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Semantic Network News Sentiment Predictors of Changes in Mobile Telephone Ego
Networks in a National Political and Civil Post-Crisis Period

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Paper submitted for the International Communication Association 2014 Preconference: Social
and Semantic Networks in Communication Research. May 22, 2014, Seattle, WA.

- The author is grateful to Richard Weeks for data curating and programming

ABSTRACT

Linking media semantic networks to changes in ego networks constructed from mobile telephone Call Detail Records (CDR) enables testing hypotheses with valid and reliable data. CDRs of phone calls and SMS exchanges between five million Orange mobile customers in the African country Ivory Coast between December 1, 2011 and April 28, 2012 were segmented into two-week periods. We used a random sample of 5,000 customers' ego networks. The nation was in a crisis-recovery period after a protracted presidential election dispute involving violent confrontations between Muslims and Christians. Although there was a formal resolution eight months earlier, associated violence and uncertainty remained about many issues. These continuing problems complicated recovery. Based on crisis communication theory and theory about social effects of positive and negative sentiment, we tested hypotheses linking news semantic network components to over-time changes in ego networks. Software extracted proximate word pairs from all messages containing the name of the country in: 1) BBC International Monitoring reports, and, 2) major international publications in English. Unique word pairs appearing within three word positions numbered 57,300. These were filtered for those containing positive and negative sentiment. The resulting 4,442 positive and 1,463 negative word pairs were counted for each of 10 time periods and aligned with the ego network data to enable a series of lagged correlations with egos' calls with others with whom they had not been recently been in mobile phone contact. Hypotheses were supported.

Keywords: semantic networks, sentiment, egocentric networks, mobile phone calls,

communication networks, social network analysis

ACKNOWLEDGMENTS

The author is grateful for to Richard Weeks for data curating and programming.

Problem Statement

Researchers have found semantic networks based on automatically extracting proximate word pairs from texts to be theoretically and methodologically useful in a wide range of contexts (Diesner, 2013). Some studies simply describe semantic networks mined from texts, e.g. (Doerfel & Barnett, 1999). Others compare semantic networks for differences and similarities in order to characterize topical features across multiple corpora (Kwon, Barnett, & Chen, 2009), yet other studies use semantic network variables as predictors of other phenomena (Chan, Salmon, Butters, & Johnson, 1995).

One of the longer running interests of social network researchers is to examine the semantic networks people produce in their social networks in a variety of media, ranging from face-to-face through various computer-mediated venues such as social media. Another kind of focus is on semantic content that enters social networks from external sources, such as news, blogs, microblogs and other text domains. Potentially valuable to the evolution of scientific work in the semantic/social network domain would be a focus on theory that would address questions such as: How does external semantic network content related to internal semantic network content of social networks and to their structures?

This paper focuses on one leg of this triplex of semantic/social network relations. It theorizes and tests hypotheses about external semantic network predictors of internal social network structures over time. More specifically we study the internal social networks of a national system at the ego-centric level. We examine as dependent variables changes in ego networks' degree and their extent of interlocking, the proportion of an ego's primary contacts that link with one another. Laumann (1973) coined the term "radial" networks for the opposite

end of the continuum at which ego's contacts are not contacts of one another. "Interlocking" networks are at the other end of the continuum. All contacts are also contacts of one another. Coleman (1988) re-labeled interlocking networks "bonding networks" because they contained family and close friends who typically exchanged strong emotional content that tied them together. Networks with varying interlock are associated with a variety of communication and other social and psychological variables (Danowski, 1986).

Of long-running interest has been greater understanding of why and how such ego network variables change over time at different stages of the diffusion of innovations or information (Danowski, 1976; Rogers & Kincaid, 1981). One subset of such studies is in the contexts of crises. For example, Danowski and Edition-Swift (1985) examined how email-based ego networks structures and their semantic content changed as a state agency experienced a crisis associated with a legislative vote to merge it with another state institution and transfer its budget to that organization.

Schramm (1971) posited that crises have four main stages: 1) Individuals become aware of the crisis by recognizing a warning sign or symbol (Perry & Mushkatel, 1984); 2) If they perceive a crisis sufficiently likely, a confirmation state occurs. People seek additional information trying to determine if the crisis is imminent or actual. They increase their communication with diverse others with whom they do not normally communicate. If they find sufficiently supportable and credible information, then a crisis belief develops (Perry & Mushkatel, 1984); 3) if they believe some behaviors can mitigate the crisis for self or others, they take action; 4) the next stage is interpretation. Individuals turn to others to discuss their views of the meaning and significance of the events and their effects. They interpret these with respect to

knowledge, norms, and values. This gives meanings to aspects of the crisis, and 5) Reintegration begins to occur as communication returns to normal patterns.

This paper studies crisis and semantic and social networks in Cote d'Ivoire from December 1, 2011 through April 28, 2012. Before reading the qualitative evidence of crisis, refresh your knowledge of the geographical location of Cote d'Ivoire (Ivory Coast). See Figure 1, noting the black arrow pointing to the country at the bottom left (*The World Factbook, 2013*).

Figure 1. Map of Northern Africa



Consider that with a population of 22.4 million, Cote d'Ivoire has 19.83 million mobile phones, 88% of the population. Contrast this with the United States' population of 316.4 million and 310 million mobile phones, at 98%. The countries are relatively similar in the penetration of mobile phones compared to all pairs of countries. Mobile phones are the principal means for daily communicating in a multiplexity of ways. The literacy of Cote d'Ivoire's population ages 15+ is 56.9% (*The World Factbook, 2013*). This indicates that textual forms of news are not directly accessible to approximately half the population.

Next we quote a synopsis of Cote d'Ivoire's crises from the U.S. CIA's *The World Factbook* (2013). Based on the described crisis context we develop theory and hypotheses to test for relationships between features of semantic networks of news as they predictor changes in ego network structures during the recovery period following the largest most recent crisis spike.

