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Effect of marital status on death rates. Part 2: Transient mortality spikes

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HIGHLIGHTS

- Transient death spikes follow major condition changes.
- There is a sharp death spike in the days following birth.
- Transfers from home to nursing home result in death spikes.
- The 2–3 months after a marriage are marked by a death spike.

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ABSTRACT

We examine what happens in a population when it experiences an abrupt change in surrounding conditions. Several cases of such "abrupt transitions" for both physical and living social systems are analyzed from which it can be seen that all share a common pattern. First, a steep rising death rate followed by a much slower relaxation process during which the death rate decreases as a power law. This leads us to propose a general principle which can be summarized as follows: *"Any abrupt change in living conditions generates a mortality spike which acts as a kind of selection process"*. This we term the *Transient Shock* conjecture. It provides a qualitative model which leads to testable predictions. For example, marriage certainly brings about a major change in personal and social conditions and according to our conjecture one would expect a mortality spike in the months following marriage. At first sight this may seem an unlikely proposition but we demonstrate (by three different methods) that even here the existence of mortality spikes is supported by solid empirical evidence.

1. Introduction

1.1. Merits and shortcomings of the death rate ratio approach

The present paper is a continuation of Richmond and Roehner [1] which for the sake of brevity, will be referred to as "Paper I".

Paper I described the Farr–Bertillon (FB) effect [2–4] which states that in all age groups the death rates d_s, d_w, d_d of single, widowed or divorced persons were higher than the death rates d_m of married persons. The ratios $r_s = d_s/d_m$, $r_w = d_w/d_m$, $r_d = d_d/d_m$ were called *death rate ratios* (or simply death ratios) with respect to married persons.

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The important point we note here is that this is not a small effect. Most death ratios are higher than two and they become as high as 5 for young widowers. Gompertz's law [5] allows conversion of death ratios into what may be called "equivalent aging". According to Gompertz's law, after the age of 30, the death rate doubles by 10 years of age. Thus, if the death ratio of a widower of age 30 is equal to 3, Gompertz's law implies that widowhood will push up his death rate to that of a married man about 16 years older.[1]

From a statistical perspective the death ratios are convenient and effective variables. They are convenient because they can be easily computed from the death rates by age and marital status. They are effective in the sense that they remove the massive effect of aging on death rates. Whereas the death rates of both married and unmarried persons increase exponentially with age, their ratios remain bounded within fairly narrow intervals.

However, the death ratios are also fairly opaque variables which do not tell us anything about the actual mechanism of the FB effect. This is because the death ratios provide only a static picture. They do not say how death rates are affected in the course of time by a change in marital status. In other words, they do not tell us how such a transition should be described at the level of a cohort of persons. It is only through a longitudinal analysis in which one follows a cohort in the course of time that one can gain an insight into what really happens.

1.2. Life as an equilibrium state in a domain of the parameter space

The present study is about death rates in various systems and in various situations. Thus, it does not seem unreasonable to explain on what conception of life and death the paper relies. For the purpose of the present paper it will be sufficient to observe that in a biological perspective life can be seen as an equilibrium in which a number of parameters remain confined within fairly narrow limits. For instance the body temperature should remain within (for instance) 30 and 45 °C. The domain of the parameter space which is compatible with life may be referred to as the life envelope.[2] Three observations are in order in relation with the present study.

- In contrast with the case of body temperature for which the limits are rather strict, for many other parameters the limits are fairly elastic. Consider the concentration of hemoglobin in blood. Whereas the reference values (for women) are 12–15 g per deciliter of blood, life remains possible even for levels as low as 4 g/dL. In addition, such boundaries are also subject to inter-individual variations. The notion of frailty which is often used in relation with elderly persons can be seen as a global contraction of the life envelope.
- Biology and medicine focus on biological parameters. Yet, for human beings social factors are also very important. This is shown very clearly by the fact that (as seen in Paper 1) death rates of non-married persons are two or three times higher than death rates of married persons. In other words, a major change in familial and social ties can drastically affect the life expectancy of people. Because, up to now, we have no means for measuring the strength of social interactions, it is impossible to define a range of reference values for such variables, however one should keep in mind the existence of such limits.
- Usually, in the process leading to death it is not just one but several parameters which go beyond their reference intervals. One reason for this is that the parameters are not independent. This collective effect can be summarized by the notion of "will to live". Testimonies suggest that often the "will to live" disappears one or two months prior to the actual occurrence of death. Although this notion has probably an objective significance, we recognize that (so far) it has not been measured and quantified. The transient death spikes analyzed in the present paper may be seen as an attempt to define this notion quantitatively. A mortality spike reflects a change in the will to live for the simple reason that it covers a time interval (usually a few months) which is too short for new diseases to fully develop.

The paper is in three parts. In the next section we develop a system theory perspective which will give us a simplified framework for the analysis of systems of living organisms. It will be seen that, the most visible effect of a state transition in a population is often the occurrence of a transient mortality spike. In this way, simply by shedding the items that are unsuitable in the new situation, the system adapts to the environment change. We then analyze several examples of sharp transitions characterized by such transient mortality spikes. This leads us to the formulation of the "Transient Shock" conjecture. Finally, we test a key prediction of this conjecture according to which one should expect a mortality spike in the months following marriages. For that purpose we explore the death rate of newly married persons in the months following their marriage. The challenge is to see whether there is a mortality spike or not.

2. Systems science perspective

In order to get a broader understanding we will adopt a system theory point of view which means that we will examine several systems during their transition from a state *A* to a state *B*. Establishing connections between systems which, at first

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1 The details of the calculation are as follows. Gompertz's law implies $(1 + a)^{10} = 2$ where a is the annual growth rate; one gets: $a = 0.072$. Now, the number of years x needed for a multiplication of the death rate by 3 is defined by: $1.072^x = 3$ which gives $x = 15.8$.

2 A similar expression is used in aviation. The flight envelope or service envelope of an aircraft designates the domain of the flight parameters in which the aircraft can fly safely.

