Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Physica A 338 (2004) 286–291
PHYSICA A
www.elsevier.com/locate/physa

Probing human response times

Anders Johansen*

Teglgårdsvej 119, 3050 Humlebæk, Denmark

Abstract

In a recent preprint (Dialog in e-mail traffic, preprint cond-mat/0304433), the temporal dynamics of an e-mail network has been investigated by Eckmann, Moses and Sergi. Specifically, the time period between an e-mail message and its reply were recorded. It will be shown here that their data agrees quantitatively with the frame work proposed to explain a recent experiment on the response of "internauts" to a news publication (Physica A 296(3–4) (2001) 539) despite differences in communication channels, topics, time-scale and socio-economic characteristics of the two population. This suggest a generalized response time distribution $\sim t^{-1}$ for human populations in the absence of deadlines with important implications for psychological and social studies as well the study of dynamical networks.

PACS: 89.65.−s; 87.23.Ge

Keywords: E-mail; Time distribution; Social networks

1. Introduction

There can be little doubt that the World-Wide-Web (WWW) and Internet e-mail provides two of the most efficient methods for retrieving and distributing information. As such, it carries an enormous potential with respect to sale and marketing of all kinds of products. A rather troublesome feature from a research perspective of many "old-age" communication channels, such as newspapers, radio and TV, interpersonal contacts and so forth, is that the diffusion of information through these channels is in general very difficult and/or time consuming to probe. This is not so with the WWW and e-mail. The fact that these communication channels are computer-based and access in principle unrestricted provides a rather unique opportunity to study in real time how

* Tel.: +45-35345004.
E-mail address: anders-johansen@get2net.dk (A. Johansen).

0378-4371/$ - see front matter
doi:10.1016/j.physa.2004.02.054

fast individuals respond to a new piece of information. It is generally believed that the rate of diffusion of information in a given population depends on a number of socio-economical factors such as education, cultural status, exposure to mass media and interpersonal channels etc. [1]. The evidence presented here propose otherwise.

Along a complementary line of research the WWW has provide a similarly unique opportunity to study fast evolving (sociological or computer) networks [2]. Most studies of the WWW have until now focused on the more easily accessed statistical properties such as the connectivity of the WWW (the distributions of outgoing and incoming links, etc.) and a consensus that the WWW is scale-free has been established. As the WWW or any other sociological network is constantly evolving any such investigation can only deliver a "snap-shot" picture of the network. The assumption is then that the dynamical features of the network is reasonably stable over the time-scales considered and that the results are representative over time. However, in order to correctly describe networks between interacting humans one must estimate characteristics specific to the nature of the "nodes", e.g., psychological traits of humans, as one may otherwise be mislead when generalizing from a "snap-shot" analysis. In fact, little is known about the internaut population's response to some external or internal event. With respect to commercial exploitation of the WWW it is obviously the response of the internaut population to some new piece of information which is of prime interest and not the topology or connectivity of the underlying network itself.

The purpose of the present paper is to provide for a characterization of the psychological/sociological traits of interacting humans in absence of formal deadlines. Using empirical data of response time distributions of internaut individuals/populations when exposed to a new piece of information, a surprisingly robust "law" for human response times will be put forward.

2. Response to an Internet Interview: Experiment I

The Nasdaq crash culminating on Friday the 14th of April 2000 caught many people with surprise and shook the stock market quite forcefully. As always, many different reasons for the crash were given ranging from the anti-trust case against MicroSoft to an "irrational exuberance" of the participants on the stock market. The author also had bid for the cause [3], which was made public on Monday the 17th of April 2000 on the Los Alamos preprint server. As a result, a 40 min interview with the author called "The World (Not) According to GARCH" was published on Friday the 26th of May 2000 on a "radio website" (www.wallstreetuncut.com) In addition, the URL to the author's papers was announced making it clear that work on stock market crashes in general and the recent Nasdaq crash in particular could be found using the posted URL. As the main subject of the interview was a somewhat technical discussion about whether stock market crashes could be predicted, it seems reasonable to assume that the population in a socio-economic context was relatively homogeneous. The experiment proceeded as follows. The number of downloads of papers from the authors homepage as a function of time (days) from the appearance of the interview was recorded. In Fig. 1, the cumulative number of downloads $N(t)$ as a function of time t after the