Close ties to France following independence in 1960, the development of cocoa production for export, and foreign investment all made Cote d'Ivoire one of the most prosperous of the West African states but did not protect it from political turmoil. In December 1999, a military coup - the first ever in Cote d'Ivoire's history - overthrew the government. Junta leader Robert GUEI blatantly rigged elections held in late 2000 and declared himself the winner. Popular protest forced him to step aside and brought Laurent GBAGBO into power. Ivorian dissidents and disaffected members of the military launched a failed coup attempt in September 2002 that developed into a rebellion and then a civil war. The war ended in 2003 with a cease fire that left the country divided with the rebels holding the north, the government the south, and peacekeeping forces a buffer zone between the two. In March 2007, President GBAGBO and former New Forces rebel leader Guillaume SORO signed an agreement in which SORO joined GBAGBO's government as prime minister and the two agreed to reunite the country by dismantling the buffer zone, integrating rebel forces into the national armed forces, and holding elections. Difficulties in preparing electoral registers delayed balloting until 2010. In November

2010, Alassane Dramane OUATTARA won the presidential election over GBAGBO, but GBAGBO refused to hand over power, resulting in a five-month stand-off. In April 2011, after widespread fighting, GBAGBO was formally forced from office by armed OUATTARA supporters with the help of UN and French forces. Several thousand UN peacekeepers and several hundred French troops remain in Cote d'Ivoire to support the transition process. OUATTARA is focused on rebuilding the country's infrastructure and military after the five months of post-electoral fighting and faces ongoing threats from GBAGBO supporters, many of whom have sought shelter in Ghana. GBAGBO is in The Hague awaiting trial for crimes against humanity (*The World Factbook*, 2013).

(<https://www.cia.gov/library/publications/the-world-factbook/geos/iv.html>)

Our research focuses on the period nine months after this most recent macro-level crisis burst. We begin with data from December 1, 2011 and extending for five months until April 28, 2012. This has been a period of continuing multiple smaller mesa-burst crises. Our goal is to theorize and hypothesize about the sentiment of semantic network content from various news sources as they may link over time with the ego network structures of Cote d'Ivoire's population, and to the hypotheses.

Relevant Literature

Crisis impacts on communication have most often been studied in the context of natural disasters. Most of it is reported in grey literature, such as a manuscript by Richardson and Bryer

(2006). An early study in the more accessible literature was by Perry and Mushkatel, (1984). Studies in several other crisis contexts have been published. One focuses on sociopolitical crisis associated with actions such as political assassinations and the effects on individual information seeking and psychological functioning (Schramm, 1971). Others have given attention to community controversies and mass communication related behaviors during (Coleman, 1957). Greenberg (1964) found that after the assassination of U.S. President John F. Kennedy individuals first communicated with individuals they had not communicated with in the past.

Danowski and Edison-Swift (1985) found the same pattern for an organizational crisis. Based on these findings we hypothesize that during this crisis stage in Ivory Coast, salient news associated with the continuing crises will result in individuals communicating with others with whom they have not previously or recently communicated. Large bursts in the number of new people talking after initial awareness of significant element of crises would arise as individuals communicate with people with whom they had not recently communicated, or had ever previously done so.

In addition to such an externally induced macro-level burst. There are also likely mid-range bursts, particularly in the aftermath of the peak crisis as highly salient new information becomes available and people communicate about it with others with a lower than average rate of prior contact with one another. It is analogous to an earthquake. The initial major burst is followed by strong but somewhat weaker aftershocks. These are mid-range information burst with atypical nodes in the social network. The third level of bursts is more micro-level. It is observable in individual-level evidence from mobile phone Call Detail Records (CDRs) (Jo, Karsai, Kertész, & Kaski, 2012; Saramäki, Leicht, López, Roberts, Reed-Tsochas, & Dunbar, 2014).

The combination of all of these types of bursts from macro to micro leave changed social network time-signatures for communication with others. Most pertinent to the current research are the bursts that radiate information through individuals not well known or known at all by the dyadic participants in the social network.

These overlays of burst patterns from different levels of analysis have implications for the connectivity of the social networks surrounding communicating nodes. With each burst involving previously unknown or infrequent contacts, the social network is tree-like with virtually no interlocking local neighborhoods surrounding the communicating nodes.

Under normal conditions a large majority of people communicate to some extent with a people who also communicate with one another, forming a social group. This is well quantified by counting the number of an ego's primary contacts that are also contacts of one another. At the higher end the networks are completely interlocking. If these contacts are friends, then the notion is that the ego's friends are all friends with one another. Laumann (1973) used the term "interlocking" to describe the networks of those at this extreme. At the other extreme is where none of the ego's contacts communicate with, or even know one another. Laumann (1973) conceptualized those at this end of the continuum as having "radial" networks, because of their hub/spoke configuration.

During crisis both kinds of network structures appear to be valuable. The bursts of communication with unknown others most rapidly disseminates information through the widest reaches of the larger social network. Besides this high virality, social systems appear to need bonding networks to progress through the reconstruction stages after the initial crisis burst. Interlocking networks communicating about the recent burst talk about the topic in order to make

sense of it, see its implications, interpret its meanings, and seek to assimilate the information in a move to attain a new stability in communication patterns.

In a post crisis period then there are likely to be blends of bursts of negative sentiment framing information, and bursts of positive information to promote understanding, seek solutions to problems, end lingering conflicts, promote healing, peace, happiness, and optimism about the future. In such a crisis recovery period, therefore, it can be expected that there is a higher proportion of positive sentiment framing information communicated, relative to negative framing. Both, however, are probably needed to progress toward resolving the period of instability. New problems will be discovered as different approaches to social healing are attempted, recollection of old wounds will be brought back to the surface by some associations that are created or remembered. Additional positive information is required to resolve these problems (Ullmer & Sellnow, 2002).

To the extent that some of these individuals had at an earlier time been in contact, they would also increase their communication with people with whom they had not been in recent contact. This would result in increased interlocking of the ego net. This pattern is consistent with more interlocking social networks being more cohesive and members feeling a greater attraction among them. This produces social support and the formation of consensus on the interpretation of information (Danowski, 1980). Accordingly, we hypothesize that during this phase, crisis salient news will stimulate increased interlocking of the ego network.

We define more salient news as that which imbeds sentiment into its content (McCombs & Shaw, 1972). Research on the implications of positive and negative emotion expressed in communication is relevant to our paper. Fredrickson and Losada (2005) have studied the ratios of positive to negative affect expressed across all communication in a time segment measured for

various system levels: individual, dyad, group, and organization. They find consistent evidence across these levels that when there is 2.9 times more positive than negative affect expressed in messages, the social unit is performing optimally over time. They call this state flourishing. “To flourish means to live within an optimal range of human functioning, one that connotes goodness, generativity, growth, and resilience.” (Keyes, 2002). When the ratio is below 2.9 the system has been found to operate less effectively and considered “languishing.” Languishing fosters distress, impairment, and limitations in activities (Lyubomirsky, King, & Diene, 2011). There is an upper limit on positivity above the threshold of 2.9. Social system units flourish with ratios upwards to ratio of 11.6. Above this level increasingly positivity leads to system destabilization” (Fredrickson, Tugade, Waugh, & Larkin, 2003).

