The Evolution of the HIV/AIDS NGO Hyperlink Network

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Hyperlink networks are dynamic systems of representational communication. In order to understand the varied influences on processes that produce these systems, this research examines the evolution of a HIV/AIDS nongovernmental organization (NGO) hyperlink network over one year. The results demonstrate that different factors influence the rate of variation, selection, and retention of hyperlinks. The presence of a greater number of corporate or government hyperlinks to a NGO Website is related to the rate of variation. Network embeddedness and issue network participation are related to the selection of hyperlinks. Finally, indegree centrality and issue network participation are related to hyperlink retention. Implications for the study of hyperlink networks as dynamic representational communication systems are drawn from the results.

Key words: hyperlink network, NGO, evolutionary theory, HIV/AIDS, network analysis.

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While computer code creating intertextual references might once have been thought to be the domain of computer scientists or information science researchers, increasingly communication researchers have suggested that placing a hyperlink on a Website is a communication choice (G. A. Barnett & Sung, 2005; Park, Barnett, & Nam, 2002; Shumate & Dewitt, 2008; Shumate & Lipp, 2008). As noted by Shumate and Lipp (2008) and Lusher and Ackland (2010), hyperlinks are connections based upon public affiliation or representation, instead of communication flow. Indeed, one can hyperlink to any Website without the author(s) of that Website becoming aware of the hyperlink. Through representational communication, hyperlinks socially construct the relevance and relationship among actors engaged in collective action. In the context of social issue communication, hyperlinks “help to establish the structure and boundaries of political communication on the Web” (Ackland, O’Neil, Bimber, Gibson, & Ward, 2006, p. 4). However, as with other collective action on the Web (see Bimber, Flanagin, & Stohl, 2005), hyperlinks and the networks constituted by them can change rapidly. Previous research has examined these dynamic networks at a single point in time. In contrast, the current research examines the dynamics of a social issue hyperlink network over time.

The purpose of this research is to ascertain the factors that influence hyperlink networks as dynamic systems of representational communication. This research makes two contributions to the study of these dynamic networks. First, it demonstrates that different factors are related to the three socioevolutionary processes, variation, selection, and retention, in unique ways. Second, this research demonstrates that social issue networks are related to hyperlink network evolution.
Nonprofit, Nongovernmental Organization (NGO) Hyperlink Networks

The current work follows that of social science research examining bounded hyperlink networks of like actors (e.g., Lusher & Ackland, 2010; Park, et al., 2002; Rogers & Ben-David, 2008; Rogers & Marres, 2000). While the Barabási-Albert (1999) model seeks to establish general laws about hyperlink evolution, such as power-law dynamics, the current research follows the path set forth by Burnett and Marshall’s (2003) and Thelwall’s (2006) critique of previous hyperlink research. They claim that general laws about hyperlinking are highly problematic because unitary claims about the nature of the Web or characterizations of the Web as a definable whole lack validity. Instead, they argue that the Web is composed of sets of interrelated activities that differ based upon the region of the internet and the goals of various actors. The current research examines the evolution of one set of actors, as opposed to the internet as whole, HIV/AIDS nonprofit, nongovernmental organizations (NGOs). This paper follows Khagram, Riker, and Sikkink (2002) by defining NGOs as “private, voluntary, nonprofit groups whose primary aim is to influence publicly some form of social change” (p. 6). Their goals, while diverse in nature, are united by a common desire for social change (Khagram, et al., 2002).

Networks of NGOs are facilitators of collective action. As Diani (2003) notes, one cannot conceive of a long-term movement occurring without interorganizational networks of collective action. Many social movement scholars have considered NGO networks as a resource to be mobilized. However, Diani (2003) and others (e.g., Bimber, et al., 2005) have gone further, arguing that collective action (i.e., social movements) is a network. In all collective action, the choice to participate involves a social dilemma (see Marwell & Oliver, 1993; Olson, 1965). Initial contributions might not result in the realization of the public good that the actor seeks, so actors conduct a mental calculus weighing the likelihood of achieving gains and the costs of those contributions.

The current study conceptualizes NGO Websites as agents for offline actors and hyperlink patterns as communicative choices (Shumate & Dewitt, 2008; Shumate & Lipp, 2008). Hyperlinks are not merely random associations, but instead represent fundamental meaning and community building. Evidence of reciprocity in hyperlink networks (Rogers & Marres, 2000; Shumate & Dewitt, 2008; Shumate & Lipp, 2008) suggests that actors are aware of others’ hyperlinking behavior and tend to reciprocate that behavior. Such awareness and action are fundamental to community building and demonstrate intentional choice.