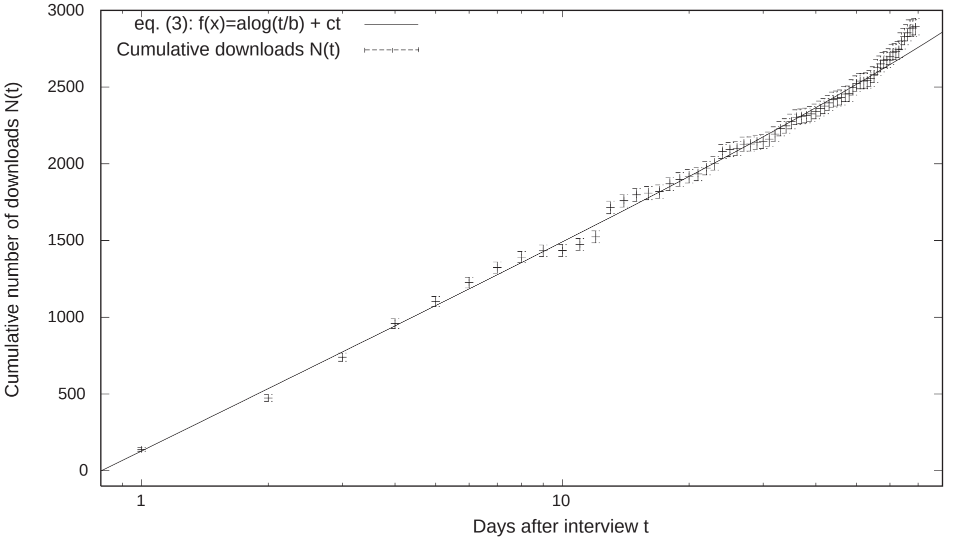

Fig. 1. Cumulative number of downloads $N(t)$ as a function of time. The fit is $N(t) = a\ln(t/b) + kt$ with $a \approx 583$, $b \approx 0.80$ days and $k \approx 2.2$ days^{-1}.

appearance of the interview is shown on a semi-logarithmic scale. The data is over one and half decade surprisingly well-captured by the relation

$$N(t) \sim a\ln(t/b) + ct \Rightarrow n(t) = \frac{\mathrm{d}N(t)}{\mathrm{d}t} \sim \frac{1}{t} + c\ . \tag{1}$$

Here k represents a constant background rate. After approximately 60 days, the data breaks away from the fitted line. The reason is the appearance of the author's URL on the Social Science Research Network server (www.ssrn.com) causing a second advertisement. Hence, the experiment became influenced by an additional distribution channel and was consequently halted after 69 days.

3. Response times in E-mail Interchange: Experiment II

In a recent preprint [4], the temporal dynamics of an e-mail network has been investigated by Eckmann, Moses and Sergi. Specifically, the time period between an e-mail message and its reply was recorded. The data set contains 3188 users interchanging 309,129 messages and was obtained from the log-files from one of the main mail servers of an university. In one sense, this experiment is the "cleanest" as only a single distribution channel can exist. However, as each e-mail message contains different information it is also the "dirtiest" with respect to the information distributed. Furthermore, it seems reasonable to assume that the population in a socio-economic context is quite heterogeneous opposed to that of the first experiment. In Fig. 2, we see that the cumulative distribution of time periods between an e-mail messages and

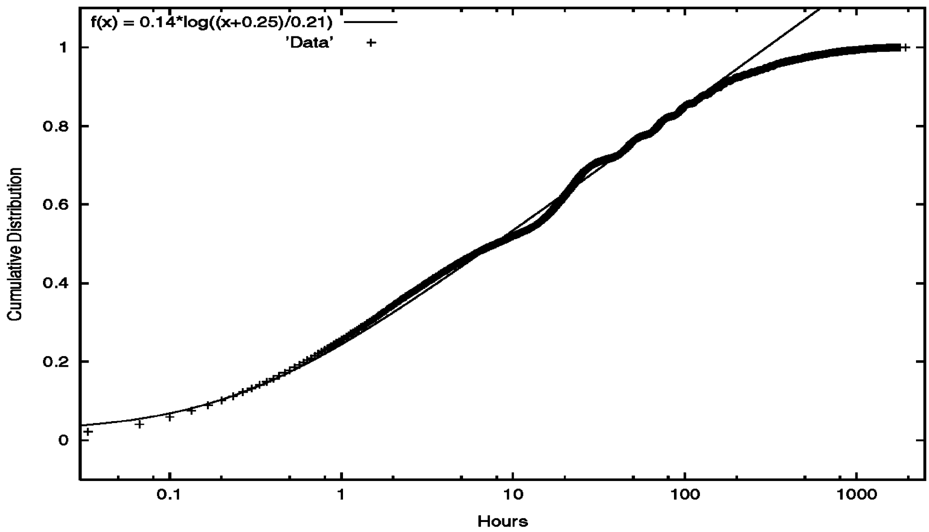

Fig. 2. Cumulative distribution of responses as a function of time. The fit is $N(t) = a\ln((t+c)/b)$ with $a \approx 0.14$, $b \approx 0.21$ h and $c \approx 0.25$ h. Due to the "wiggles", the fit has been stabilized by first estimating c from the data and then fitting a and b keeping c fixed.

