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A Replication and Extension of Goldenberg, Libai & Muller: A Complex Systems Look at the Underlying Process of Word-of-Mouth

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Abstract

Goldenberg, Libai & Muller (2001) achieved two outcomes: empirical support for a fundamental theory of communications, known as the “strength of weak ties” (Granovetter 1973), and an explication of small-worlds simulations in marketing. Where Goldenberg et al found that weak-ties had as much or more effect on information dissemination than did strong ties, a near-exact replication, reported in this paper, found that weak-ties had less than one third of the influence of strong-ties. An exact replication and extension, to be presented at the conference and under review with the same journal as the Goldenberg study, leads us to be sceptical of the original findings.

Introduction

A highly regarded paper by Goldenberg, Libai and Muller (2001) published in *Marketing Letters* proffers fairly convincing evidence for the validity of Granovetter's (1973) theory of the strength of weak ties. This theory posits that occasional, seemingly unimportant contacts frequently make information available to otherwise isolated groups and are thus necessary for the dissemination of knowledge.

A simplified version of the simulation model, adapted as an Excel spreadsheet, is accessible from Goldenberg's website (complexmarkets.com) for students to get a feel for the relative influences of different parameters on the dissemination process. To the author's surprise, a full-factorial experiment, which included all available levels in the model, failed to provide similar results as in the published paper. It was decided to attempt to replicate the original study.

Strength of Weak Ties

Mark Granovetter's theory of the strength of weak ties seems to have gained currency more in the fields of political science and social economics than in marketing. This is a pity since it can help explain a great deal about how to better communicate with hard-to-reach target markets (Barabasi 2003). It is the theoretical underpinning for our understanding that a critical mass of knowledge, or roll-models, is needed for a person or a group to transform behaviour, a phenomenon popularly called a tipping point (Gladwell 2000).

For the purposes of this paper we can consider consumers to be members of relatively isolated networks of members who have regular close contact with each other with strong influence. Members of these networks also occasionally communicate with members of other networks but with much weaker influence. Contacts amongst strong tie members are permanent while weak ties are temporary.

Figure 1 is drawn from this study, illustrating how spatial relationships affect the likelihood of transition, in this case from uninformed to informed.

Agent-Based Modelling

Agent-based models are generally computer-based simulations of complex systems. Typically independent "agents" operate concurrently and interact with each other in space and time. This makes it possible to explore the connection between the micro-level behaviour of individuals and the macro-level patterns that emerge from the interaction of many individuals (Wilensky, 1999). Developed at the conceptual level by John Von Neuman in the 1940's the approach took off in the 1990's with the development of fast personal computers, and applied research by Craig Reynolds (2007), Stephan Wolfram (2002), and those at the Santa Fe Institute (2007).

The role and influence of word-of-mouth has been modelled elsewhere using agent-based-models. For example, models of WOM are under prototype with the Information Cities project with the Swedish Institute of Computer Science (SICS, 2007). Recommendations by strangers online is of particular interest to marketers – e.g. Rafea et al. (2002), Beck (2007), Kambe et al (2007) – indeed tracking and modelling of online WOM is a growing business for Internet research consultants – e.g. Icosystem Solutions (2007).