Losada (1999), Losada & Heaphy (2004), Fredrickson and Losada (2005) have used Chaos Theory and Lorenz equations (Lorenz, 1993) to further hypothesize that

“1. Flourishing is associated with dynamics that are nonrepetitive, innovative, highly flexible, and dynamically stable; that is, they represent the complex order of chaos, not the rigidity of limit cycles and point attractors. 2. Human flourishing at larger scales (e.g., groups) shows a similar structure and process to human flourishing at smaller scales (e.g., individuals). 3. Appropriate negativity is a critical ingredient within human flourishing that serves to maintain a grounded, negentropic system. 4. The complex dynamics of flourishing first show signs of disintegration at a positivity ratio of 11.6. 5. Human flourishing is optimal functioning characterized by four key components: (a) goodness, indexed by happiness, satisfaction, and superior functioning; (b) generativity, indexed by broadened thought–action repertoires and behavioral flexibility; (c) growth, indexed by gains in enduring personal and social resources; and (d) resilience, indexed by survival and growth in the aftermath of adversity.” Frederickson

and Losada (2005). In periods of languishing, the social unit loses behavioral and conceptual flexibility and the ability to question; it is stuck in self-absorbed advocacy (Frederickson & Losada, 2005). Losada & Heaphy (2004) have found that within organizations, positive experiences engender broader information processing strategies and greater variability in perspectives across organizational members. Sutcliffe & Vogus (2003) have found positivity predictive of organizations' resilience during periods of threat.

In the news coverage of crises there is evidence that in the initial stages there is more emotional content about the effects of the crisis on the individuals and their responses to it (Papacharissi & de Fatima Oliveira, 2012). Because of the increased arousal that crises produce among participants and observers, descriptions of it in news may contain more sentiment content than at later stages. Negative sentiment is more likely expressed for aspects of the crisis that are considered bad in terms of societal norms and in terms of the emotional responses of observers/reporters describing people's experience of physical harm, chaos, emotional distress, suffering and uncertainty. Later, as recovering from the initial negative impact of the crisis begins to grow, more positive sentiment is expressed as observers/reporters see people helping one another recover, and as aid comes from nations and NGOs of a humanitarian nature. Then, as rebuilding of the social and physical community develops during the integration and stabilization phases, positive sentiment will likely grow. Nevertheless, during these stages problems remain and new problems and crises emerge. As a result negative sentiment news content is produced along with the positive.

In terms of the relative effects of positive and negative news on ego network structures, it is hypothesized that positive news has a greater effect on ego networks than does negative news. Tang, Zhang, Sun, Rao, Yu, Chen, & Fong (2012) found that when feeling happy, 64% of the

users were inclined to share their happiness with others through a mobile phone call. When unhappy, only 36% of the users called others on a mobile phone. Positive emotion led to making a mobile phone call almost twice as often as negative emotion did. Moreover, positive mood states lasted 5.22 times longer than negative mood states. The number of mobile phone calls made will therefore likely be more than 5 times as many as when the person feels negative emotion.

Furthermore, the individual in a positive mood state is approximately 5 times more influenced by friends, acquaintances, and strangers who are in a positive mood to stay in a positive mood state, than are individuals experiencing negative emotions likely to be influenced by others' moods. This social multiplier effect on positive mood, when combined with the 5 times higher rate of mobile phone calls to others results in positive emotion, perhaps results in more than 5 times as many mobile phone calls to others. In addition, individuals in a positive mood were more likely to call people with whom they were less close. Individuals in a negative mood were more likely to call only their closest friends.

We therefore hypothesize that positive news will stimulate feelings of positive mood in individuals, which will result in these egos making more calls to people with whom they have had less recent contact than will people in a negative mood. This is in contrast to the initial reporting of the crisis when negative news will motivate people to talk to others with strangers (Greenberg, 1963) or with others with whom they have not recently had contact (Danowski & Edison-Swift, 1985). In the post-crisis stages of interpretation and reintegration, in contrast, it may be expected that the greater likelihood of positive news content, hence positive mood, is associated with increased communication with others with whom they have not had recent contact.

Research (Danowski, 1986) has found that bridging (radial) social networks, which reach across individuals who are not in strong bonding (interlocking) networks, communicate more positive message content. In contrast, the egos with interlocking networks communicate more negative information and distrust of others. This would likely reduce the likelihood of the latter kind of ego networks being influenced by positive news. In contrast, those with a greater preference for radial networks, who are more positive in their communication, probably also have more positive mood, and therefore more likely to attend to positive news as it flows through the social system network. The then may serve as a network multiplier on the effect of positive news stimulating communication with individuals who have not recently been in contact. Because of the radial networks connect wider reaches of the social network as they bridge structural holes in it (Burt, 1992), they add a rapid viral effect to positive messages. These aid in developing common meanings for aspects of the crisis and the formation of more shared interpretations of crisis potential crisis effects and means of mitigating the negative ones. As well, this positive communication promotes reintegration of the social system (Ullmer & Sellnow, 2002).

Positive news may also have an effect to stimulate more interlocking among some individuals. The small group literature has found that attraction for others is the basis for increased cohesion and communication in groups (Evans & Dion, 1991). Positive information is more likely to heighten feels of attraction for one another as individual exchange positive content and experience positive emotion. This would then likely increase the mobile calls among individuals who already have a propensity to be in interlocking networks, but who have not talked with these “friends of friends” recently. So, positive news can be expected to increase

both kinds of ego network variables, the number of people called who have not called each other recently, and the extent to which these individuals call one another.

Time-ordered Effects

News content takes time to diffuse through social networks. This was clearly embodied in the two-step flow hypothesis about news dissemination (Katz, 1957). A wide and numerous range of studies since then places importance on the time dimension of information flow in social systems. Multi-step flow models are particularly relevant in a nation such as Cote d'Ivoire because of a literacy for only approximately half (56%) the population. As a result, illiterates being aware of news reports in text form in any traditional or new media will be mediated by other individuals where the starter node in a chain is a literate individual who attends to the textual news content and communicates about it with others. These conditions are the rationale for the hypothesis that lagged associations of word pairs from news sources will be stronger than zero-order effects.