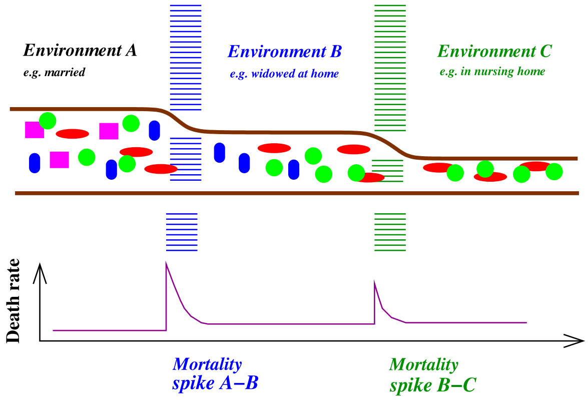

Fig. 1. Successive transition shocks. The figure shows a system of items (for instance electronic chips) which goes successively through three environments. Here, the term "environment" is used in a broad sense which includes operating conditions. Although all of same type, these items are not completely identical. Their variability is represented by their different shapes: circles, ellipses or squares. At each transition the items which are not adapted to the new environment "die" and are eliminated. As examples one can give the following cases. (i) A set of lightbulbs going through three states: A = turned off, B = turned on, 60 V, C = turned on, 220 V. (ii) New born babies: A = pre-natal, B = first day of post-natal life, C = first year of life. (iii) A cohort of persons going through three states: A = married, B = widowed at home, C = widowed in nursing home.

sight, seem very different yet nevertheless follow the same law is typical of the approach used in physics. An apple and the Moon may be very different in appearance, yet as shown by Newton, they are ruled by the same gravitational law. It will be seen that the transient behavior of physical systems is fairly similar to what is observed in the transitions occurring in human systems. For instance when a collection of VLSI (Very Large Scale Integrated) semi-conductor chips are put in operation, there is first a period of high failure rate. This time of excess failure rate which may last for a few months is commonly referred to as being an "infant mortality" phase by reliability engineers.

Evidence taken from physical as well as human systems will lead us to the conjecture that in a transition $A \rightarrow B$ there are usually *two* steps and not just one.

(1) First, there is a short-term transition shock which results in an upsurge of failures.
(2) Secondly, there is a long-term change in the failure rate as the system gets adapted to its new state.

Figs. 2a and 2b show different scenarios of transient regimes.

The expression "gets adapted" may raise a question. How can there be an adaptation for physical devices? Is adaptation not a feature that is specific to living systems? In the expression "the system gets adapted" the word system does not refer to a single item but to a sample of items, for instance it will designate a batch of, say 1000, semi-conductor chips. Although these chips look identical and were manufactured through the same production process, they are in fact slightly different. Some have small defects which will drastically reduce their life-time. Little by little the chips with defects will fail and be eliminated. As a result, the set of "surviving" chips will globally experience a smaller failure rate than the initial sample. It is in this sense that the whole set of chips becomes better adapted to its new state.

This process is schematically represented in Fig. 1. Let us make it more concrete by adding some data for the birth case, namely: A = pre-natal, B = early post-natal, C = late post natal. In 1910, with B = first day and C = first year for the transition $A \rightarrow B$, the deaths due to "defects" (premature birth, malformations, congenital debility, injuries at birth) represented 94% of the total deaths whereas in the transition $B \rightarrow C$ these causes represented only 30% of the deaths [6, p. 154]. For the purpose of comparison, we consider similar data for 1992. In this case (due to data availability), B = first hour, C = first two months. Whereas the deaths due to "defects" represent 90% in the transition $A \rightarrow B$ they represent only 32% in the transition $B \rightarrow C$ (Vital Statistics of the United States 1992, Volume 2, Part A, Section 2, p. 50–51).

In passing we note that Darwin's theory of "survival of the fittest" does apply to this process although a little reflection quickly shows that in the present case the catch phrase "survival of the fittest" is nothing but a tautology. For the example of the chips the very fact of surviving also defines the "fittest". For living organisms, one may imagine that generation after generation there is an adaptation to a changing environment. Yet, the example of the sample of chips shows that for selection and adaptation to take place there is no need for any transformation at individual level. The only requirement is that in the initial sample there is a dispersion of some of its characteristics. Then, the "right" characteristics will be selected through the failure process. *Ipso facto*, the survivors will be the fittest.

In the following subsections we give several examples of parallels between physical and biological systems.

2.1. Infant mortality for lightbulbs

Everybody has observed that most often lightbulbs fail when they are turned on. Why is this so? Physicists may be well aware of the mechanism, but we hope that the following discussion can throw some light on the case of more complicated systems.

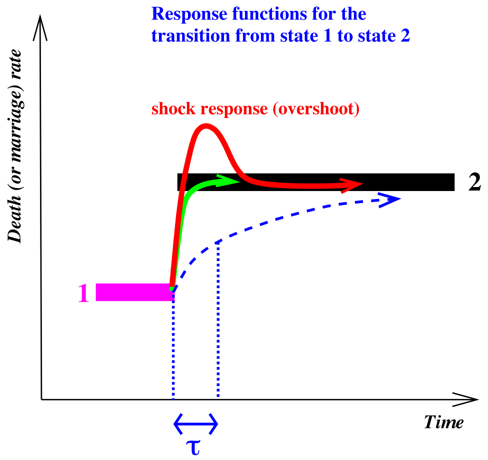

Fig. 2a. Transient response functions. States 1 and 2 characterize two marital situations. One can distinguish two kinds of responses: those with overshoot (red curve) and those without overshoot (green or blue curves). The latter converges steadily toward their stationary value. The time constant τ defines the duration of the transient response. Thus, the transition defined by the green curve has a shorter time constant than the one corresponding to the blue curve. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