Beyond conceptualizing hyperlinking as intentional communicative choices, the nature of those choices is also important. Communication scholars differentiate between information flow and representational/positioning communication (for example see McPhee & Zaug, 2000). Information flow communication describes messages that are transmitted through verbal, nonverbal, or written channels to senders. In contrast, representational communication describes messages about with whom, or what, an actor is affiliated. For example, a person might frequently communicate with a famous friend about various hobbies and interests. Such communication would differ from indicating to others that one has a famous friend (a.k.a., name dropping). Similarly, Shumate and Lipp (2008) and Lusher and Ackland (2010) describe hyperlinks as representational communication rather than information flow. One can choose to hyperlink to another’s Website without ever having transmitted messages to or received messages from the owner of that Website. Instead, a hyperlink is a public acknowledgement of another.

The properties of information flow verses representational communication networks logically differ. For the receiver, the cost of receiving information flow relations increases with each link. Receiving too many information flow links can result in information overload, leading to a practical ceiling effect in indegree centrality (i.e., the number of links coming to an actor). In contrast, there is no corresponding cost to receiving additional representational communication links. While one might
receive more internet traffic as a result of users relying on the representational link, the choice to place a hyperlink on one’s Website itself has no direct cost to the target of that link. As such, one would expect hyperlink networks to be characterized by relatively unconstrained indegree distributions (i.e., power law distributions), whereas information flow networks’ indegree distributions would be constrained by the costs of receiving additional links.

NGO hyperlink networks among organizational Websites are an underresearched network. Public affiliations through hyperlinks play an important role in NGO collective action (Biddix & Park, 2008; Lusher & Ackland, 2010). Hyperlinks provide a powerful way for both members and nonmembers (e.g., NGOs engaged in another issue, publics) to locate and make sense of the number of NGOs working on an issue (see for example Rogers & Ben-David, 2008). Public goods are beneficial resources or outcomes commonly shared, and are often tied to the creation of communication-systems (Fulk, Flanagin, Kalman, Monge, & Ryan, 1996) or policy outcomes (Knoke, 1990). Like other forms of collective action, the contribution of a hyperlink to another organization (i.e., posting a hyperlink on one’s Website) is a contribution toward the collective goals of the two organizations. Like contributions to other communication-based public goods, a social dilemma is also present. The choice to contribute hyperlinks promotes the collective good (Shumate & Lipp, 2008), but receiving hyperlinks without contributing them has prestige benefits (Kleinberg, 1999; Rogers & Marres, 2000).

An Evolutionary Model of NGO Hyperlink Network Dynamics

Although previous researchers have examined hyperlink networks as systems of representational communication (Lusher & Ackland, 2010; Shumate & Lipp, 2008) and suggested their role in NGO collective action (Biddix & Park, 2008; Lusher & Ackland, 2010), few have recognized their dynamic nature. Indeed, due to the low cost of establishing a hyperlink, organizational Websites quickly can be altered to include new or remove old hyperlinks. The dynamics of this system of representational communication are of interest for two reasons. First, as a system of communication, the choice to create or remove a hyperlink should be understood within the context of the already existing network of relations. Although previous research has examined the pattern of these relations, it yet has to take up these embedded choices to create or remove hyperlinks and thereby, change the nature of the system of communication. Second, once researchers move to understanding these networks as dynamic, various processes of change are brought into relief. Different Websites might change their portfolio of hyperlinks more or less frequently and the choices to create or retain hyperlinks might be influenced by different factors. In order to take up these issues, the current research turns to evolutionary theory to describe the dynamic processes that shape NGO hyperlink evolution.

Several social scientists and organizational scholars argue that socioevolutionary theory should be used to understand social and organizational dynamics (e.g., Aldrich & Ruef, 2006; Campbell, 1965; Monge, Heiss, & Margolin, 2008). Similarly, this research argues that socioevolutionary theory provides a useful framework for understanding the processes that shape NGO hyperlink networks over time. Campbell defines three processes that govern socioevolutionary dynamics: variation, selection, and retention.

Variation is defined as changes in routines, competencies, resources, forms, or most importantly for this research, network ties (Campbell, 1965). As such, rate of variation indicates the amount of change that occurs in a given time period. In hyperlink networks, some NGOs might make changes to their hyperlink portfolio more often than other NGOs. As such, the rate of variation in the hyperlink network would be higher for these NGOs than for other NGOs.

One factor that might influence the rate of variation is receiving ties from other populations of Websites (Monge, et al., 2008). In the current research, these other populations include governments...
and corporations. Governments have varied relations with NGOs. Similarly corporations might have competitive, cooperative, or neutral relationships with NGOs. However, in recent years, corporations have increasingly formed a variety of types of relationships with NGOs, including symbolic ones designed to transfer affect (Dickinson & Barker, 2007) and capital (Shumate & O’Connor, 2010) through communicating affiliation to various stakeholders. In short, NGOs are influenced by relationships with actors in other sectors, including corporations and governments and these influences are likely to be reflected on the Web.