A summary of the hypotheses tested in this study is as follows:

- 1) During the post-crisis recover period there is more positive news content than negative news content about events in the country.
- 2) Positive news content will have stronger associations with changes in ego networks than negative news content.
- 3) News content sentiment is associated with increases in ego network communication with individuals with whom the ego has not recently had contact.
- 4) News content sentiment is associated with increase in the extent of interlock in the ego network.

- 5) There will be more associations between sentiment news content and number of new nodes than with their extent of interlocking.
- 6) Positive news content will be associated with a greater increase in the number of people an ego communicates with who have not had recent contact than will negative news content.
- 7) Positive news content will be associated with a greater increase in the interlocking of individuals among these “new” or “renewed” ego contacts than will negative news content.
- 8) Lagged associations of news content sentiment with ego network degree and interlock are stronger than zero-order associations.

METHODS

Data

One set of data were mobile phone Call Detail Records (CDR) gathered in the African country of Ivory Coast (Cote d’Ivoire) over a five-month period, from December 1, 2011 to April 28, 2012 (Blonde, Each, Chan, Claret, Deville, Hens, Merlot, Smoreda & Ziemlicki, 2012). The dataset consists of 2.5 billion records of calls and text messages exchanged between 5 million customers of Orange in Cote d’Ivoire. Orange Labs in Paris anonymized the data and did other data processing. CDRs contain the following variables: timestamp, caller id, called id, call duration, antenna code.

Only individuals who were customers throughout the observation period were retained in the data. Directionality of calls was removed by removing the distinction between incoming and

outgoing calls. The observation period included a total of 3600 hours, with about 100 hours of data missing because of technical reasons.

One of the data sets Orange produced was an ego network dataset. We use this one in the current research. The data contain the ego networks of 5,000 randomly selected individuals including calls among all individuals out to two degrees of separation from the ego, except the communication between the second order nodes was not included. The aggregated the calls made between these individuals within 10 two-week intervals across the 20-week observation period.

A common practice in Ivory Coast is for some mobile phone owners to provide their phone to people on the street for a fee, resulting in CDR records with a very large number of outgoing calls and most calls using the same cell tower antenna. Such customer with on average more than 133 calls per day were excluded from egos selection.