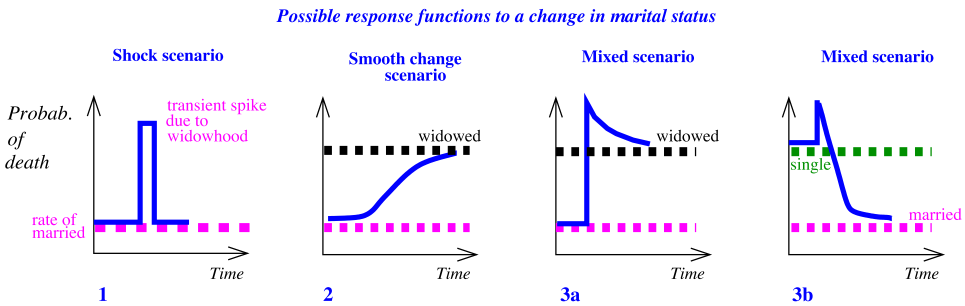

Fig. 2b. Different transition scenarios. The pure shock scenario 1 has no slow relaxation phase. The smooth change scenario 2 has no steep upgoing phase. The mixed scenarios 3a and 3b have a steep upgoing phase as well as a slow relaxation phase. Scenario 3a (with equal initial and stationary probabilities) is observed in the suicide spike following imprisonment (see Fig. 5) and also in the transition home-to-nursing home (see Fig. 6). The same scenario (but with unequal initial and stationary probabilities) is observed in the transition married-to-widowed (see the section entitled "Transient shock after widowhood"); the scenario 3b is observed in the transition following birth (see Fig. 4) and in the transition single-to-married (see Fig. 9b).

Firstly, one must realize that incandescent lightbulbs are governed by two very different time scales.

- An *electrical time lag* is due to the self inductance L of the filament. L may be small but it is not zero. If one assumes that L is of the order of one micro-Henry and the resistance of the filament at room temperature about one Ohm, the time constant L/R of the light bulb will be of the order of one microsecond.
- Secondly, there is a *temperature time constant* which is 100,000 times larger than the electric time constant. In order to emit light a tungsten filament must reach a temperature of about 2500 °C. Needless to say, this takes much longer than a few microseconds. A reasonable order of magnitude is about 100 ms. As the filament becomes hotter, the resistivity of tungsten increases strongly; it gets multiplied by a factor of about 10. This means that for at least 10 ms the "inrush" current will be some 10 times greater than the standard operating current. In other words, there will be an overshoot phenomenon in which the current will greatly exceed its steady-state value. That is why light bulbs often fail immediately after being turned on.

Incidentally, overshooting proves that the system is *not* ruled by a *linear* first order differential equation; however a *nonlinear* first order equation is not excluded. A linear second-order differential equation in the under-damping regime is characterized not only by overshooting but also by subsequent oscillations that are not observed in the systems studied in this paper.

The previous discussion shows that by observing the response function of a system one can identify and better understand various phenomena which take place within the system. The same approach will be tried here for cohorts of people who experience a sharp transition in their situation.

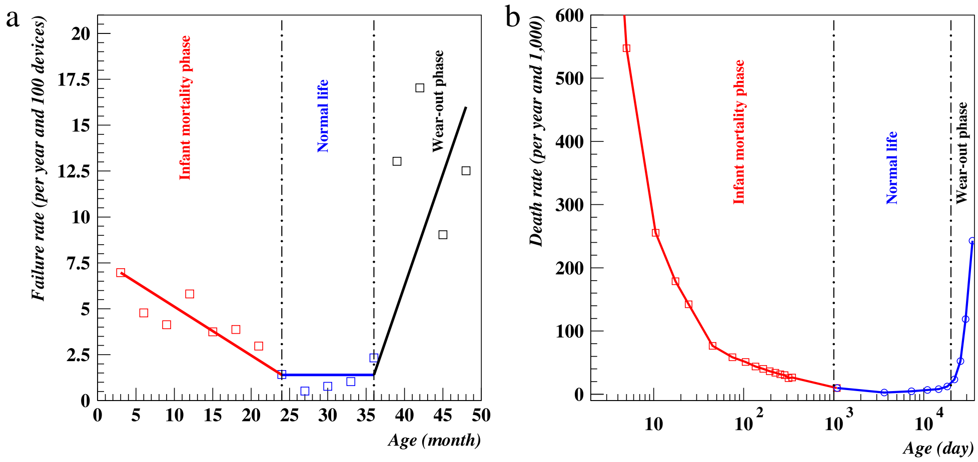

Fig. 3. Two examples of bathtub curves. Left: Annual failure rate of hard drives used by the cloud storage company Backblaze. The data are based on a set of several thousand drives operating without interruption. The large dispersion is partly due to the fact that the set included drives from different manufacturers. Right: Human mortality rates, male and female together, USA, 1923. It is by purpose that we show data from a time when infant mortality was much higher than it is now because this makes the infant mortality phase more clearly visible. The decrease with age follows a power law: $y \sim 1/t^{\alpha}$, $\alpha = 0.88 \pm 0.05$ (with a confidence probability level of 0.95), whereas the increase is an exponential with a doubling time of about 10 years. In 1910 the exponent of the power law was equal to 0.65 ± 0.04.
Source: Hard drives: Beach [8]. Human mortality: (i) Infant mortality: Linder and Grove [9, p. 574–575]. (ii) Adult mortality: Linder and Grove [9, p. 150].

2.2. Bathtub curves

In a general way, the physical items for which the notions of failure and life-time have a significance are items that cannot be repaired. Examples are light bulbs, fluorescent lamps, electronic chips, hard drives.[3] For such items it is customary to distinguish 3 successive periods.

- After the item has been turned on, there is an infant mortality period characterized by a decreasing failure rate.
- It is followed by a "useful life" marked by a failure rate that is low and relatively stable.
- Finally comes a wear-out period during which the failure rate increases.

Because of its shape with two upgoing sides, this curve has been designated the bathtub curve [7]. The graph of the mortality rate of many living organisms has a similar shape (see Fig. 3b for human mortality rates).

2.3. Bathtub curve for hard drives

A physical case of bathtub curve can be observed for hard-drives (Fig. 3a). The following observation was made in 2013 and relies on a sample of several thousands hard-drives in use at the Backblaze cloud storage company [8].

- The so-called infant mortality period lasted 1.5 years and is characterized by a decreasing failure rate whose average is 5%.
- The useful life lasted also 1.5 years and it has a failure rate of 1.4%.
- Finally, the wear-out period started on average 3 years after operation was started. It is characterized by an increasing failure rate whose average is 12%. After 4 years in operation about 80% of the devices were still working.

2.4. Bathtub curve for human populations

The three phases considered in reliability control are clearly visible for human mortality rates particularly if a logarithmic scale is used for the time axis.

