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Development of information diffusion models based on mathematical models of disease diffusion

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Abstract

Purpose: Analysis of information diffusion process based on models of spread of epidemics is one of the issues considered by the researchers. Limited studies have addressed investigation and analysis of scientific information diffusion. Current study was conducted aiming at identifying scientific information diffusion process among academic faculty members using mathematical models of spread of diseases during 2016.

Methodology: Mathematical models of spread of epidemics including SIS, SI, and SIR models were used for analysis of scientific information diffusion. The study was conducted using semi-experimental method on 147 faculty members in three stages including evaluation of current status at time t0, after implementation of intervention of models including susceptible, infected (informed) and recovered (information saturation). Using statistical methods, chance of disease transmission from each compartment to the next one was measured.

Findings: Research findings suggested feasibility of SIS, SI, and SIR models in describing information diffusion process. People who are susceptible to scientific information will not remain in a constant state after receiving information. So that 51.6% of the people remain in a state of informed and 39.1% return to susceptible conditions. Also, only 9.3% of people will switch to saturated and unnecessary conditions.

Conclusion: Application of models of epidemics spread and its extension to scientific information diffusion is accurate. In addition, mostly individuals will remain at constant state after receiving scientific information.

Keywords: Information diffusion; Mathematical models of epidemics; Information; Epidemics

Introduction

Information diffusion phenomenon has been highly welcomed by the researchers in information era. This is one of the most key social phenomena which is quickly and accurately forming considering development of information and communication technology in recent years [1]. Diffusion refers to the process in which information, inventions or a disease as the phenomenon is transmitted from one individual to the other [2]. In the early 20th century, medical researchers reviewed the epidemics among humans, and presented mathematical models for the spread of diseases [3]. The study of the propagation of diseases through the use of mathematical models of spread of diseases was an idea first proposed by Gaffman and Neville in 1964 by presenting the theory of idea diffusion based on the theory of disease transmission [4]. A lot of research has been done on information diffusion among people of the community by comparison with the spread of epidemics [5-9]. The diffusion of rumors [11, 12], news [10], and innovation [13], behavior [14, 15], culture [16], viral marketing [17], spread of social behaviors and norms [14-18], and so on are in this group of studies.

Investigation of studies based on disease spread models indicate that part of information is diffused through social bonds from one individual to the other one with specific conditions and regulations, and finally it can be transmitted and diffused to a large part of the population considering ground of information extension [19].

Considering extension of information and communication technologies as well as users' welcome to social networks, considerable part of studies in "information diffusion" area deals with investigation of information diffusion in social networks and affecting factors. It is observed that models and studies provided in academic papers are mostly based on relatively simple hypotheses which are considered as an example for information diffusion in real conditions. It should be acknowledged that various factors are involved in information diffusion; other than network structure, including real or virtual factors such as human behavior are involved [20-22].

In studying epidemiology of diseases, various individual and environmental factors may cause that infected patient assigns different situations in these models, thus variety in epidemics models is observed. Using Gaffman and Neville theory, information and pathogenic agent are similar in spread, and are transmitted from one individual to other due to contact and proximity. Thus, in many studies, information diffusion process is considered as equal to disease spread [23].

In this study, extension of theories and studies of information diffusion area is addressed. It was conducted with an innovative approach using mathematical models of epidemics, such as Susceptible- Infected- Recovered: (SIR) and Susceptible- Infected- Susceptible: (SIS) and Susceptible- Infected: (SI) and it was attempted to extract scientific information diffusion models among faculties of Hamadan University of Medical Sciences based on mathematical models of epidemics.

Methodology:

Current study was conducted aiming at investigating scientific information diffusion process among academic faculty members using mathematical models of epidemics. According to mathematical models of epidemics, contribution of each suspectible (S), infected (I), and recovered (R) compartments in the research sample was determined. To this end, semi-experimental research design was used. In order to determine contribution of suspected compartment, the sample was trained for investigating information diffusion process among faculty members towards the scientific content. Thus a group of faculty members declared their tendency to participate in the course. The group was pre-tested by a questionnaire, based on the educational content and scientific information that the sample was supposed to study. The level of participants' information in this period relative to the questions of the questionnaire was considered based on the five-point Likert scale including very low (1), low (2), average (3), high (4), and very high (5). Finally, 105 people with a score of less than 3 were included in the study as the suspected individuals, and the rest were excluded from the study. Educational content was provided within two days total of 10 hours aiming at proximity of suspected individuals with scientific information (information to which they were sensitive) This period was held as workshop with continuous participation of participants during training. Post-test was run at the end of second day. Measurement tool in this stage was the same as pre-test measurement tool. This stage was designed aiming at developing informed compartments (I) in mathematical model of epidemics in investigation of scientific information diffusion process among faculties. In the following, obtained scores were analyzed using SPSS software, ed. 21. In this stage, individuals with average score of 3 and above are placed in infected compartment. Second compartment was identified in this stage. In the next stage, reaction and behavior of the research sample after infection to information and formation of informed individuals' compartment was reviewed. To this end, status of individuals under study was investigated after two months using measurement tool of first and second stage so that contribution of third compartment is recognized. Then chance of transmission of individuals from second compartment to the third one was extracted using probability matrix.