On the internet, many organizational actors seek to shape public discourse. These include governments, corporations, and NGOs. However, while governments and corporations had dominance in public discourse offline, “the internet changes the balance of power between NGOs, companies and governments” (Bray, 2000, p. 47). NGOs are highly desirable affiliation partners (Dahan, Doh, & Teegen, 2009), having more public trust than either governments or corporations (Wootliff & Deri, 2001). However, some NGOs are seen by cross-sector partners as friendlier than others (Lucea, 2009). Some NGOs are likely to receive a greater number of hyperlinks from governments and corporations. As such, they are more embedded in the set of relations that cross sectors. Network embeddedness refers to the existing set of ties that constrain and/or encourage particular behaviors (see Borgatti & Foster, 2003 for a review). According to evolutionary theory (Astley, 1985), greater cross-sector network embeddedness would lead such NGOs to update the hyperlinks on their Websites more frequently. Therefore, I hypothesize:

H1: NGOs with a greater number of hyperlinks from government and corporate Websites 2 months prior prefer to change their ties more quickly than NGOs with fewer ties from these Websites.

Selection is defined as the choice of one alternative over others (Campbell, 1965). In hyperlink networks, selection is the choice to hyperlink to a particular type of NGO Website. Some NGOs may possess particular characteristics that make them more desirable to some or most NGOs. Further, network embeddedness might make choosing some NGO Websites more attractive than others.

Van de Bunt and Groegwein (2007) highlight three types of network embeddedness that might influence interorganizational network evolution: creating ties to reciprocate relations, to complete transitive closure, and to organizations that have a significant number of existing relations. The first factor that might influence the target of NGO hyperlinks is reciprocity. Rogers and Marres (2000) theorize that reciprocity occurs in hyperlink networks in order for organizations to position a set of NGOs at the center of an issue. While the choice to hyperlink does represent some cost to the NGO, such costs are outweighed by the collective action benefits for their issue network (Shumate & Lipp, 2008). Reciprocating ties enhances the other NGO’s position, favoring collective visibility over individual prestige. However, previous research examines the presence of reciprocal ties rather than their formation over time. Nonetheless, based upon this previous research, I hypothesize:

H2: NGOs prefer to reciprocate hyperlinks from other NGOs.

The second type of embeddedness that might influence hyperlink network evolution is the closure of transitive ties (van de Bunt & Groenewegen, 2007; see Kossinets & Watts, 2006 for a similar argument regarding e-mail patterns). Triadic closure occurs when NGO A hyperlinks to NGO B under the following conditions: NGO C already has a hyperlink to or from both NGO A and NGO B (i.e. transforming a chain of three NGO Websites into a triad that each has a connection to the other). Triadic closure occurs between organizations because partners of partners tend to have a good network reputation and such organizations are less costly to find. In a similar way, NGOs
might locate new reputable Websites through the hyperlinks of their partners. As such, I hypothesize that:

H3: NGOs prefer to create hyperlinks that result in transitive closure.

One of the factors that might influence to which NGOs another NGO will hyperlink over time is popularity. Popularity has been supported as a key feature in network evolution in other types of social networks, including citation patterns and the network of routers that comprise the internet (Leskovec, Kleinberg, & Faloutsos, 2005). Further, Pennock, Flake, Lawrence, Glover, and Giles (2002) have found support for preferential attachment, or the preference for popular others, in a hyperlink network of corporate and newspaper sites. However, they found popularity to be less robust explanation in university and scientists’ homepages.

In the current work, NGOs with greater popularity are thought to be preferred in the hyperlink network due to social influence among sites and recognition of the legitimacy of some NGOs. As noted by Shumate and Lipp (2008), social influence is an important element in collective action theory. Both Olson (1965) and Knoke (1990) note that social influence provides a selective incentive for public good contributions. As such, normative linking patterns in connective goods enable the public good, rather than compete with the public good. Popular NGO Websites are likely to have a greater number of visitors and higher perceived credibility (Park, et al., 2002). Therefore, NGOs that link to popular NGOs encourage publics to visit the most credible NGOs within the movement. Preferential attachment (i.e., hyperlinking to Websites with a greater indegree centrality) is suggested in the evolution of issue-specific NGO hyperlink networks. Therefore, I hypothesize:

H4: NGOs prefer to add hyperlinks to NGOs with high indegree centrality.