3. Analysis of transient mortality spikes

3.1. Birth as first statistical evidence of transient mortality spikes

The transition from pre-natal to post-natal life is probably the most dramatic change in human existence. Therefore, if our conjecture is correct, one would expect a transient mortality spike of great amplitude. Currently, in the most advanced

[3] For the notions of failure rate and life-time to have a well-defined meaning there are two main conditions. (i) The failure of the item should be clearly defined. (ii) The item should not be repaired. Let us give two illustrations. Nowadays, shoes are no longer repaired but their failure cannot be clearly defined. In contrast, the failure of a computer script can be clearly defined; although a self-contained script does not age, the notion of "aging" makes sense for a script which uses external routines. The script will fail as soon as these routines become incompatible with its own syntax.

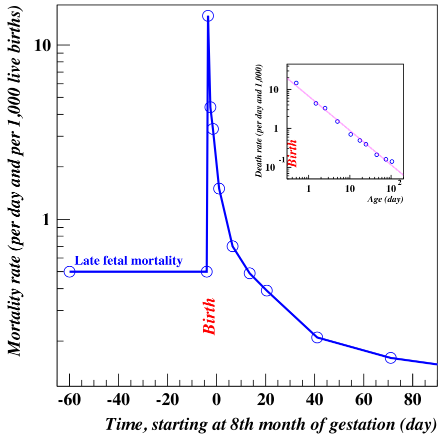

Fig. 4. Response function following the transition from gestation to birth. USA, 1923. The graph shows the change in death rate which occurs in the wake of the birth transition. During gestation the fetal death rate is fairly constant. Then, following birth, "defects" which were not of great consequence during gestation suddenly lead to a dramatic increase of the failure rate. In terms of annual death rate, the peak rate is about 3500 times higher than the mortality rate in the age interval 5–14. In the weeks following birth the death rate has a power law decrease. For the inset log–log plot of the same data the coefficient of linear correlation is 0.996 and the slope is 0.88. In 1960, the maximum was almost at the same level but the fall was faster. In 2013 the maximum was 10 times lower and the fall rate about the same as in 1960. There is a similar "infant mortality" pattern for other changes in living conditions and also for the failures of technical devices following operation start. As an example one can mention electronic chips [10].
Source: Linder and Grove [9, p. 574–575]; Child mortality statistics, 2013, Table 17, Office of National Statistics (UK): [11–13].

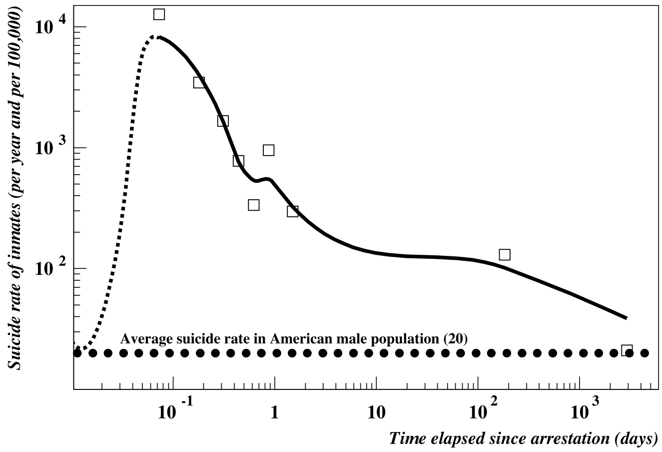

Fig. 5. Suicide rate of inmates as a function of the time elapsed since their arrest. The data are for the United States in the 1980s. In the two days following incarceration, the suicide rate decreases rapidly. Subsequently, the decrease continues at a much slower rate. After two years the suicide rate becomes almost identical to the rate in the general male population. If one excludes the last two points the decrease roughly follows a power law: $y \sim 1/t^{\alpha}$ with an exponent $\alpha = 1.2 \pm 0.4$.
Source: Hayes et al. [14, p. 36]; Roehner [15, p. 669–670].

countries the infant mortality rate (i.e. mortality during the first year) is of the order of 2 per 1000 live births which is about 10 times higher than the death rate in the age interval 5–14. As shown in Fig. 4, the death rates in the days and weeks immediately after birth are much higher than the infant mortality rate.

3.2. Suicide spike following imprisonment

The fact of being arrested and incarcerated certainly marks a dramatic change in living conditions, all the more so when it happens to somebody for the first time. It turns out that there is a huge suicide spike in the first hours of incarceration (Fig. 5). Once converted into an annual rate, the rate is about 500 times higher than in the general population. In subsequent days, a relaxation process sets in which slowly brings down the rate toward the suicide rate in the general population.

3.3. Suicide spike in the weeks following release from prison

From the perspective of our transition conjecture, there is a phenomenon which is even more revealing because less expected. It is the fact that there is also a death spike in the weeks after prisoners are released. As shown by the Table 1, in

Table 1
Number of deaths per week of ex-prisoners in the weeks after their release.
Source: Sattar [16, p. 34].

Situation	Suicide: number of deaths per week		Natural causes: number of deaths per week		Accidents: number of deaths per week	
Week 1	4.00	[1.00]	4.00	[1.00]	13.0	[1.00]
Weeks 2, 3, 4	1.70	[0.42]	2.33	[0.57]	8.3	[0.64]
Weeks 5–12	0.87	[0.22]	1.63	[0.40]	6.2	[0.47]
Weeks 13–24	0.54	[0.13]	0.66	[0.16]	5.9	[0.45]

Notes: The data are for the UK in the 1990s. The numbers within brackets show the data in normalized form (first week = 1). The decrease in the number of suicides per week reflects a transient state marked by a reorganization of social ties. For death by natural causes a factor which may play a role is the fact that terminally ill prisoners are often released so that they can die in hospital (incidentally, this "improves" the death record of the prison). Regarding accidents, it is likely that motor vehicle accidents are the main factor because it is known that they are the first cause of death for young men between 20 and 40. However, we ignore why this factor should be particularly high in the first week after release.