Mathematical Model of Information Diffusion

Existing mathematical models which describe epidemics process are very useful for researchers of medical sciences. They use mathematical models of epidemics in order to describe spread of diseases in a specific population [24] and plan and determine preventive measures accordingly, and we utilized these models in this study.

Overall every model uses several parameters, values of which should be specified based on the observations. Table 1 gives parameters of model of disease epidemiology and their equivalents with scientific information diffusion parameters.

Table1. Characteristics of epidemiological and knowledge and information sciences models

Parameters of models	**Epidemiological models**	**Scientific information models**
N	Population size	Number of study participants
S (Susceptible)	Population size at t_0	Number of study participants who have not adequate knowledge
I (Infected)	Population size at t_1	Number of study participants who have adequate knowledge Score≤3
R (Recovered)	Population size at t_2	Number of study participants who have adequate knowledge after two months period

In relation with scientific information diffusion, S denotes individuals susceptible of receiving information in the current study. It means the information which is trained in this study. I also indicated that individuals which switch state to informed or infected from suspected state due to proximity with information and under influence of training, and R includes recovered individuals. These individuals will be needless of receiving new information in relation with the trained subject because of gaining adequate and useful information.

Findings:

Identifying Contribution of Compartments

In order to identify contribution of susceptible compartment, 147 faculties of university were entered into study based on self-declaration. Following running pre-test, 105 ones gained below 3 scores of total score and they were identified as susceptible or sensitive to scientific information learning in the form of contribution of susceptible (S) compartment.

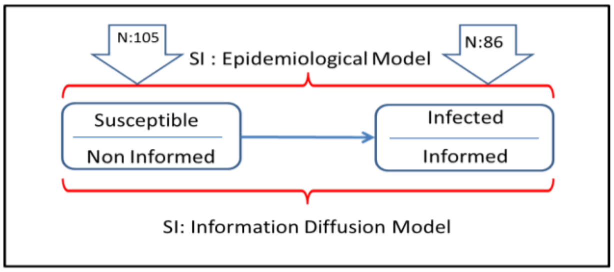

Figure1. Distribution of study participants based on compartments of SI Model

Following intervention and holding educational course, post-test was run. It was done in order to identify contribution of infected compartment, which included individuals which were in the S compartment in the first stage and switched state to I compartment due to proximity to information. Findings of this section indicate. This population included 86 ones. In other words, 105 ones of the sample were susceptible, which 86 of them changed state to infected or informed compartment from susceptible compartment following proximity to information and passing the course.

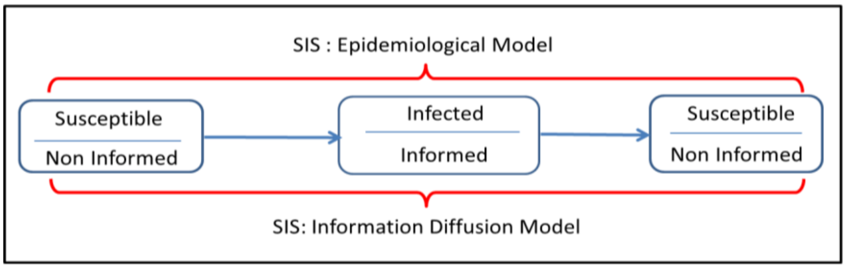

Figure2. Distribution of study participants based on compartments of SIS Model

In the next step, the respective sample was measured two months after identifying infected/informed compartment using information level identification tool, utilized in two previous stages. So that their state is informed. Findings indicate that out of 86 infected individuals, 8 ones (5%) were in recovered state after two months. 35 ones (23%) returned to susceptible state and 43 ones (29%) remained in infected state.

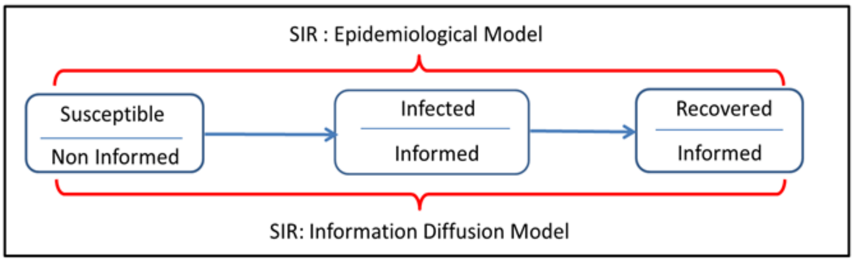

Figure3. Distribution of study participants based on compartments of SIR Model

In the following, probability of transmission from time interval t1 to t2 was evaluated.