Other networks are another factor that may influence NGO hyperlink evolution (Monge, et al., 2008); two important networks for NGOs are issue networks and the network of relationships with governments and corporations. Similar communication in Websites has been found to be significantly related to the connectedness of various Websites (Menczer, 2004). In political networks, issue networks describe politicians (Kim, Barnett, & Park, 2010) or NGOs (Rogers & Ben-David, 2008) that are engaged in similar policy discourse; in such networks, the politicians or NGOs that address the same social issue are linked. Issue networks are an important part of how NGOs engage in collaborative policy discourse on the Web (Bach & Stark, 2004). In addition, issue networks are related to hyperlink networks. Kim and colleagues (2010) found that U.S. politicians’ Websites that engage the same social issues were likely to be hyperlinked. The current research extends prior research on the relationship between issue networks and hyperlink networks in two ways. First, this research examines the degree to which issue networks of NGOs with varied opinions and views, as opposed to politicians engaged in a policy conflict, are related to their hyperlinks. Second, rather than examining the relation between the hyperlink network and the issue network at one point in time, this research investigates if the NGO issue network continues to influence hyperlink network selection. Based upon previous research, I hypothesize:

H5: NGOs prefer to create hyperlinks to other NGOs with similar Website communication about their social issue.

As illustrated in the variation section, corporations and government relationships to NGOs have an important influence on evolutionary processes. These processes might extend to selection (see Monge, et al., 2008). NGOs are thought by many managers to fall into two categories, those that are
cooperative and those that are not (Lucea, 2009). NGOs that are cooperative are likely to benefit from the resources of both corporations and governments, while NGOs that are not must rely on other resources (e.g., foundations, members, individual donors). Resources have a powerful influence on NGO hyperlinks. Gonzalez-Bailón (2009) demonstrates that NGOs with the greatest economic resources receive the greatest number of hyperlinks. She theorizes that other types of resources, like corporate and government hyperlinks, might act as incentives for hyperlinking as well. However, she examined the hyperlink network at a single point in time. The current research pushes the argument further, positing that such heterogeneous selection incentives continue to influence the hyperlink network. As such, I hypothesize:

H6: NGO Websites that receive a large number of government and corporate hyperlinks will be preferred by NGOs in the creation of new hyperlinks.

Retention occurs when organizations reaffirm past selections and maintain past routines by re-enacting selections over time (Campbell, 1965). In hyperlink networks, the choice to keep a hyperlink for a period of time represents retention. Some hyperlinks might be more likely to be retained than others. Previous research on hyperlink networks does not take up the question of the retention of hyperlinks, instead focusing on their presence or absence. As such, this research explores this evolutionary process by asking:

RQ: Which of the above mentioned factors are also related to the retention of hyperlinks?

**Method**

**Sample and Procedure**

Data from HIV/AIDS NGO Websites was collected each month for 12 months, from September 2006 through September 2007, using Issuecrawler (Rogers, 2009). A modified snowball sampling strategy was employed to determine network boundaries because there was not a suitable directory to use to set the boundaries of the network.

The sampling strategy is as follows. A set of seed URLs was obtained in two steps. First, the author obtained a list of all organizations from the 2003 volume of the Yearbook of International Organizations whose aims and descriptions included HIV, AIDS, or SIDA. This yielded a total of 71 organizations with valid Websites (89% had a valid Website).

However, because Issuecrawler is sensitive to the use of seed URLs when conducting its snowball sampling, an additional step was used to gather NGO names that were not listed in the YIO. Two research assistants independently used Google “links to” to identify all the organizations that linked to these 71 HIV/AIDS international NGOs. Each of these Websites was examined. This yielded a total of 241 organizational Websites, including the initial 71 from the YIO. These organizations included corporate Websites, government Websites (including intergovernmental organizations), and education organization Websites. Search engine Websites and Websites that were not proxies for organizations (e.g., blogs, informational Websites) were excluded. The identified organizational Websites were the seed URLs for the monthly crawl.

The site maps of these organizations were examined and most site maps did not have information beyond three levels away from the index page. As such, the crawler was run with a page depth of three and over three iterations each month. Each subsequent Webcrawl was based upon the results of the previous network. The largest number of Website domains included in 1 month was 190 and the smallest was 185. Each Website was examined and the HIV/AIDS NGO network was extracted from the
main network. There were 133 HIV/AIDS NGOs that appeared at any time in the hyperlink network. HIV/AIDS NGOs were located in 27 countries across Africa \( (n = 5) \), Asia \( (n = 4) \), Australia/New Zealand/Pacific Islands \( (n = 5) \), Western Europe \( (n = 44) \), Eastern Europe \( (n = 3) \), North America \( (n = 61) \), and South and Central America \( (n = 6) \). The majority of Websites included English-language text \( (n = 114) \). Other languages included Spanish \( (n = 13) \), Portuguese \( (n = 7) \), Italian \( (n = 4) \), Russian \( (n = 4) \), German \( (n = 2) \), Arabic \( (n = 2) \), Dutch \( (n = 1) \), Danish \( (n = 3) \), and Bulgarian \( (n = 1) \). In addition, the corporate/government organization by HIV/AIDS NGO hyperlink network was extracted each month. Seventy-six corporate or government, including intergovernmental organization, Websites were included at any time over the 12 months. More details are available in the supplemental material.