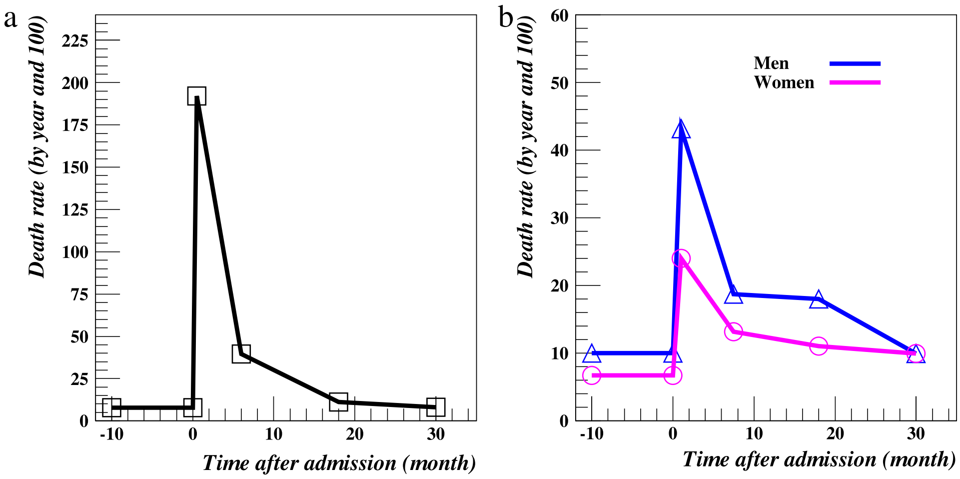

Fig. 6. Mortality spikes in the transition from home to nursing home. (a) Left-hand side: the data concern persons admitted to state mental hospitals in Maryland; their average age was 73.9; there were approximately as many males as females. The very high rate reached in the first month is not a mistake: 16% of the patients died in the first month and $12 \times 16 = 192$. In the first year the mortality was about 15 times higher than in the general population of same age. (b) Right-hand side: the data concern French persons admitted to nursing homes in Paris and the vicinity; their average age was 78; there were 125 men and 480 women. The horizontal lines prior to time $t = 0$ correspond to the death rate of persons of same age in the general population.
Source: Maryland: Camargo and Preston [17]. Paris: Locoh [18].

the first week, the suicide rate is some 8 times higher than 3 months after release; the other death rates (illness or accident) are also higher.

3.4. Transition from home to nursing home

Numerous observations have shown that when people are moved from their home to an hospital or a nursing home, they experience a substantial increase in their death rate. Two cases will be reported in Fig. 6 which show that within a few months after admission the increase can be as high as a multiplication by 5 or 10.

Camargo et al. [17] studied all first admissions of patients over 65 years old to the state mental hospitals in Maryland. Their average age was 74. 85% of the patients were diagnosed as psychotics. As reported in Fig. 6a, they found very high death rates in the month following admission. In more recent times [20] found a similar post-admission mortality in a sample of 555 persons. Incidentally, a book entitled "Old, Alone, and Neglected" by Jeanie Kayser-Jones [21] should be mentioned because it provides a useful qualitative description of social conditions in nursing homes.

A similar study was performed in France by Ref. [18]. The average age at admission was 78 years. The fact that these persons were not psychotic patients certainly explains that the death rates were about 5 times lower than in the previous study. Nevertheless, the death rate peak is about 5 times higher than the annual rate in the general population of same age.

An objection has been raised by some authors. They said: "It may be that the transfer decision taken by the caregivers (i.e. the relatives who are taking care of the elderly persons) was motivated by a sudden deterioration of the health of the persons". If that would be the case the mortality spikes shortly after admission would lose their significance in relation with the transfer. This objection can be answered in two different ways.

- First, one should recall that it is within one or two months after admission that the death spike is the most serious. Such a time interval is very short compared to the survival time of most of the diseases which affect elderly persons (e.g. Alzheimer disease, cancer) which is rather of the order of a few years. In other words, even if the health of the persons had been declining it should not lead to death so quickly. In addition, one should keep in mind that most often the admission into a nursing home is subject to a delay due to the existence of a waiting list.

- One must recognize that the previous argument is purely qualitative and for that reason is not completely convincing. A better answer is to focus on cases for which the transfer decision is taken independently of the situation of the persons. That is for instance the case when an institution is closed and all patients must be transferred to other places. Two cases of relocation have been studied and reported in the literature: Aldrich et al. [22] and Killian [23]. Mortality spikes after relocation were reported in both papers.

3.5. Transient Spike (TS) conjecture

The previous observation leads us to the following statement.

> "*Any abrupt change in living conditions generates a mortality spike which acts as a kind of selection process*".

This statement which will be called the *Transient Shock* conjecture provides a qualitative model which leads to testable predictions.

3.6. Predictions

The previous observations put us in the same situation as a person who has seen the Sun rise around 7:00 am during 7 days. Naturally, he (or she) will expect Sunrise in the following days also to occur around 7 am. In order to make this prediction the person does not need a mathematical model of the solar system. Incidentally, such a model would need a lot of inputs based on astronomical observations (e.g. the minor and major axis of the orbits) but nevertheless would not be able to predict the length of the day which is a purely empirical parameter.

Apart from the cases already tested, can we make other predictions? Here are a few examples.

- For a person to lose his (or her) job is certainly a major change in living conditions. Therefore, one would expect a transient mortality spike in the weeks following the loss of the job. Does it exist? The short answer is "So far we do not know". There have been many studies about the suicide rates of unemployed persons. For instance, Weyerer et al. [24] have conducted a long-term study. Unfortunately the correlation between unemployment and suicide rates are very low and hardly significant (under 0.20). In contrast one would expect a significant suicide spike not in the long run but only in the weeks following the loss of the job. The problem is to find appropriate statistical data.
- For elderly persons, the fact of moving to another area far away from their circle of relatives and friends is a difficult transition for which one would expect a mortality spike.
- For immigrants the fact of leaving their family behind and moving to a country where people speak a different language certainly represents a difficult transition. Some statistical data are available for immigrants who came to the United States at the end of the 19th century or beginning of the 20th century [25], [6, pp. 586–595]. It appears that for a broad sample of countries the suicide rate of immigrants is much higher than either the rate in their country of origin or the rate in the United States [26, pp. 217–220]. Unfortunately, the data do not allow us to follow this phenomenon in the course of time.
  Nowadays, one would similarly expect that immediately after their arrival in California or Arizona, immigrants from Mexico will have a higher suicide rate than in their country of origin.
- The transition single-to-married is a major change. Therefore one would expect a mortality spike in the months following the marriage. This is the purpose of the next section.
- The transition married-to-widowed represents a major change. Therefore one would expect a mortality spike in the months following the death of the spouse. This point will be briefly discussed at the end of the paper.