Every pair of individuals' IDs are listed but the direction and total number of calls is not. Here is a sample of the data:

```
1052 20002
20002 20022
20019 20031
20129 20119
20132 20119
20134 20119
20102 20135
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From these data we computed the number of first degree nodes connected with each ego and measured the extent to which these nodes were interlocking. The interlock metric ranging from 0.0 to 1.00. An individual whose contacts were all contacts of each other had a score of 1.0

while at the other end of the continuum an ego none of whose contacts were contacts of each other were coded as 0.00.

In addition we identified the number of unique contacts an individual had in a time period. All contacts that did not appear in the previous time periods were counted and their interlock computed. These constitute “new” ego networks for the individual in the time period. For each individual in each time period the number of new nodes and their interlock were computed. When we aggregated the data to the two week periods so as to be at the same level of aggregation of out news story word pairs, we computed the summary statistics of mean, median, standard deviation, skewness, and kurtosis. The means were used in this paper for two variables: the average number of new nodes in a time period, and the average interlock value among these nodes.

News Event Data

We extracted from LexisNexis Academic the full text of all news stories in English in “Major World Publications” about a nation over a period of 151 days that included the term “Cote d’ Ivoire” or “Ivory Coast.” Also collected were all such documents from *BBC Monitoring Africa – Political*, supplied by *BBC Worldwide Monitoring International*. These include texts from translations of web sites, radio broadcasts, television broadcasts, and newspapers. In addition we extracted all news containing the country name in the French daily, *Le Monde*, because Cote d’ Ivoire is a former French colony. These data are reserved for a future study. The aggregate file used here contained 336,075 words, 11,502 of which were unique.

Semantic Networks

Text files for the observation period were placed in a single file and segmenting into days by the TimeSlice program in WORDij (Danowski, 2013). Next, for each day, all word pairs appearing within three word positions and having frequencies of 3 or higher were extracted with the WordLink program in WORDij. As well, an analysis was run on the aggregated text file and all word pairs with frequencies of 3 or more were extracted. No stemming was performed. A stop word list dropped basic grammatical function words that do not carry much semantic content, such as “that, the, to,” etc. These resulting number of unique word pairs extracted numbered 57,300.

Sentiment

We selected from the 57,000 word pairs those that contained either a positive or negative sentiment word from a dictionary we created of positive and negative sentiment words. These were selected in two ways. One was to take the LIWC (Pennebaker, Francis, & Booth, 2001) sentiment dictionary items and de-stem them unto all lexical variants. Two was to select from a comprehensive list of English language modifiers all words and lexical variants that had clear positive or negative meanings. The source we used for this was the Automatically Generated Inflection Database (AGID), fourth revision, January 3, 2003. The author, Kevin Atkinson, describes it as an automatically created database of inflections from a large word list

Computing Positivity Ratios

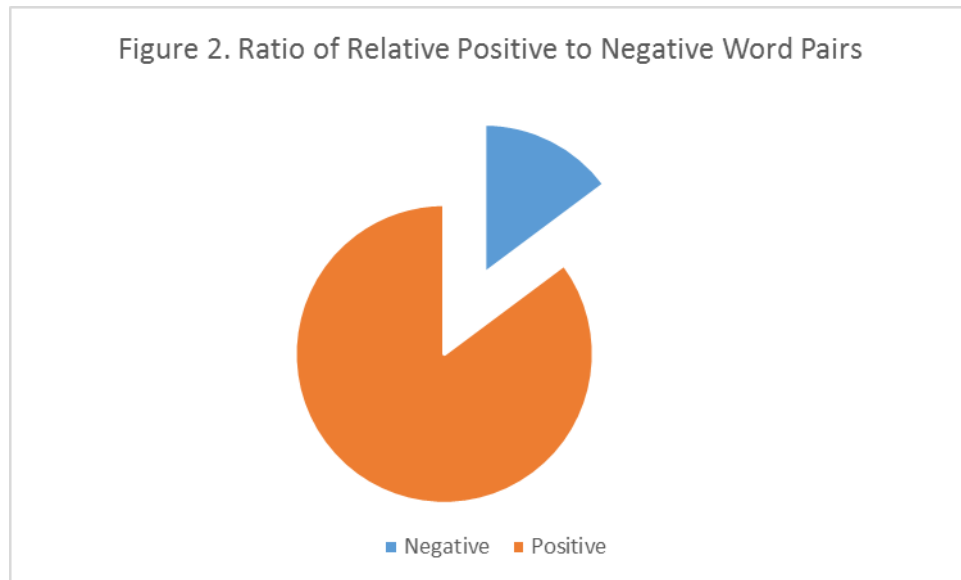
As a result of these two efforts we produced a file with 1,201 positive sentiment words, and a file with 2, 323 negative sentiment words. Previous research used these files (Danowski, 2013).

RESULTS

These raw counts of occurring sentiment word pairs need to be understood in terms of the sizes of the dictionaries of negative and positive words used as filters for the 57,000 word pairs. Relative to the dictionary there was a ratio of only .65 negative sentiment word pairs relative to the number of dictionary words, while for the positive sentiment dictionary of 1201 sentiment words there were 3.74 times more actual occurrence of positive word pairs. Comparing these two ratios, there are 5.75 times more positive than negative word pairs among the 57,000 word pairs. Figure 2 depicts this ratio. It helps put into perspective how much more positive word pairs occurred in the news than negative ones. A Z-test of the significance of the difference between these two ratios is significant (The Z-Score is -41.5083, $p < .0000$). The result is significant. Hypothesis one is supported.

Table 1. Sentiment Counts

	Negative	Positive
Sentiment word pairs	1510	4489
Dictionary words	2323	1201
Ratio	0.65	3.74



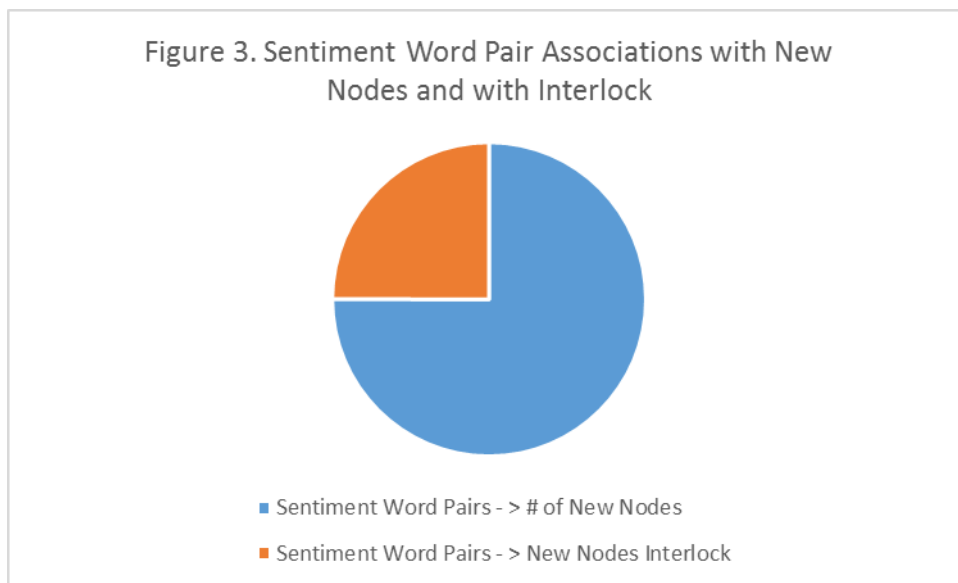
To test hypothesis 2 that positive news is associated with stronger associations to changes in ego networks than negative news content, we summed up the number of significant associations across all lags for the two ego network variables for positive and negative word pairs. We produced a rectangular matrix of the sentiment word pairs by the 10 two-week periods that corresponded to the mobile phone data time segmentation. Each column of the matrix represented a time period where cell entries were the actual frequencies for pairs for it. If a pair did not occur it was given a value of 0.

To be statistically significant at $p < .05$ with the lag of 3, the correlation coefficient had to be $\pm .76$ or greater. There were 2,737 significant associations for positive news word pairs and 885 for negative ones. The difference is statistically significant (Chi squared = 506.594, d.f. = 1, $p < .0001$). Hypothesis 2 is supported.

Hypotheses 3 and 4 posited that sentiment word pairs would be associated with both the number of new individuals with whom the ego had mobile calls with in a time period but had no such calls in a previous period, as well as the interlock variables. There were significant

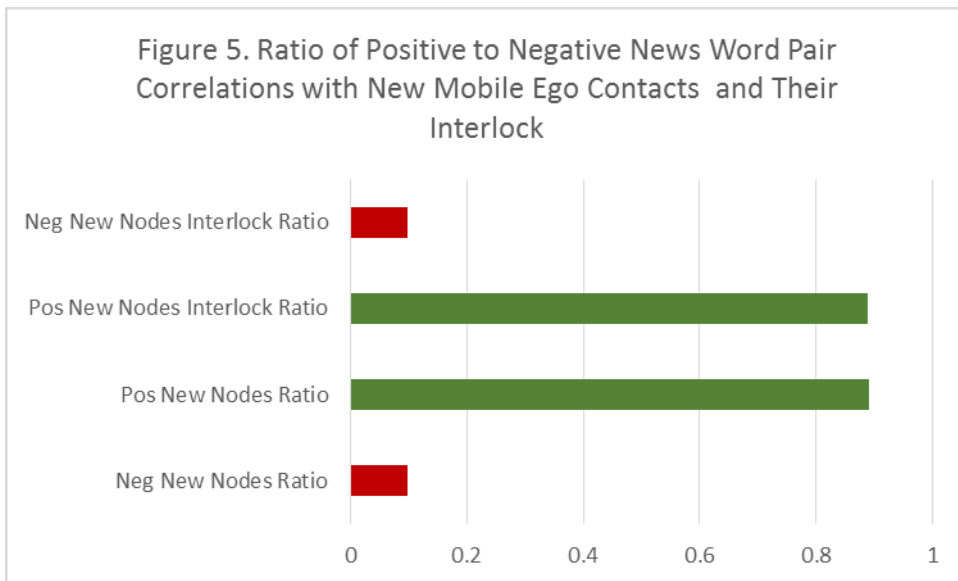
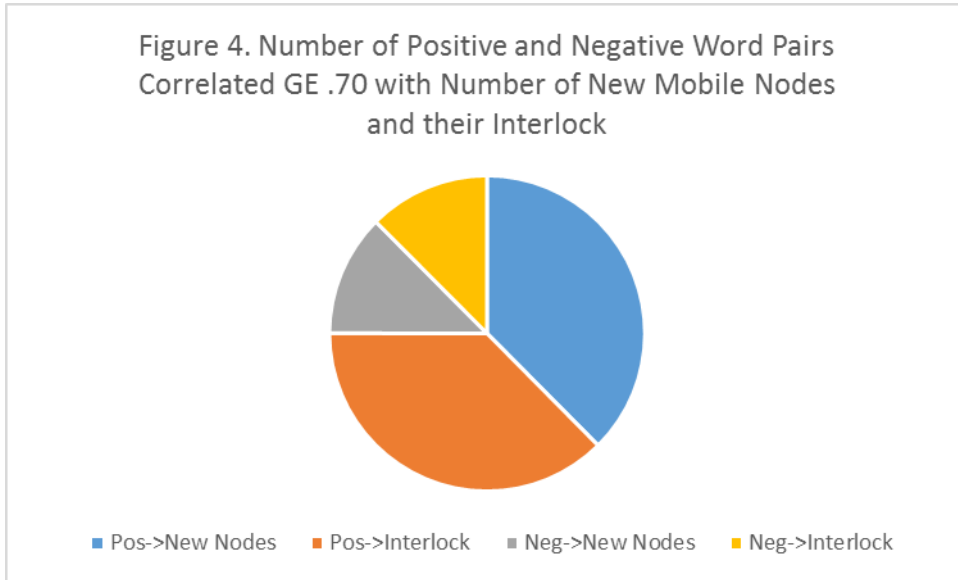
correlations greater than or equal to .76 for both network variables. There were 1314 for the new nodes variable and 444 for their interlock. Hypotheses 3 and 4 are supported.