Measures

*NGO Hyperlinks* were recorded by Issuecrawler each month. The analysis, because of the lack of variability between months, focused on changes that occurred between observations 3 months apart: November 2006, February 2007, May 2007, and August 2007. The hyperlinks between Websites variable was binary. The descriptive information about each of these networks is located in Table 1.

*Outdegree* was the effect against which all others are conditioned and was a measure of the degree that there is propensity for actors to send ties to others (Snijders, 2001). *Constant network rate* was defined as the degree to which the base rate stays the same across time periods and does not vary depending upon actors (Snijders, Bunt, & Steglich, 2010). Both measures were included in the modeling of the evolution of the HIV/AIDS NGO hyperlink network.

Three measures based upon network embeddedness were included (see Snijders, 2001 for formulas). *Reciprocity* was defined as the addition of a hyperlink so that two NGOs mutually link to one another. *Transitive closure* was defined as the addition of ties that result in three Websites having ties to one another. *High indegree*, or popularity indegree, was defined as the addition of hyperlinks to a Website in relation to its indegree centrality.

*Government and corporate ties* were defined as the number of hyperlink ties from government organizations and corporations to HIV/AIDS NGOs. Government and corporate ties were a changing covariate and were indicated in September 2006, December 2006, March 2007, and June 2007.

*Website communication similarity* was indicated by the degree to which all English text from the ‘About Us’ section of HIV/AIDS NGO Websites contained similar social issue discourse. There were 22 organizations for which suitable English text could not be identified and their resonance scores were indicated as missing.² Resonance was computed using Centering Resonance Analysis techniques, by the Crawdad text analysis system (Corman & Dooley, 2006), which examined noun phrases and their distance from one another in any text (Corman, Kuhn, McPhee, & Dooley, 2002). The process yielded

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptive statistics across 4 time periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
<tr>
<td>Density</td>
<td>0.035</td>
</tr>
<tr>
<td>Average degree</td>
<td>4.697</td>
</tr>
<tr>
<td>Number of ties</td>
<td>620</td>
</tr>
<tr>
<td>Number of mutual ties</td>
<td>43</td>
</tr>
<tr>
<td>Number of asymmetric ties</td>
<td>534</td>
</tr>
<tr>
<td>Number of active NGOs</td>
<td>115</td>
</tr>
<tr>
<td>Number of domains before extracting NGO network</td>
<td>190</td>
</tr>
</tbody>
</table>
two relevant outputs. First, Centering Resonance Analysis produced word maps for each text. These word maps indicated the frequency of nouns, the relationship between noun pairs within the text, and a visual map of each document. Based upon the noun pairs, I used an emic approach to identify words that indicated the most controversial topics in HIV/AIDS social change work: “microbicide” and “microbicides,” “needles,” and “gay” and “bisexual” (see Patton, 2002 for background). Three affiliation matrices were created based upon the resonance scores NGOs had for each of these issues. Then these three matrices summed, creating a semantic network that measured common Website communication.

Analysis
This project used an overtime network analysis technique called actor-oriented modeling (Snijders, 2001; Snijders, et al., 2010). This study used SIENA 4.0 (Ripley & Snijders, 2010) within the R-project package to analyze a longitudinal model with four observations (see Snijders, et al., 2010). SIENA combined empirical estimation with simulation to understand network evolution (see supplemental material for more about the model assumptions). Estimates were based upon the network structure and changes across time periods (see Table 2 for a summary of the changes that occurred across time periods). Simulations were used to infer the process of change that occurred between time periods.

Conditional method of moments estimation was implemented. Convergence was indicated by $t$-ratios less than 0.1. All parameters converged in the reported models. Changes in network composition were accounted for using structural zeros. A parameter was considered significant when the estimate was 1.96 times the magnitude of the standard error. In order to test the hypotheses and investigate the research questions, several nested models were created. Based upon the suggestions made Ripley and Snijders (2010), a model that included the hypothesized parameters, without the retention parameters, was created first (i.e., the hypothesized model). Then, the model was examined and nonsignificant variables were removed (i.e., the revised model). Next, an exploratory model was created that included retention parameters for each of the significant selection effects (for more on why retention effects depend upon selection effects see Snijders, 2001). Finally, a model was created that included the main effects and the retention effects that were significant (i.e., the final model). Each of the results from these models is included in Table 3.

Results
Hypothesis 1 stated that the number of government or corporate hyperlinks to a NGO Website two months prior would be positively related to rate of variation. This hypothesis was supported ($Estimate = 0.14$, $SE = 0.02$). NGOs that had more hyperlinks to their Website from corporations and government organizations preferred to vary the hyperlinks on their Websites than NGOs that received fewer of these hyperlinks.