So far, we have mostly focused on death rates. Similar transition spikes can be expected also for other rates, for instance marriage rates. For instance, one may expect a transient remarriage spike after widowhood. Around 1850 in the Netherlands, Switzerland and France the remarriage rate of widowers was 3–4 times higher than the marriage rate of single persons [27]. On the other hand when a widower wishes to get re-married he must first develop a network of friends which may take some time. This effect which goes against a remarriage spike seems to have become of more importance in the 20th century. In 1960 in the United states, the long-term marriage rate of widowers was of same order as the marriage rate of single persons [19, p. 103]. However, this does not completely exclude a short-term remarriage spike.

4. Mortality spike in the transition single-to-married?

4.1. Abrupt, instantaneous transitions versus smooth transitions

In everybody's life marriage is certainly a major transition. We know that its long-term effect is to reduce mortality rates by a factor 2 or 3. We attributed this effect to increased interaction. However, this does not necessarily exclude a transient mortality spike in the months following the marriage because it may be that some persons who were well adapted to their

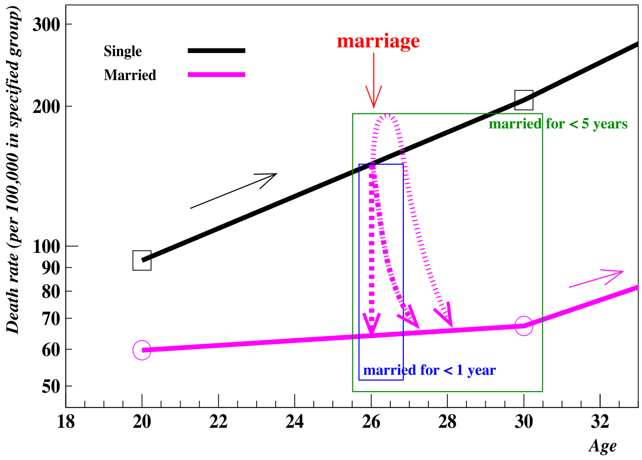

Fig. 7. Is there a mortality spike shortly after marriage? The solid lines depict the actual death rates for single individuals (black line) and married persons (magenta line) in the USA for the year 1996. We see that the death rate of single persons is not only higher than the rate of married persons but also increases faster, a point already highlighted in Paper 1. The dotted and broken lines illustrate schematically the changes which may occur in the transition single-to-married for persons who marry at age 26. So, for example, one may observe (i) an instantaneous transition (broken line), (ii) a smooth transition (mixed broken-dotted line) or (iii) a transition with overshoot (dotted line). The role of the two rectangular boxes is explained in the text. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: National Vital Statistics Report, Vol. 47, No 9, 10 Nov 1998, Table 21, p. 73.

non-married status will not be adapted quite as well to their new marital status. The question of whether or not there is a transient shock following marriage is important because if the answer is "yes" it will show that mortality shocks do not only occur as a result of bereavement but in fact are brought about by any major change in living conditions.

In Fig. 7 the vertical downward transition line means that as soon as a person gets married his (or her) biological and psychological characteristics change overnight in a way which ensures that the person's new death rate becomes immediately equal to the death rate of married persons. Common sense makes such an abrupt scenario unlikely. It seems more reasonable to assume that it takes some time for the married person to assume all characteristics of married persons. In physics, no transitions, not even phase transitions, are instantaneous.[4] The assumption of a smooth transition corresponds to the two other transient regimes depicted in Fig. 7. Incidentally, whether there is overshooting or not is unimportant for the forthcoming explanation.

Just for the purpose of illustration let us assume that the transient regime lasts a time $\theta = 3$ months and that its average death rate is $d_t = 90$ (per 10^5). Then, the meaning of the two rectangular boxes can be explained in the following way.

- The small rectangular box encloses the trajectory that must be taken into account if one focuses on persons married for less than one year; this time interval will be denoted by T. In this case the transient regime represents 1/3 of the one-year trajectory. As a result, the average death rate of married persons would be: $90 \times (1/3) + 65 \times (2/3) = 73$ (the average rate of married persons was taken equal to $d_m = 65$). Thus, the amplitude of the death rate spike with respect to married persons would be $73/65 = 1.12$. More generally, it would be:

$$s(\theta, T, d_t) = (d_t/d_m)(\theta/T) + (1 - \theta/T). \quad (1)$$

  If $\theta = 0$,then s will be equal to 1 no matter what are T and d_t.
- Similarly the large rectangular box encloses the trajectory to be taken into account for persons married for less than 5 years. In this case the transient regime represents only 1/15 of the 5-year trajectory. As a result, the average death rate of married persons would be: $90 \times (1/15) + 65 \times (14/15) = 66.6$. In this case the excess-mortality with respect to married persons becomes negligible. More generally, if $T \to \infty$, then s will go to 1 no matter what are θ and d_t.

The previous argument tells us that in order to discover and measure accurately an excess-mortality, one should focus on the shortest possible time interval following marriage. In the first two observations considered below we will take T equal to one year, but for the last observation T will be equal to only 2–3 months.

Another important implication of the previous reasoning is that for a spike to exist one does not need to assume that newly married persons experience specific difficulties in adapting to their new situation. As we have seen any smooth, non-instantaneous transition will produce a spike. Special difficulties, if any, would just result in a larger θ and possibly in overshooting, which in turn would amplify the spike [21].

[4] Thus, for water in a test-tube at a temperature of −5 °C, that is to say in a state of undercooling, the transformation into ice will take of the order of one second. For a larger quantity it will take longer because the transition starts from a seed and then propagates to the whole volume.