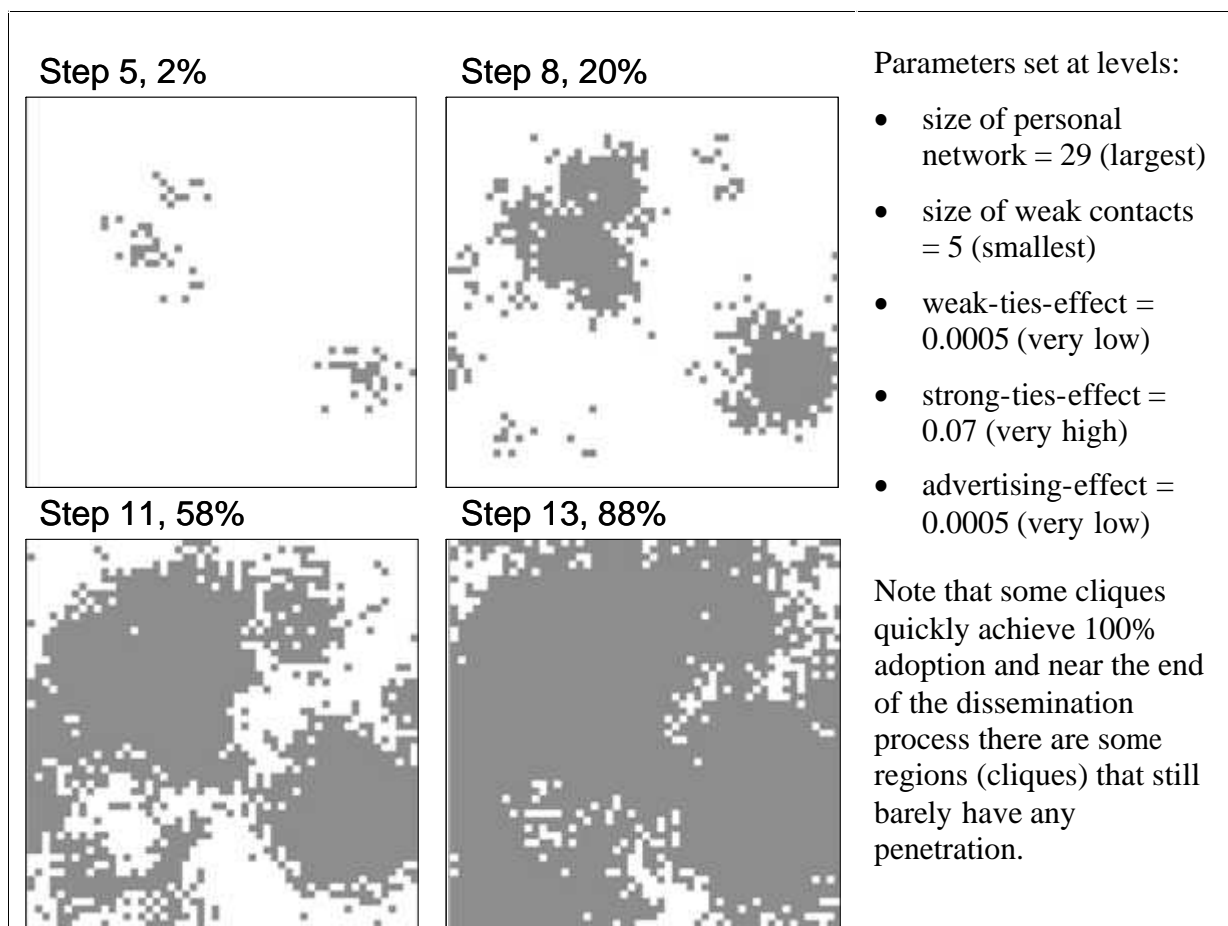


Figure 1: Four consecutive stages of the evolution of the Cellular Automata model used in this study, indicating the steps in time and the level of dissemination

Replication of the Goldenberg study

Replication of the Goldenberg study required the selection of appropriate software, coding of the model and selection of appropriate parameters.

Software

The author chose to use NetLogo (Wilensky, 1999) for this study. NetLogo is a programmable modelling environment for simulating natural and social phenomena. The NetLogo program is available as a free download and has a large and enthusiastic user base from all varieties of the physical and social sciences. Goldenberg's simulation was created using home-made software written in C++. NetLogo is freely available and the programs designed by the author may be downloaded from the author's website (humewinzar.com) so that other researchers can check the results and the modelling assumptions for themselves, and expand on the models.

Parameters

In this model the probability of any one agent becoming informed of a brand at time (t) is given by the following equation:

$$p(t) = (1 - (1 - a)(1 - w)^j(1 - s)^m)$$

where:

- a parameter defining the effectiveness of advertising, range 0.0005-0.01,
- w parameter defining the effectiveness of weak contacts, range 0.005-0.015,
- s parameter defining the effectiveness of strong contacts, range 0.01-0.07,
- j is the number of informed others within an agent's personal network, range 5-29,
- m is the number of informed others from outside the personal network with whom one agent has made contact, range 5-29.

At each iteration in the model, for each agent, a random number between 0 and 1 is drawn from a uniform distribution. If the score $p(t)$ is larger than the random number then the agent moves from uninformed to informed – 0 to 1.

Agents were modelled as the cells in a $53 \times 53 = 2809$ matrix. Goldenberg used a matrix of 3000 agents. (Actually, a preliminary test confirmed the inverse-square relationship between sampling error and sample size. It showed that a $35 \times 35 = 1225$ matrix would give similar results, with only slightly lower R^2 , and with 70% reduction in processing time.)

Each of the five independent variables – size of personal network, size of weak contacts, weak effects, strong effects, and advertising effects – were manipulated at four levels. Thus, a full-factorial experimental design gives $4^5 = 1,024$ information dissemination process simulations. Goldenberg manipulated each parameter at seven levels giving $7^5 = 16,807$ simulations.

Results

We are interested in the relative effects of the independent variables at important stages of the information dissemination process. Three sets of regressions were calculated with the dependent variable as the number of time intervals from (1) launch to 16% penetration, (2) 16% to 50% penetration, and (3) 50% to 95% penetration. Results are summarised in Table 1. Results are all presented as standardised Betas for easy comparison of the effects of each influence and comparison between the two studies. The effects of two important regressors, Size of personal network and Size of weak contacts, were not reported in the Goldenberg study.