Formula for calculating probability of transmission from infected/informed compartment to the next compartment:

$P_{ij}(t_1,t_2)=p(X(t_2)=j|X(t_1)=i)$

Table2. Probability of epidemic models compartments

		T2(after 2 months)			
		Susceptible(2)	**Informed(3)**	**Recovered(4)**	**Total**
T1	**Susceptible(2)**	10(45%)	10(45%)	2(10%)	22(100%)

Informed(3)	25(39.1%)	33(51.6%)	6(9.3%)	64(100%)
Total	35(41%)	43(50%)	8(9%)	86(100%)

n(%)

Results obtained from calculation of compartment 2 to 3 transmission probability indicate that:

Values in parenthesis represent transmission probabilities in each stage in t1 to each stage in t2. For example, probability from S to S is 45 percent, and probability from I to I is 6.51 percent.

If we want to calculate the odds ratio of transmission from each stage to the transmission to other stages, thus:

The odds of transmission from 2 to 2, is 1.32 times of transmission from 2 to 3.

The odds of transmission from 4 to 2, is 1.1 times of transmission from 2 to 3.

The odds of transmission from 2 to 2, is 1.2 times of transmission from 2 to 4.

Discussion and Conclusion

Identification of human behavioral patterns in information diffusion area has been widely studied by researchers in various research works. Despite the fact that the researchers welcomed study of various aspects of information diffusion using mathematical models for the spread of diseases, the study of scientific information diffusion was still neglected; therefore, in this study, it was attempted to identify patterns of scientific information diffusion using mathematical models of epidemics.

Current study supported assumption of similarity of information and pathogenic agent in transmission process due to proximity [4]. Thus investigation of process of scientific information diffusion using mathematical models of epidemics including SI, SIS, and SIR is possible. In fact, information diffusion process can be modeled using mathematical models of epidemics.

SI model includes those individuals who entered the study as susceptible and switched state to informed or infected following proximity and training information. This model also include those who left non-informed state and neither returned to the first state nor their information was added after two months. This state in infection diseases and epidemics occur when the susceptible one is caught by the disease due to proximity with pathogenic agent (which can be an infected individual), and he is actually transmitted to infected compartment from susceptible compartment, and he stays infected, like infected by hepatitis

SIS model includes those who entered study as susceptible and are transmitted to infected or informed compartment following proximity with the information. They switched state and returned to susceptible state after two months. In fact they lost the information obtained in the previous stage. It seems that environmental and personal factors are involved in this issue.

Information diffusion process in SIR model describes the group which entered the study as susceptible to information reception, and switched to infected or informed compartments following proximity with the information. They were evaluated after two months and the results showed that they reached optimal level of respective information. Thus, they reached recovered state or needless of gaining new information state. This model in disease spread process covers those who gain perfect recovery or die after a while after infection to disease. In practice, they are exited from the model cycle. They found that behavior of humans is similar to virus behavior. They naturally tend to share information to achieve fame, high trust or money. They noticed importance of word of mouth and considered verbal communication as the main factor in information diffusion, and unlike virus diffusion, they regarded information diffusion as dependent on the nature and optional features of humans [25-27]. Researchers also could simulate a dynamic microblog network and introduced factors affecting better diffusion of information in microblogs [28].

Wang (2015) proposed ESIS model which includes emotions in diffusion of information in social networks [29].This is one of the information diffusion models. Trend of recent studies indicate that similarity of information and pathogenic agent can be used in modeling information diffusion in different spaces such as scientific, news, marketing, and political areas. These information may occur in real or virtual communities.

Information diffusion process in scientific communities is not influenced by one or more independent factors, and obviously personal and environmental factors affect it. Every study is conducted with specific conditions and limitations and information diffusion is interpreted in it. It should also be noted that scientific information and its diffusion process is an optimal process, while pathogenic facto and interpretation of its models is non-optimal conditions, which vary in interpretation of models and their match. The study by Zi-Ke indicated that diffusion process is highly influenced by network structure [30]. Khelil reported information diffusion in mobile networks as similar to spread of disease in the community. In his study, each infected individual plays role as a node which can be information nutrition source. He addresses role of node congestion in information diffusion [31]. In disease spread process also contact level of individuals with each other is an effective factor in severity of disease spread. Woo considers social and on line media as suitable ground for progress of political and marketing information goals. He investigates diffusion in web networks using SIR model [31]. His study showed that using mathematical models of epidemics can be well used in investigation of diffusion process in web networks [32].

It is also suggested that information diffusion process in social scientific networks as well as scientific information diffusion process in web is studied in future works.

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