Close friend interactions 45 to 54 (posts and comments, impanel)				1.059	
				(0.008)	
				0.000	
Stranger interactions 45 to 54 (posts and comments, impanel)				-0.699	
				(0.010)	
				0.000	
Stranger interactions 45 to 54 (posts and comments)				0.927	
				(0.011)	
				0.000	
Close friend interactions 55 to 64 (posts and comments, impanel)					0.901
					(0.012)
					0.000
Stranger interactions 55 to 64 (posts and comments, impanel)					-0.678
					(0.013)
					0.000
Stranger interactions 55 to 64 (posts and comments)					0.917
					(0.014)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 5. Figure 3, Panel B

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	2.314	2.595	2.453	2.109	1.163
	(0.014)	(0.008)	(0.012)	(0.012)	(0.019)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions 18 to 24 (tags, impanel)	1.321				
	(0.012)				
	0.000				
Deceased	-0.008	-0.010	-0.024	-0.006	0.062
	(0.017)	(0.010)	(0.012)	(0.018)	(0.031)
	0.618	*0.319*	*0.038*	*0.728*	*0.048*
After death	-0.366	-0.029	0.146	0.142	0.199
	(0.011)	(0.007)	(0.007)	(0.009)	(0.016)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased:After death	0.011	-0.003	-0.006	-0.024	-0.070
	(0.017)	(0.011)	(0.013)	(0.017)	(0.030)
	0.521	*0.770*	*0.611*	*0.141*	*0.021*
Stranger interactions 25 to 34 (tags, impanel)		1.324			
		(0.006)			
		0.000			
Stranger interactions 35 to 44 (tags, impanel)			1.301		
			(0.010)		
			0.000		
Stranger interactions 45 to 54 (tags, impanel)				1.214	
				(0.010)	
				0.000	
Stranger interactions 55 to 64 (tags, impanel)					1.019
					(0.013)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 6. Figure 3, Panel C

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	3.782	4.162	4.188	4.032	3.384
	(0.006)	(0.004)	(0.003)	(0.003)	(0.005)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions 18 to 24 (posts and comments, impanel)	1.369				
	(0.004)				
	0.000				
Deceased	-0.005	0.006	-0.001	0.003	0.007
	(0.006)	(0.004)	(0.004)	(0.004)	(0.006)
	0.422	*0.147*	*0.718*	*0.407*	*0.283*
After death	-0.523	-0.162	0.013	0.094	0.169
	(0.006)	(0.003)	(0.002)	(0.002)	(0.003)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased:After death	0.016	0.003	-0.006	-0.002	-0.006
	(0.011)	(0.005)	(0.004)	(0.004)	(0.007)
	0.157	*0.555*	*0.180*	*0.540*	*0.363*
Stranger interactions 25 to 34 (posts and comments, impanel)		1.350			
		(0.003)			
		0.000			
Stranger interactions 35 to 44 (posts and comments, impanel)			1.380		
			(0.002)		
			0.000		
Stranger interactions 45 to 54 (posts and comments, impanel)				1.398	
				(0.002)	
				0.000	
Stranger interactions 55 to 64 (posts and comments, impanel)					1.338
					(0.004)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 7. Figure 3, Panel C

	Unintentional injury	Suicide	Cancer	CVD	Drug overdose
(Intercept)	1.225	1.225	1.224	1.224	1.226
	(0.021)	(0.021)	(0.022)	(0.022)	(0.022)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Close friend interactions (impanel)	1.220	1.221	1.222	1.222	1.222
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions (impanel)	-1.952	-1.950	-1.950	-1.952	-1.953
	(0.045)	(0.046)	(0.046)	(0.046)	(0.046)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions	2.300	2.299	2.296	2.298	2.299
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased	0.018	0.026	0.018	0.023	0.026
	(0.014)	(0.013)	(0.014)	(0.013)	(0.013)
	0.196	*0.058*	*0.180*	*0.095*	*0.050*
After death	-0.247	-0.248	-0.248	-0.248	-0.247
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Unintentional injury	0.010				
	(0.012)				
	0.375				
Deceased:After death	0.066	0.085	0.075	0.079	0.084
	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)
	0.002	*0.000*	*0.000*	*0.000*	*0.000*
After death:Unintentional injury	0.040				
	(0.016)				
	0.009				
Suicide		-0.040			
		(0.015)			
		0.006			
After death:Suicide		-0.038			
		(0.017)			
		0.023			
Cancer			0.021		
			(0.009)		
			0.028		
After death:Cancer			0.024		
			(0.010)		
			0.017		
Cardiovascular disease				-0.008	
				(0.010)	
				0.403	
After death:Cardiovascular disease				0.003	
				(0.012)	
				0.778	
Drug overdose					-0.043
					(0.012)
					0.001
After death:Drug overdose					-0.043
					(0.032)
					0.183
Observations	2,043,837	2,043,837	2,043,837	2,043,837	2,043,837

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 8. Figure 3, Panel D. Stratified on age. 18 to 24 age group coefficients shown.