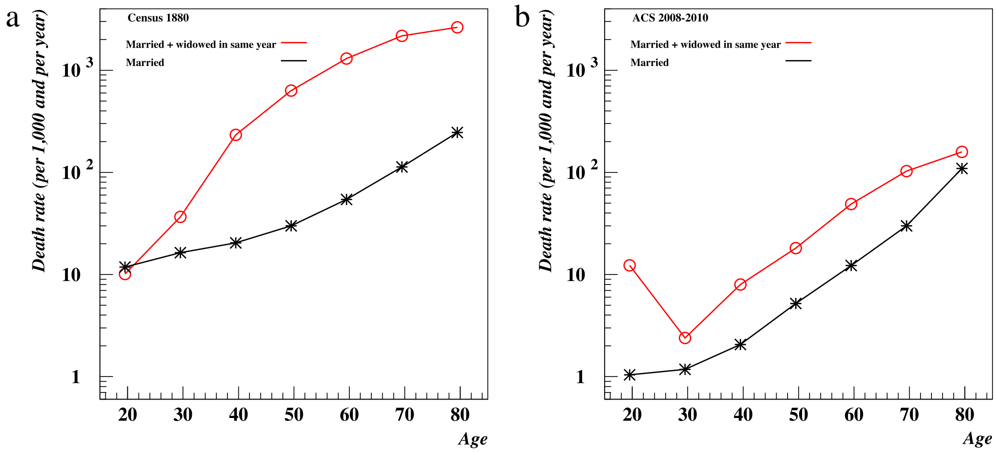

Fig. 8. Death rate in the first year of marriage. As most marriages last several decades the overall rate for married people (in black with stars) is a long-term rate as opposed to the other curves (in red) which are short-term rates over the first year of marriage. Needless to say, the persons who got married and became widowed in the same year are in fairly small number. In the 5% sample of the census of 1880 they were 579 and in the ACS 2008–2010 survey they were 397. It can be seen that the death rate in the first year of marriage is consistently higher than the overall death rate of married persons.
Source: ACS 2010-3 years (2008–2010) extracted from the IPUMS database [28]. The file comprises 9,093,098 lines (each line corresponds to a different person). It can be noted that the IPUMS website offers a set of databases giving census records at individual level. It covers the United States as well as a number of other countries. Freely accessible, it is a very useful tool for comparative analysis.

4.2. Design of the observation

We are looking for a short term effect; typically, one would expect a time constant of a few months. Moreover, even if the spike reaches a level twice as high as the death rate d_s of single persons, it will still be small because at that age d_s itself is very small. In other words, as our target is a fairly small effect its observation requires large samples.

As always, there are two methods, namely longitudinal or transversal analysis.[5]

- In principle, longitudinal analysis is possible only in countries where a cohort can be followed in the course of time through the civil registry statistical system, as is for instance the case in the Scandinavian countries. It can be observed that in the framework of such a database the present exploration would be considerably easier than for the deaths of widowers simply because for young people in any month the number of newly married people is about 1000 times larger than the number of newly widowed persons of same age.
- For transversal analysis one needs to design a suitable "experiment". A possible methodology based on the monthly distribution of deaths will be tried below.

4.3. Semi-longitudinal analysis

Usually census data cannot be used to do longitudinal analysis because they provide a picture of the population at a given moment. Few questions are usually asked about the past. There is a good reason for that, namely the fact that the recollection of people about events more than 2 or 3 years old is unreliable.

Here we will make use of a census question[6] that concerned the *recent past*: "Did you get married within the last year". If we select the persons who responded "yes" and if among them we select the persons who declared to be widowed at the time of the census interview, we will get the persons who got married and then lost their spouse within 12 months. In other words, we will be able to compare the death rate of married persons in their first year of marriage to the long-term death rate of married people.

The results of these observations are summarized in the graph below. The question about marriage within the past year was asked only in a few censuses, basically the census of 1880 and the "American Community Survey" after 2006. This survey is conducted every month on a different sample of about 300,000 persons. Over the whole year, it concerns about 3 million persons. The definition of the death rate of the persons married and widowed in the same year requires some explanations.

5 Transversal (also called cross-sectional) studies refer to the analysis of data collected at a specific point in time.

6 According to the website of IPUMS, the variable MARRINYR identifies persons who had married within the 12 months preceding the date of the ACS (American Community Survey) interview. Although this survey is carried out monthly. The Census Bureau does not make publicly available the interview months of respondents. Protection of confidentiality is the reason that is put forward despite the fact that it is not obvious why knowing the month of the interview should be an issue. It can be observed that, although the term "interview" is routinely used, in fact, the questionnaires are sent out by post or Internet (real interviews are conducted only in a number of special cases). This suggests another reason for not giving the month: although the questionnaires are all sent out on the same day, the dates of the replies may possibly extend over more than one month.

For a given age interval, among the n_1 persons who got married in the past year we select the n_2 persons who became widowed. The ratio $r = n_2/n_1$ represents a death rate; however its real definition must be considered more closely.

Firstly, for the persons that we selected we know that their marriage (M) and the death of their partner (W) occurred less than one year before the interview, so if the marriage occurred toward the end of this one-year interval (I) it must be followed almost immediately by the death of the partner. On the contrary, if M occurred at the beginning of I, then widowhood may occur at any time within I. Thus, in order to define the death rate of married people more precisely we need to know what is the average time interval between M and W.

In the absence of any contrary evidence, it is natural to assume that both M and W are distributed uniformly over I. However, because of the condition $M < W$, M and W are not independent random variables. A simulation reveals that in such a situation the average $E(W - M)$ is one quarter of the length of I. Thus, in order to express r as an *annual* death rate, it must be multiplied by a factor $k_1 = 4$.

There is a second correction which needs to be done. The ratio r is not really a death rate per individual, but rather a rate for the end of marriage. As the death of *any* of the two partners will result in ending the marriage, we see that r actually refers to twice the death rate per person. In order to express r as a rate per individual it must be multiplied by a factor $k_2 = 1/2$. Thus, altogether, r must be multiplied by $k_1k_2 = 2$.

On the graph for 1880 we can see that the death rate almost reaches a level of 1000 per thousand. This should not be surprising. Rates higher than 1000 simply mean that the whole group died in less than one year. For old age the observed values of n_1, n_2 indeed reveal a high mortality. For instance, in the last age group, namely 75–84, of the 93 persons who got married in the past year, 61 became widowed in the interval between their marriage and the census interview. By contrast, in the 2008–2010 survey the n_2/n_1 ratios are much lower. Thus in the last age-group, there were 782 persons who got married in the past year and only 31 became widowed prior to the interview.