Table 2  Changes in ties across four time periods

<table>
<thead>
<tr>
<th>Period</th>
<th>$0 \rightarrow 0$</th>
<th>$0 \rightarrow 1$</th>
<th>$1 \rightarrow 0$</th>
<th>$1 \rightarrow 1$</th>
<th>Jaccard Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 $\rightarrow$ 2</td>
<td>16898</td>
<td>38</td>
<td>135</td>
<td>485</td>
<td>.74</td>
</tr>
<tr>
<td>2 $\rightarrow$ 3</td>
<td>16933</td>
<td>100</td>
<td>36</td>
<td>487</td>
<td>.78</td>
</tr>
<tr>
<td>3 $\rightarrow$ 4</td>
<td>16929</td>
<td>40</td>
<td>75</td>
<td>512</td>
<td>.82</td>
</tr>
</tbody>
</table>
Table 3  Results of four models

<table>
<thead>
<tr>
<th>H</th>
<th>Effect</th>
<th>Hypothesized Model</th>
<th>Revised Model</th>
<th>Exploratory Model</th>
<th>Final Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation (period 1)</td>
<td></td>
<td>0.39*</td>
<td>0.39*</td>
<td>0.41*</td>
<td>0.37*</td>
</tr>
<tr>
<td>Variation (period 2)</td>
<td></td>
<td>0.43*</td>
<td>0.43*</td>
<td>0.44*</td>
<td>0.41*</td>
</tr>
<tr>
<td>Variation (period 3)</td>
<td></td>
<td>0.88*</td>
<td>0.88*</td>
<td>1.04*</td>
<td>0.84*</td>
</tr>
<tr>
<td>Outdegree</td>
<td></td>
<td>−3.17*</td>
<td>−4.21*</td>
<td>−2.84*</td>
<td>−2.05*</td>
</tr>
<tr>
<td>H1 # corporate/government ties variation</td>
<td></td>
<td>0.13*</td>
<td>0.13*</td>
<td>0.15</td>
<td>0.14*</td>
</tr>
<tr>
<td>H2 Reciprocity selection</td>
<td></td>
<td>0.56*</td>
<td>0.54*</td>
<td>0.63</td>
<td>0.57*</td>
</tr>
<tr>
<td>H3 Transitive ties selection</td>
<td></td>
<td>0.84*</td>
<td>0.65*</td>
<td>5.04</td>
<td>0.61*</td>
</tr>
<tr>
<td>H4 High indegree selection</td>
<td></td>
<td>0.06*</td>
<td>0.60*</td>
<td>0.92*</td>
<td>1.06*</td>
</tr>
<tr>
<td>H5 Comm. similarity selection</td>
<td></td>
<td>0.60*</td>
<td>0.58*</td>
<td>1.62</td>
<td>1.17*</td>
</tr>
<tr>
<td>H6 # corporate/government ties selection</td>
<td></td>
<td>0.03</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RQ Reciprocity retention</td>
<td></td>
<td>—</td>
<td>1.43</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RQ Transitive ties retention</td>
<td></td>
<td>—</td>
<td>−8.91</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>RQ High indegree retention</td>
<td></td>
<td>—</td>
<td>−1.72</td>
<td>−1.91*</td>
<td>—</td>
</tr>
<tr>
<td>RQ Comm. similarity retention</td>
<td></td>
<td>—</td>
<td>−1.04</td>
<td>−1.38*</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. * indicates that the estimate was 1.96 greater, in magnitude, than the standard error.

Hypothesis 2 was supported (Estimate = 0.57, SE = 0.25). It stated that HIV/AIDS NGOs would demonstrate a tendency to reciprocate ties over time. Hypothesis 3, that HIV/AIDS NGOs would demonstrate a selection preference for ties that would result in transitive closure, was supported (Estimate = 0.61, SE = 0.21). Similarly, HIV/AIDS NGOs demonstrated a tendency to hyperlink to NGOs with high indegree centrality (Estimate = 1.06, SE = 0.13). Therefore, hypothesis 4 was supported. Additionally, HIV/AIDS NGOs favored creating hyperlinks to other NGOs with similar Website communication about issues, supporting hypothesis 5 (Estimate = 1.17, SE = 0.39). Hypothesis 6, that NGO Websites that received a higher number of hyperlinks from corporate and government Websites would be more likely to be selected, was not supported (Estimate = 0.03, SE = 0.03). This parameter was not retained in the revised or final models.

The research question asked which of the selection parameters would also be related to retention. Two parameters were retained in the final model and were significant. Indegree popularity was significant (Estimate = −1.91, SE = 0.36 ) and the combined parameter was negative (1.06 + −1.91 = −0.85). Hyperlinks to more popular Websites were more likely to be dissolved than hyperlinks in general. The effect of similar Website communication on retention was negative (1.17 + −1.38 = −0.21), and the parameter was significant (Estimate = −1.38, SE = 0.64). Hyperlinks to Websites that have more similar communication were more likely to be dissolved than hyperlinks in general.