	Unintentional injury	Suicide	Cancer	CVD	Drug overdose
(Intercept)	4.291	4.291	4.291	4.291	4.292
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Stranger interactions (impanel)	1.644	1.645	1.644	1.644	1.644
	(0.019)	(0.018)	(0.018)	(0.019)	(0.019)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased	0.002	0.002	-0.002	0.004	0.006
	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)
	0.904	*0.865*	*0.876*	*0.768*	*0.643*
After death	-0.446	-0.446	-0.446	-0.446	-0.446
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Unintentional injury	0.004				
	(0.009)				
	0.701				
Deceased:After death	0.021	0.011	0.014	0.014	0.013
	(0.026)	(0.025)	(0.025)	(0.025)	(0.025)
	0.417	*0.654*	*0.584*	*0.577*	*0.596*
After death:Unintentional injury	-0.023				
	(0.015)				
	0.121				
Suicide		0.004			
		(0.009)			
		0.627			
After death:Suicide		0.018			
		(0.013)			
		0.151			
Cancer			0.026		
			(0.006)		
			0.000		
After death:Cancer			0.008		
			(0.007)		
			0.277		
Cardiovascular disease				-0.018	
				(0.007)	
				0.008	
After death:Cardiovascular disease				0.005	
				(0.009)	
				0.571	
Drug overdose					-0.027
					(0.011)
					0.013
After death:Drug overdose					0.007
					(0.014)
					0.627
Observations	2,043,837	2,043,837	2,043,837	2,043,837	2,043,837

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 9. Figure 3, Panel D. Stratified on age. 18 to 24 age group coefficients shown.

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	-0.103	0.460	0.463	0.471	0.076
	(0.018)	(0.016)	(0.019)	(0.020)	(0.021)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Close friend interactions 18 to 24 (impanel)	0.074				
	(0.008)				
	0.000				
Stranger interactions 18 to 24 (impanel)	-0.062				
	(0.008)				
	0.000				
Stranger interactions 18 to 24	1.523				
	(0.016)				
	0.000				
After death	-0.246	-0.267	-0.245	-0.207	-0.187
	(0.010)	(0.010)	(0.010)	(0.012)	(0.015)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Deceased (not unintentional injury)	-0.076	-0.051	-0.021	-0.005	-0.020
	(0.046)	(0.046)	(0.048)	(0.072)	(0.081)
	0.099	*0.263*	*0.659*	*0.941*	*0.804*
Deceased	0.052	0.033	0.012	0.048	-0.016
	(0.044)	(0.042)	(0.047)	(0.067)	(0.078)
	0.233	*0.424*	*0.796*	*0.468*	*0.834*
Age (centered at 30)	-0.001	0.009	-0.069	-0.185	-0.110
	(0.012)	(0.015)	(0.014)	(0.017)	(0.021)
	0.953	*0.530*	*0.000*	*0.000*	*0.000*
Deceased (not unintentional injury):After death	-0.008	-0.106	-0.087	-0.062	0.013
	(0.032)	(0.031)	(0.037)	(0.046)	(0.039)
	0.796	*0.001*	*0.019*	*0.176*	*0.747*
Deceased:After death	0.087	0.145	0.123	0.100	0.118
	(0.030)	(0.029)	(0.038)	(0.047)	(0.044)
	0.004	*0.000*	*0.001*	*0.032*	*0.007*
Deceased:Age (centered at 30)	-0.012	0.030	0.010	-0.040	0.013
	(0.015)	(0.027)	(0.028)	(0.034)	(0.042)
	0.442	*0.275*	*0.721*	*0.237*	*0.762*
After death:Age (centered at 30)	0.096	0.067	0.018	0.003	-0.037
	(0.008)	(0.010)	(0.011)	(0.012)	(0.015)
	0.000	*0.000*	*0.092*	*0.774*	*0.015*
Deceased:After death:Age (centered at 30)	0.008	-0.009	-0.003	-0.011	-0.099
	(0.012)	(0.021)	(0.021)	(0.022)	(0.029)
	0.511	*0.681*	*0.880*	*0.603*	*0.001*
Close friend interactions 25 to 34 (impanel)		0.093			
		(0.011)			
		0.000			
Stranger interactions 25 to 34 (impanel)		-0.094			
		(0.015)			
		0.000			
Stranger interactions 25 to 34		1.514			
		(0.015)			
		0.000			
Close friend interactions 35 to 44 (impanel)			0.106		
			(0.013)		
			0.000		
Stranger interactions 35 to 44 (impanel)			-0.128		
			(0.009)		
			0.000		
Stranger interactions 35 to 44			1.561		
			(0.028)		
			0.000		
Close friend interactions 45 to 54 (impanel)				0.096	
				(0.010)	
				0.000	
Stranger interactions 45 to 54 (impanel)				-0.101	
				(0.015)	
				0.000	
Stranger interactions 45 to 54				1.453	
				(0.038)	
				0.000	
Close friend interactions 55 to 64 (impanel)					0.144
					(0.015)
					0.000
Stranger interactions 55 to 64 (impanel)					-0.200
					(0.023)
					0.000
Stranger interactions 55 to 64					1.281
					(0.018)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 10. Figure 3, Panel E