its reply $N(t)$ can be modeled in terms of a response time t of the recipient of the e-mail message,

$$N(t) \sim a\log\left(\frac{t+c}{b}\right) \Rightarrow n(t) = \frac{\mathrm{d}N(t)}{\mathrm{d}t} \sim \frac{1}{t+c}\,. \qquad (2)$$

Here the constant c as a first approximation incorporates the fact that the measured time is not the true response time. The prime reason for the "shift" c is that most people do not download new e-mail messages instantaneously but instead every 10 min or so. Furthermore, some time is obviously needed in order to formulate and write the reply. The values of the fit parameters are $a=0.14$, $b=0.21$ and $c=0.25$, see figure caption for details of the fitting procedure. We clearly see that Eq. (2) is an excellent approximation of the data over three decades. An additional feature of the data that can be rationalized is the first "wiggle" occurring around 10–16 h. Many people send e-mail messages just before leaving their work place. Since people generally share the same working hours (provided that they live in the same time zone), those messages are not answered before the next day. The main result to be extracted from this experiment compared to the previous one is that the response time distribution of the population exposed to new information is *independent* of the specific nature of the new information. This suggest that the observed behaviour indeed has its origin in psychological traits of the population. Furthermore, it should be noted that whereas the previous experiment deals with time scales of up to 2 months, this experiment deals with time scales up to only 1 week, i.e., a difference in time scales of approximately a factor of ten. Nevertheless, the same distribution is obtained. This suggest that the difference in time scales are mainly due to differences in communication channels, i.e., impersonal or personal.

4. Discussion

The results shown in Figs. 1 and 2 suggests that the general response rate of a human population $n(t)$ is that of a power law $n(t) \sim 1/(t+c)$ where c depends on the details of the distribution channel(s) used. Such power-law dependence of the rate of "events" are found in both natural and sociological systems. Two quite different examples are the Omori law for the rate of aftershocks as a function of time elapsed since the main shock [5] and the distribution of returns in the SP500 exceeding a specified threshold as a function of time elapsed since the "main event", i.e., the "crash", [6]. A more appealing analogy, at least on a qualitative level, is provided by the relaxation of spin glasses subjected to a magnetic field: At time t after the appearance of the interview (experiment I), the exposed population consists of two groups, namely those who have not downloaded a paper and those who have. Similarly with respect to experiment II, at any time t the population considered consists of two groups, namely those who have an e-mail to answer and those who have not. The transition from the first state to the second demands the crossing of some threshold specific to each individual. We thus imagine that the announcement of the URL/the reception of emails plays the role a "field" to which the exposed population is subjected and study the relaxation process by monitoring the number of downloads/the number of replies as a function of time. Hence, we may view the process of downloading/replying as a diffusion process in a random potential, where the act of downloading/replying is similar to that of a barrier-crossing in the Trap model of spin glasses [7]. The most pressing unanswered question raised by the two experiments is whether the observed power law only is a characteristic of the entire population or if it is also true for an individual over time. A qualitative argument that "ensemble averaging" may be the same as "time averaging" on the individual level ("ergodicity") is that people react very differently to the same piece of information, i.e., one cannot generally deduce *why* people react on a specific piece of information. The reason is that individuals perceive the same piece of information quite differently due to individual psychology despite similar socio-economical status, e.g., not all rich people have an ambition to get richer because of the risk and/or work-load involved. This interpretations is supported by the results from the second experiment, where the new piece of information is changes with time and individual and *nevertheless* we get the same functional relationship between the time of the presentation of the new information and the response time distribution of the population. However, it seems a priori a quite formidable task to empirically verify whether these considerations are valid or not.

Acknowledgements

I thank D. Sergi, E. Moses and J.P. Eckmann for the data of experiment II.

References

[1] E.M. Rogers, Diffusion of Innovations, The Free Press, New York, 1995.
[2] Duncan J. Watts, Six Degrees: The Science of a Connected Age, W.W. Norton & Company, New York, 2003; Albert-Laszlo Barabasi, Linked: The New Science of Networks, Perseus Publishing, Cambridge, 2002.
[3] A. Johansen, D. Sornette, Eur. Phys. J. B 17 (2000) 319.
[4] J.P. Eckmann, E. Moses, D. Sergi, *Dialog in e-mail traffic*, preprint cond-mat/0304433.
[5] F. Omori, J. Coll. Sci. Imp. Uni. 7 (1895) 111;
T. Utsu, Geophys. Magn. 30 (1961) 521.
[6] F. Lillo, R.N. Mantegna, Phys. Rev. E 68 (2003) 016119.
[7] J.P. Bouchaud, J. Phys. I France 2 (1992) 1705.