**Discussion**

The purpose of this research is to examine the factors that influence the dynamics of NGO hyperlink networks. Three evolutionary processes shape the configuration of these networks: variation, selection, and retention (Campbell, 1965). The results of the current research support the relationships between several factors and the rate of variation, selection of particular types of hyperlinks, and retention of hyperlinks with some NGOs.
Variation in the hyperlink network is not consistent across all NGOs. Instead, NGOs with a greater number of government or corporate hyperlinks referencing their organization 2 months prior enact a higher rate of variation. The results suggest that the HIV/AIDS NGO hyperlink network is not a closed ecological system; it is related to the actions of both corporations and governments. Cross-sector hyperlink network embeddedness is a source of increased variability.

Selection in the hyperlink network is influenced by three types of network embeddedness. Existing network structures that make it possible to reciprocate a hyperlink, to create transitive closure, or to link to a Website with a higher number of existing hyperlinks influence the creation of new hyperlinks. Support for these structural effects implies: a) that NGOs are aware of which other NGOs hyperlink to them, b) that they are aware of which NGOs are hyperlinked to by other NGOs in their local network, and c) that they are aware of the popularity of some NGOs in the larger hyperlink network. Each of these effects supports the view that HIV/AIDS NGOs hyperlinks are rationally contributed and that HIV/AIDS NGOs are aware of the structure of at least part of the hyperlink network.

In addition, communication content of Websites is related to the selection of hyperlinks. NGOs with similar Website communication are more likely to create hyperlinks to each other than to other organizations. Extending the work of Kim and colleagues (2010), this research suggests that NGO issue networks are related to the selection of hyperlinks over time. Using centering resonance analysis (Corman, et al., 2002) to inductively identify social issues and their prominence, this research demonstrates that NGOs discuss HIV/AIDS in different ways. In the current research, three controversial issues are related to HIV/AIDS NGO hyperlinking: microbicides, intravenous drug usage (e.g., needles), and homosexual intercourse. The means of transmission of HIV/AIDS has tended to characterize patterns of response to the disease in the past (see Patton, 2002). The results suggest that communication about both the means of transmission (e.g., intravenous drug use, homosexual intercourse) and means of prevention (e.g., microbicides) also are related to HIV/AIDS NGOs’ hyperlink evolution. The different dimensions of HIV/AIDS as an issue reflected in this communication plays an important role in understanding a) what collective action goals NGOs seek and, in the future, b) how these different approaches to the same social issue are related to one another.

NGOs that receive ties from corporate and government Websites, including intergovernmental organization Websites, were hypothesized disproportionately to be the target of new hyperlinks in the HIV/AIDS NGO network. This hypothesis is not supported. Lucea (2009) suggests that NGOs see each other differently than their corporate and government counterparts. This difference in cognition might be the reason why corporate and government hyperlinks do not seem to act as a resource for NGOs in hyperlink networks.

The difference between the variation and selection effects presents an intriguing contrast and an illustration that variation and selection effects, while both shaping network evolution, work differently. In particular, the influence of corporate and government hyperlinks on variation but not selection suggests that faster variation might suppress the popularity of some Websites within the hyperlink network. Collective action research suggests that NGOs that do not believe that they will benefit from hyperlinking to some NGOs will be less likely to do so (Bardsley & Moffatt, 2007). Building reciprocal and transitive structures in the network that mutually reinforce NGOs’ positions are undermined by organizations that frequently change their hyperlinks. As such, while these organizations might receive recognition from other sectors, they might not be seen as reliable hyperlinking partners by NGOs.

Finally, two factors are related to the retention of hyperlinks. Indegree centrality and similar issue network participation negatively are related to the likelihood of hyperlink retention. Organizations might initially link to popular Websites in hopes of enhancing their own position within the hyperlink network through reciprocity. If no reciprocal response is given or no benefit is derived, these hyperlinks might be short-lived (Bardsley & Moffatt, 2007). Alternatively, hyperlinks to these Websites may be
weak ties are that are not reinforced through other types of relationships between the NGOs. Kossinets and Watts (2006) found that weak ties among individuals, as indicated by their frequency of e-mail contact, were more likely to dissolve over time than strong ties. A similar logic may apply to hyperlinks among NGOs. If ties to highly popular NGO Website or NGO Websites with similar communication are not reinforced, either through reciprocity or through another type of relation, then these ties may be less likely to be retained than other stronger ties.

The current research presents a preliminary step in understanding the dynamics of NGO hyperlink networks over time. First, it illustrates that some NGOs change the hyperlinks on their Websites more often than others, and these NGOs are more likely to receive hyperlinks from corporations or government organizations. Second, it illustrates that network embeddedness and issue network participation effect the continued creation of hyperlinks. NGOs prefer to reciprocate hyperlinks, create hyperlinks that result in transitive closure, and link to Websites that already receive a greater number of hyperlinks. Further, NGOs that commonly participate in the same issue network have a tendency to choose to hyperlink to one another. Third, hyperlinks to very popular Websites and to NGOs in the same issue network are less likely to be retained than other hyperlinks. In sum, the research demonstrates that although variation, selection, and retention each play a role in the dynamic structure of NGO hyperlink networks, each process is correlated with different factors.