We can see that this replication presents results that are broadly in agreement with the results reported by Goldenberg, except that the Beta estimates for weak-ties-effect are substantially lower than in Goldenberg's results. In all other respects, the results of this replication offer similar conclusions to those of the original study. These are listed below.

- **Result 1:** The influence of weak ties on the speed of information dissemination is at least as strong as the influence of strong ties. **Not supported:** Weak ties effects were never more than 40% of Strong ties effects. See Table #1.
- **Result 2:** Beyond a relatively early stage of the process, the effect of external marketing efforts (e.g., advertising) quickly diminishes and strong and weak ties become the main forces propelling the process. Supported: Similar results but not to the same dramatic extent as in Goldenberg. See Table #1.
- **Result 3:** The effect of strong ties on the speed of information dissemination increases as personal network size increases. Supported.
- **Result 4:** As the number of weak ties contacts increases, the effect of strong ties decreases while the effect of weak ties increases. Supported.
- **Result 5:** As the level of advertising increases, the effects of both strong and weak ties are marginally impacted, in inverse directions: the effect of strong ties increases while the effect of weak ties decreases. Supported.

Table 1: Relative effectiveness of Advertising, Strong ties & Weak ties at 3 stages of the Information Dissemination process - Standardised regression estimates - (with results from Goldenberg study for comparison)

	T ₀ -T _{16%}		T _{16%} -T _{50%}		T _{50%} -T _{95%}	
size_of_personal_network	-.29	n.r.	-.52	n.r.	-.53	n.r.
size_of_weak_contacts	-.18	n.r.	-.39	n.r.	-.40	n.r.
Weak ties	-.10	(-.26)	-.24	(-.40)	-.25	(-.38)
Strong ties	-.25	(-.25)	-.39	(-.33)	-.40	(-.37)
Advertising	-.68	(-.61)	-.22	(-.11)	-.09	(-.04)
Adjusted R ²	0.65	(0.66)	0.68	(0.60)	0.68	(0.63)

(n.r.) = not reported.
 Dependent Variable:
 ○ T₀-T_{16%} = number of time periods from launch to 16% market penetration
 ○ T_{16%}-T_{50%} = number of time periods from 16% to 50% market penetration
 ○ T_{50%}-T_{95%} = number of time periods from 50% to 95% market penetration

While Goldenberg et al. focused on the relative effects of strong and weak ties the size of both personal networks and weak contacts is important. Goldenberg et al. did not report parameter estimates for these two variables but a possible range of values can be inferred. Each variable in an experimental design such as this is entirely independent of each other independent variable, so there is no risk of multicollinearity in the data. Thus the sum of the squared standardised Betas will equal R². For the Goldenberg results to add up then the parameter estimates for the effects of size of personal network and size of weak ties would have to be significantly different from those presented in this study – For example, Beta for Size of personal network would have to drop from 0.53 to 0.40.

Discussion

In most respects these results delivered similar results to those reported by Goldenberg. The major difference, and the one for which Goldenberg makes the greatest claim, is in the relative effects of weak ties compared with strong ties. Where Goldenberg claimed that weak ties had similar effects to strong ties, this paper suggests that weak ties are influential, but not nearly as influential as strong ties. Where Goldenberg claimed solid support for Granovetter's (1973) theory of the strength of weak ties, this research suggests more limited support. Comparing the results found in this study with those published in Marketing Letters it is difficult to escape a feeling of scepticism. Several important dimensions and results are missing from the Goldenberg paper, which make it more difficult to ensure an exact replication of the original study. There was only one difference between the set-ups of the two models – in this study the five independent variables were tested at four levels each compared with seven levels each for the original study. However all were tested with the

same range of values, this study found similar levels of explained variance and similar explanatory power of strong ties. It doesn't seem right that only weak ties were different.

Future Research

A possible explanation for the different results is the spatial proximity of agents in the NetLogo model in this study. That is, in this study all agents were located on a two-dimensional plane so that each agent is surrounded by eight neighbours one cell away. Two cells distance gives 24 neighbours. Feasibly we could locate agents in three-dimensional space, giving 26 neighbours within one cell distance. If close ties are defined as a function of distance then this is likely to affect the extent that agents and agent groups remain exclusive and independent of contamination by outside influences. If the Goldenberg study did not include any allowance for this feature then some confounding between strong and weak influences is possible. Indeed another simulation, which explicitly allowed for possible influence by weak ties that coincidentally were located close by, does show greater influence for weak ties. This increases our concern for the validity of the Goldenberg results. At time of writing the author has tested three more variations of the model with each independent variable manipulated at seven levels so that I am confident that the replication is sound. In each case the results give the same conclusions as are presented here. That is, weak ties are important but not nearly as important as Goldenberg et al suggest. Further, the influences are proportional rather than linear. These larger results are currently under review with *Marketing Letters*, which published the original paper.

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