Hypothesis 5 stated that there would be stronger associations of sentiment news content with the number of new nodes than with their interlocking. Figure 3 shows the relative distributions of these associations. There were three times the number of significant associations between sentiment word pairs and the number of new nodes in the ego networks, compared to the degree of interlocking among these nodes. The differences were statistically significant ($Z=34.72$, $p < .0001$).



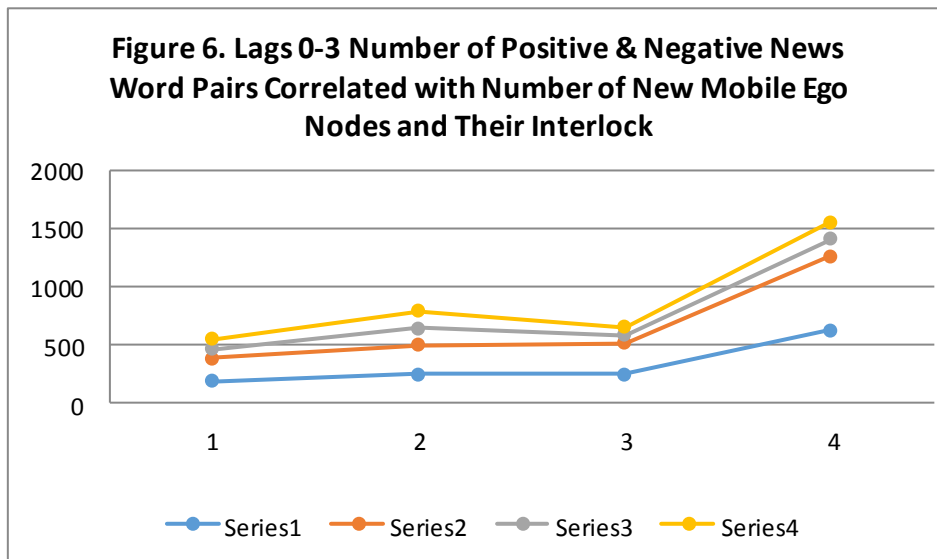
Hypothesis 6 and 7 posited that there would be more significant associations for positive news word pairs and the two network variables than there would be for negative news word pairs. Figures 4 and 5 show the same relationships but portrayed in different graphic styles. The positive word pairs were significantly stronger in association with both ego network variables than the negative ones. There were three times the positive than negative word pair associations

to the ego network variables. The differences were statistically significant ($Z = 31.44, p < .0001$).



Hypothesis 7 stated that lagged associations of news sentiment word pairs will be stronger than zero-order associations. Figure 6 shows the number of significant correlations between the sentiment word pairs and the ego network variables at four points in time.

The figure shows the dominance of the 3-period lag, which is a total of 6 weeks. This difference is statistically significant (Chi sq. = 160.9, $p < .0001$).



Exploring Topic Patterns

Figure 7 shows the top 40 strongest relationships between positive news word pairs and the number of “new” nodes with whom an individual has mobile phone contact. These quantitative data enable a qualitative assessment of the topical nature of primary content involved in the associations. The most frequent concepts are involving the president, country, good, thanks.

Figure 7. Sample Correlations at Lag 3 between Positive News Word Pairs and New Mobile Nodes

return_peace	.97
ivorian_security	.97
president_welcome	.97
president_support	.97
president_agreement	.97
president_determined	.97
<u>president_strong</u>	.97
president_warm	.97
president_proud	.97
year_peace	.97
divoire_security	.87
divoire_commitment	.97
divoire_strongly	.97
happy_cote	.97
happy_divoire	.97
happy_welcome	.97
happy_peace	.97
country_share	.97
country_security	.97
country_strong	.97
country_hopeful	.97
<u>good_year</u>	.97
good_democracy	.97
<u>good_restore</u>	.97
<u>good_elections</u>	.97
good_friend	.97
good_partner	.97
good_progress	.77
good_thing	.77
colleagues_delighted	.97
thank_country	.97
thank_farmers	.97
thank_service	.97
thank_ecowas	.97
thank_malaria	.97
thank_working	.97
<u>thank_work</u>	.97
<u>thank_commitment</u>	.97
thank_women	.97
thank_american	.97

For negative news word pairs the dominant concepts are violence and insecurity.

Figure 8. Sample Correlations at Lag 3 between Negative News Word Pairs and New Mobile Nodes

gbagbo_lost	.97
<u>year violence</u>	.97
<u>divoire fight</u>	.97
divoire_difficult	.97
<u>country violence</u>	.97
<u>months violence</u>	.89
months_shook	.97
now_shake	.97
reconciliation_serious	.97
government_violence	.97
<u>government losing</u>	.97
new_defense	.97
new_threats	.97
include_dissenting	.97
deadly_disputed	.97
crisis_disputed	.97
broke_disputed	.97
violence_country	.97
violence_presidential	.97
violence_conflict	.97
violence_remained	.97
violence_spring	.97
violence_shock	.97
resulted_losing	.97
people_violence	.97
humanitarian_aggravate	.97
criminal_threat	.97
insecurity_country	.97
insecurity_areas	.97
insecurity_western	.97
continued_threat	.97
actors_aggravate	.97
assistance_vulnerable	.97
elections_violence	.97
perpetrated_abuses	.97
village_destroyed	.97
areas_fighting	.97
homes_destroyed	.97
moved_violence	.97
groups_threat	.97

DISCUSSION

This research used a novel approach to studying semantic networks in relation to social networks. The social networks were mobile phone call based ego networks. Mobile phone networks constructed from complete records of call details provide a means of measuring

networks that have high face validity, given the pervasiveness of mobile phones in the population studied. The inclusion of text message exchanges as well as voice calls increased the likely fit of the mobile phone networks with basic interpersonal social networks.

Another novel feature of this research was the linking of external news content to changes in ego networks over time. This enabled testing hypotheses about news effects on mobile phone networks over time. We collected news documents from major world newspapers, as well as translations of websites, broadcasts, and new media. Furthermore, the 57,000 unique word pairs WORDij's WordLink extracted from the aggregate text file for the entire 5 month period captured most of the content except for stop words and words with frequencies 1 and 2. The two-week intervals of the ego network data were perfectly aligned with the content data. This enabled examining lags of up to 3 time periods for the news variables in relation to ego network variables. At the same time, we could identify which pairs of callers had not called each other in a previous period. Accordingly, we could link news content with the emergence of new communication contacts, examining zero-order correlations though up to three lags.

Moreover, the theoretical rationale for the study placed importance on filtering word pairs for those that involved positive and negative sentiment. This enabled testing hypotheses linked the most engaging news content, sentiment words that stimulate new communication network formations. We extracted word pairs from a variety of media, news stories, broadcast media, and new media. Rather than using a crude "bag of words" approach that counts all words in a document as linked, we used only highly proximate word pairs, those appearing within three word positions on either side of a focal word, resulting in a word window with a functional size of 7 words. This created greater contextual validity than does the typical "bag of words" approach.

The over-time nature of the study enabled identification of two of the three necessary conditions for establishing causality: association of the variables, and knowledge of time-order between them. We left the third element of establishing causality, ruling out rival explanations, for future research.