Limitations and Future Research
This research, while a significant step toward understanding the role of various factors in NGO hyperlink network evolution, is limited to one social issue industry and one year. Similar to research on other types of NGO interorganizational relationships (Atouba & Shumate, 2010; Shumate & O’Connor, 2010), NGOs in different social issue industries are likely to have different types of hyperlinks. Further, evolutionary theory suggests that interorganizational network evolution is likely to be path dependent (W. P. Barnett, Mischke, & Ocasio, 2000), making the varied histories of various NGO populations an important factor in their continued evolution. As such, research on other social issues and across longer time frames is necessary to assess the generalizability of these findings. In addition, the current research is limited by the nature of texts that were examined. Twenty-two of the 133 texts were excluded from the analysis, and entered as missing data, because there was not a suitable English language ‘About Us’ text to analyze. Future research should make efforts to include texts in multiple languages and to find ways to compute similarity between texts across languages. Finally, the current analysis examined HIV/AIDS NGOs worldwide. In some countries and regions, different trends may predominate and, as such, future research should examine hyperlink networks for regional and country by country differences.

This research suggests that variation, selection, and retention are each influenced by different factors. Future research should further test this proposition and explore other factors that might influence each of these processes. There are at least the possible fruitful additions: (a) the ways that issue networks and hyperlink networks might coevolve; (b) the ways that other types of offline relationships may coevolve with hyperlinks; and (c) the influence of change in corporate/government hyperlinks on change in NGO hyperlink networks.

First, the relationship between the semantic text and hyperlink structure of the internet is important for the development of search engines to identify relevant content (see Menczer, 2004). As such, research that demonstrates the varied ways in which Website content and link structure are related has important implications. The finding that retention and selection mechanisms operate differently for similar Website content provides a first step towards a more nuanced understanding of these dynamics.

A second fruitful area for research is to expand the scope of the current project by examining how varied offline relations are related to hyperlink network evolution. Indeed, Pilny & Shumate (in
press) found that hyperlinks were positively related to financial ties, membership ties, and collaboration ties among NGOs offline. An important next step in this line of research is to examine how these and other offline relations, including corporate interlocks, may coevolve with the hyperlink network among NGOs. Similarly, financial resources may represent an important cofounding variable. NGOs with greater resources may update their hyperlinks more frequently because they can afford to pay Webmasters to do so.

A third fruitful area for research is to consider how change in corporate and government hyperlink networks with NGOs may cascade across the NGO hyperlink network. Leskovec and colleagues (2005) Forest Fire model presents an avenue for such research. In their model, some “highly flammable” nodes create rapid first changes that “burn” across the network through their immediate connections. Similarly, NGOs that are experience rapid changes in their corporate and government hyperlinks may produce changes in the NGO hyperlink network that burn across the network, causing significant disruption to the existing hyperlink structure.

Conclusion

The purpose of this research is to examine the evolutionary processes that influence NGO hyperlink network evolution, focusing on the factors that influence variation, selection, and retention. This paper makes two contributions to research and theory about NGO hyperlink networks. First, it demonstrates that the processes of variation, selection, and retention are influenced by different factors. As such, future research should examine hyperlinks as dynamic systems of representational communication and explore these underlying processes. Second, this research indicates that NGO issue networks are related to the creation of hyperlinks, but that these hyperlinks are particularly short-lived. As such, it suggests different motivations for some hyperlinks and that if hyperlinks do not result in gains, they might be as quickly dissolved as they are created.

The internet has transformed modern collective action (Bach & Stark, 2004; Bimber, et al., 2005), including the ways that NGOs represent their relationships. This research represents a first step in differentiating the processes influencing hyperlink network evolution over time. More research and theorizing are needed to understand the dynamics of these networks.

Notes

1 Issuecrawler is a well-documented Web crawler that has been used extensively to study transnational issue and hyperlink networks (e.g., Rogers, 2009; Rogers & Ben-David, 2008). For more on the tool, please visit: http://www.govcom.org/Issuecrawler_instructions.html
2 Because Crawdad relies on semantic distance, automated translation of texts with different tendencies for the placement of noun-phrases would have created a confounding variable in the analysis.
3 Upon the suggestion of one of the reviewers, a model was created that also included indegree activity, in-in degree assortativity, and three cycles effect (see Ripley & Snijders, 2010 for description) to control for alternative explanations. None of these parameters were significant and results are available by contacting the author.

References


Supporting Information

Additional supporting information may be found in the online version of this article: Technical Method Appendix

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