	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64
(Intercept)	-0.104	0.472	0.376	0.245	-0.053
	(0.017)	(0.014)	(0.016)	(0.015)	(0.014)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Close friend interactions 18 to 24 (impanel)	0.074				
	(0.008)				
	0.000				
Stranger interactions 18 to 24 (impanel)	-0.062				
	(0.008)				
	0.000				
Stranger interactions 18 to 24	1.523				
	(0.016)				
	0.000				
After death	-0.125	-0.183	-0.222	-0.203	-0.231
	(0.013)	(0.008)	(0.008)	(0.010)	(0.009)
	0.000	*0.000*	*0.000*	*0.000*	*0.000*
Unintentional injury	0.076	0.051	0.021	0.005	0.020
	(0.046)	(0.046)	(0.048)	(0.072)	(0.081)
	0.099	*0.263*	*0.659*	*0.941*	*0.804*
Deceased	-0.039	0.020	0.003	-0.005	-0.021
	(0.025)	(0.022)	(0.022)	(0.032)	(0.025)
	0.114	*0.374*	*0.876*	*0.863*	*0.393*
Age (centered at 60)	-0.001	0.008	-0.053	-0.127	-0.064
	(0.011)	(0.013)	(0.011)	(0.011)	(0.013)
	0.953	*0.530*	*0.000*	*0.000*	*0.000*
After death:Unintentional injury	0.008	0.106	0.087	0.062	-0.013
	(0.032)	(0.031)	(0.037)	(0.046)	(0.039)
	0.796	*0.001*	*0.019*	*0.176*	*0.747*
Deceased:After death	0.089	0.028	0.031	0.025	0.014
	(0.020)	(0.016)	(0.015)	(0.018)	(0.016)
	0.000	*0.081*	*0.037*	*0.173*	*0.364*
Deceased:Age (centered at 60)	-0.011	0.026	0.008	-0.027	0.007
	(0.015)	(0.023)	(0.021)	(0.023)	(0.025)
	0.442	*0.275*	*0.721*	*0.237*	*0.762*
After death:Age (centered at 60)	0.092	0.058	0.014	0.002	-0.022
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
	0.000	*0.000*	*0.092*	*0.774*	*0.015*
Deceased:After death:Age (centered at 60)	0.008	-0.007	-0.002	-0.008	-0.058
	(0.012)	(0.018)	(0.017)	(0.015)	(0.017)
	0.511	*0.681*	*0.880*	*0.603*	*0.001*
Close friend interactions 25 to 34 (impanel)		0.093			
		(0.011)			
		0.000			
Stranger interactions 25 to 34 (impanel)		-0.094			
		(0.015)			
		0.000			
Stranger interactions 25 to 34		1.514			
		(0.015)			
		0.000			
Close friend interactions 35 to 44 (impanel)			0.106		
			(0.013)		
			0.000		
Stranger interactions 35 to 44 (impanel)			-0.128		
			(0.009)		
			0.000		
Stranger interactions 35 to 44			1.561		
			(0.028)		
			0.000		
Close friend interactions 45 to 54 (impanel)				0.096	
				(0.010)	
				0.000	
Stranger interactions 45 to 54 (impanel)				-0.101	
				(0.015)	
				0.000	
Stranger interactions 45 to 54				1.453	
				(0.038)	
				0.000	
Close friend interactions 55 to 64 (impanel)					0.144
					(0.015)
					0.000
Stranger interactions 55 to 64 (impanel)					-0.200
					(0.023)
					0.000
Stranger interactions 55 to 64					1.281
					(0.018)
					0.000
Observations	1,065,480	1,338,566	1,329,977	1,279,195	1,011,755

Note: Excludes observations less than two months from death. Robust standard errors shown in parentheses and p-values in italics. Continuous variables logged, scaled by standard deviation, and centered at logged mean, unless otherwise noted. "Impanel" variables are means over the January through June 2011 impanel period.

Supplementary Table 11. Figure 3, Panel E

Variable summaries and categorizations.

Facebook activity	PC1 (volume)
tags sent	0.19
friends accepted	0.21
tags received	0.22
photos and videos	0.23
friends initiated	0.23
posts received	0.24
news feed loads	0.25
statuses	0.25
posts sent	0.25
likes sent	0.26
messages sent	0.26
messages received	0.27
comments sent	0.27
friends contacted/contacting	0.28
comments received	0.28
likes received	0.28

Supplementary Table 12. *Principal component analysis of common Facebook activities (PC1).* This table shows the first component of a principal component analysis on major Facebook activities.

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