The analysis found support for the eight hypotheses in the context of crisis in Cote d'Ivoire. It is in a post-crisis period in light of the main crisis produced by the struggle over who would be president, and it is in the stage of fleshing out the meanings of the crisis-producing events from the varying perspectives of the main groups. The country nevertheless remains in a state of simmering conflicts that rise to the surface in violent acts and other events that produce a stream of meso-level crises. Nevertheless, the society is seeking interpretations for the preceding macro-level crisis of national leadership imbedded in major violent conflicts. It is seeking the effective reintegration of the nation.

In accordance with the literature on recover from crisis, we found much more positive news content than negative news content about events in the country. Positive news content created stronger associations with changes in ego networks than negative news content by approximately 3 to 1. News content sentiment, whether positive or negative, linked with the ego calling and texting with people not in recent contact. At the same time, news content sentiment correlated with increases in interlocking of the ego network, although at only one third the rate of new contact creation. Moreover, positive news word pairs had approximately triple the number of associations with new mobile phone nodes than in these nodes extent of interlocking.

Lagged associations of news content sentiment with ego network degree and interlock are stronger than zero-order associations. A lag of 3 two-week periods, or 6 weeks, was the longest possible given the five-month time width of the mobile phone dataset. Lags are perhaps

indicative of greater reliance on literate opinion leaders and informal information brokers, given that only approximately half the population is illiterate and hence unable to directly access the text content from newspapers, blogs, websites, and social media.

In short, we found a good fit of our theoretical expectations regarding sentiment of news semantic network components about the country, given the state of crisis recovery of the nation. There appears to be an opening up of freer flowing interpersonal networks and wider and more rapid spreading of positive information and emotion than may have been likely nearer the main spike of the crisis period. At the same time, there is evidence of increased cohesive networks exchanging positive information rather than the usual negative message content. These processes are likely to speed societal healing and rebuilding. There is evidence to suggest increasing happiness, thankfulness, and positive feelings about the government and its leaders. These patterns may lift the nation's well-being higher than it has been in modern times. Positive news and mobile phone communication appear to be playing an important role in these movements toward a better life in Cote d'Ivoire.

Our access to the complete mobile phone records of a major carrier in the country has made empirically observable this fine-grained yet wide-scope investigation of a positive movement toward happiness, peace, thankfulness, and its likely compatible economic, health, and institutional correlates. Disclosures by Snowden have likely turned global public opinion away from acceptance of the value of nationwide bulk logging of all mobile cellular telephoning. Nevertheless, this study shows that when such data is anonymized and made accessible to neutral third party researchers, positive contributions to aiding societal well-being can flow from use of these data.

Limitations

During the years of crisis there was considerable relocation in and out of Cote d'Ivoire. Phithakkitnukoon, Calabrese, Smoreda, & Ratti, (2011) found that relocation to a distant place requires 8 to 9 months for the individual to rebuild their mobile phone network in their new location with new people. Although calls remains frequent with core family, contact drops off considerably with others from the former location. Some of our 5,000 randomly selected mobile users may have recently relocated in the country. It is possible that they just began rebuilding their mobile network contacts shortly before entering the observation period. This could, if there were a substantial proportion of these individuals in the random sample, present a rival explanation for our findings. Data to possibly rule this out could not yet be located.

Another limitation is the question of generalizing findings from this African developing country to other countries. African culture is considered to place more importance on oral communication than developed countries. (Ong & Hartley, 2012). There are unknown possible differences in the cultural meanings and practices associated with mobile phones compared to other countries, even other African nations.

Among the four different D4D data sets available, the ego data set had the most limited information. It contains only the caller and called IDs. Other data sets in the D4D Cote d'Ivoire set include complete call records with anonymized ID, time and date stamp, call duration, number called, all antennae used during the call, along with side data giving geo-coordinates of each antenna and in which of 255 sub prefecture units of government it is near. The country's rural and two urban areas are not distinguishable from other sub prefectures. In addition, the Muslim north is combined with the Christian south. If Orange Labs reconfigured their data to include the additional detailed information for each pair of calls used to create the ego dataset,

researchers could control for regions and also analyze the mobility of ego networks. This would be useful to extend the theory tested in this study.

Another limitation is that weather has been found to affect mobile communication. The only archived weather data available for Cote d'Ivoire is from two locations, one in each of the urban areas, and the number of weather variables is not as some researchers may desire. Weather is an uncontrolled variable that does affect mobile communication. Research finds that on bad weather days individuals make shorter and fewer calls. Moods are more negative on bad weather days and more positive on good weather days (Phithakkitnukoon, Leong, Smoreda, & Olivier, 2012).

Tweet content, more than news stories, may have a more refined relationship with mobile call networks. The author contacted the main office of Topsy. They first partnered with Twitter to maintain a complete archive of the fire hose of tweets since 2008. Topsy requires \$30,000 for a subscription that would enable capturing the five months of tweets associated with Code d'Ivoire. Nevertheless when they discovered I was not a commercial customer but an academic, they refused to allow me to become a customer had I wished to do so. Now that Apple has acquired Topsy it is not clear what changes may take place in access to Twitter data.

Another company, Data-Sift, discounts their subscription for an academic researcher to \$8,000 for access to both the real-time firehouse and archived tweets for Cote d'Ivoire during the five-month window for the current study. Content of the tweets could be analyzed with the same procedures we used in the current study, plus they use the Saliency software to index sentiment. This would allow comparing various sentiment operationalizations.

Future Research

Additional Network Sentiment Analysis

The SNAZ (Danowski, 2013) program from which we borrowed the target positive and negative dictionaries for the extraction of positive and negative news word pairs, takes a seed word, traces the weighted shortest paths from the seed to each of the sentiment words, then computes the intensity of the positive and of the negative paths. This could be used in future research once key targets are identified by the kind of analysis done in this paper. For example, a key target would include “president.” This would provide a “zoom in” on the key entities identified first from the approach used in this paper. In addition, there are many dozens of other sentiment analysis operationalizations, many of them proprietary. The scientifically documented ones would be useful to test against the same data to determine their relative predictive validity.

Event Analysis

GDELT is a database containing event coding that may be of use in association with the ego network mobile phone data (Leetaru & Schrodt, 2013). Another approach to using more specific events would be to take empirically identified concepts in the current kind of research then do a Key Word in Context (KWIC) search to quickly identify significant events. Event signatures can be developed from the over-time patterns of correlations with the ego network variables. These may provide a more refined association than the GDELT events, which is an open empirical question. As well, it can be determined if the GDELT events can be predicted in advance from the news sentiment word pair data.

Topic Analysis

Topic analysis is somewhat similar to event analysis. The two overlap to the extent there are material similarities between the domains represented in each. We have explored Linear Dirichlet Analysis (LDA) for topic identification in prior research, but the lack of developed guidelines for parameter selection makes analysis very subjective as to parameter selection. Each

different parameter setting results in different topic outcomes. (Chang, Gerrish, Wang, Boyd-graber, & Blei, 2009; Danowski, 2011; Pleple, 2013).

Ontology Analysis

It may be useful to explore approaches that are based not on event ontologies but on more micro-level actor, action, object, etc. type of ontologies. This may reveal more refined information to predict changes in ego network variables.

Longer Time Frame

A longer or more fine-grained time frame would be valuable in this kind of investigation. The data provider constrained this particular ego data dataset to 10 two-week intervals. Nevertheless, other of their data we are currently analyzing allows us to segment 151 daily time intervals in association with news sentiment word pairs and individual mobility. Because of likely differences in mobility by such factors as urban/rural areas, we are segmenting the data by 255 sub prefectures throughout the country. There are 50,000 randomly sampled individuals selected every two weeks. By aggregating data to the sub prefecture level we can perform a cohort analysis because the random samples represent the population.

Segmenting Ego Networks

This analysis aggregated all ego networks and measured the increases in number of new nodes per time period and their interlock. It has recently been reported that that mobile phone users have different “social signatures” which carry across other new media (Saramäki, Leicht, López, Roberts, Reed-Tsochas, & Dunbar, 2014). It would be useful to explore segmentation of ego networks in the context of the current study. As noted in the literature review, individuals with radial versus interlocking networks behave differently in a number of ways (Danowski, 1986).

If message content data were available from within the ego network calling and texting, then a quantitative comparison of the semantic network structures of the external news content and the internal news content could be performed with nodes as the communication moved through the network. This would enable assessment of a variety of concepts, including the degree to which some types of individuals maintain higher fidelity of information and what kinds of distortions are entered by what kinds of individuals.

Mixed Methods

Combining the current methods with ethnographic interviews in the population about how they process news content would add valuable information to the refinement of theory in the current line of research. Although anonymity would prohibit interviewing the same individuals as identified in the CDR data, sub prefecture locations as identified in a companion study (Danowski, 2014), could narrow the qualities on which interviewees were selected.

More Study of Positive Sentiment in Semantic and Social Networks

Although sentiment research is exploding, most of it is driven by commercial interests indexing social media posts for clients in order to mitigate negative comments. More scientific communication research on positive sentiment in communication networks would be valuable in advancing theories of semantic and social networks.

Promoting Positive Social Outcomes

Bulk mobile phone data collection, as demonstrated in this study, need not be restricted to commercial or intelligence applications. These data can be put to uses that reduce human suffering, improve well-being, happiness, and have other positive benefits. More research along these lines, particularly controlled field experiments, would further these pro-social uses of mobile phone databases. Mobile phone providers, giving anonymized CDR records to third-party

academic researchers with no conflicts of interest is a practice that should be expanded for the betterment of the human condition.

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