4.4. Longitudinal analysis

Usually, censuses do not give any information about death events for the simple reason that the persons who respond are still alive. However, in a few cases a question was asked about possible death events of relatives. That was the case in the American Community surveys which were made after 2006. The question was "Have you been widowed in the past year?". Through another question we are also able to learn for how many years the persons had been married. Taken together, these data allow us to follow the persons in the course of time and to perform a longitudinal analysis.

We considered 5 cohorts C_i of married persons who got married in 2000, 2001, 2008, 2009 and 2010 respectively. Their death rate was computed as $d_i = D_i/C_i$ where the D_i denote the number of spouses who became widowed in 2010. For some age groups the D_i are fairly small. In order to reduce the statistical fluctuations which come along with such small numbers, we lumped together the data for the cohorts 2000–2001 and 2008–2009. The results are shown in Fig. 9. One sees that at a given age the death rate decreases with the length of time spent in married status.

As the existence of a mortality spike after marriage is rather counterintuitive, we need to discuss the reliability of census data. Censuses are conducted with great care but ultimately their accuracy depends on whether or not the respondents answer the questions correctly. In the present case, what is to be expected regarding the ratios $d_i = D_i/C_i$? One expects that D_i, the number of persons who became widowed in the year of the survey, will be fairly accurately reported because these are recent events in the respondents' lives. The same observation holds with respect to marriage for the persons who got married in 2009 or 2010. For more distant years such as 2000 and 2001 the recollection is probably not so good. However, for those years the data can be checked through a comparison with transversal data. The comparison shows that the two sets of data are fairly consistent with one another.

One may wonder what is exactly the connection between Fig. 9a and 9b. The dashed vertical line corresponds to persons aged 35 who became widowed in 2010 which means that their spouse died in 2010. Its intersections with the different curves correspond to marriages in different years. The highest death rate (5 per 1000) is for marriage and death in the same year. The second highest death rate is for marriage in 2009 that is to say death one year after marriage, and so forth for the following points.

4.5. Transversal analysis

From the two previous subsections we know that there is a mortality peak in the first year of marriage. The TS conjecture would suggest a taller spike in the one or two months immediately following marriage. In the present section we use monthly data to explore this effect.

The idea on which the present transversal analysis is based is to use the seasonality pattern of the marriages.

Just for the sake of explaining the methodology, we assume that all persons who get married die immediately. Regarding the seasonal distribution of marriages there can be two cases.

- If it is uniform the deaths will also be distributed uniformly.
- On the contrary, if all marriages occur in May, the death rate curve will display a huge peak in May.

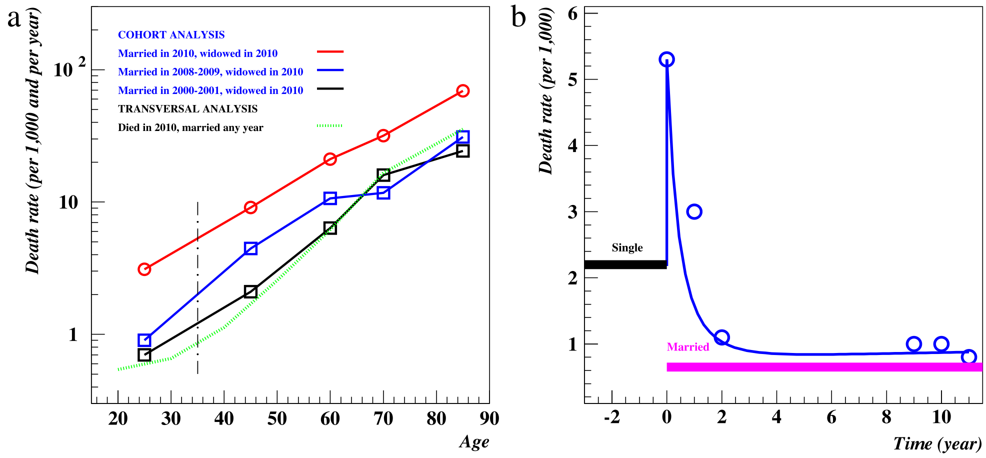

Fig. 9. Death rate for married people as a function of age and length of marriage. (a) The green dotted line (without marker symbols) gives the long-term death rate of married persons who died in 2010. It almost coincides with the death rate of people who have been married for 10 years (black line and squares). On the contrary, the cohort of the persons who got married and widowed in the same year (red line and circles) displays an inflated death rate, especially for young ages. The vertical dashed line at age 35 corresponds to the section shown in the figure on the right-hand side (additional explanations are given in the text). (b) The figure shows the death rates experienced by a cohort of age 35 that gets married at time $t = 0$. Immediately after marriage, there is a death-rate spike whose time constant is of the order of one year. Then the death rate converges toward its steady state average which (as we know from Paper 1) is lower than the death rate of never-married persons. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: The cohort analysis is based on the AC survey of 2010. The data are available on the IPUMS (Integrated Public Use Microdata Series) website of the Minnesota Population Center, University of Minnesota. This ACS-2010 (1 year) file comprised 3,061,735 persons. The transversal analysis which lead to the curve with the stars is based on data given in the "National Vital Statistics Report" of 8 May 2013 (p. 8).

Of course, in reality only a few married persons die. Nevertheless any significant death spike in May–June–July would signal an excess mortality in the three months following the marriage.

In the United States the monthly frequency of marriage peaks in May and June. The marriage rate in May–June is about twice the marriage rate in January. These monthly fluctuations are much larger than the seasonal fluctuations of the death rates for which the max/min ratio is about 1.2 (with the maximum in winter and the minimum in summer). Thus, if we see an increase in death numbers in the months following May–June, it may be attributed to a transient death effect triggered by the marriages. Of course, in order to be convincing such an increase must occur mainly in the age groups in which the marriage rate is highest. It should *not* be seen in age groups over 35.

For this investigation we need monthly mortality data by age and marital status. Monthly mortality data are indeed available in the "Vital Statistics of the United States" but they are not broken down by age and marital status. Fortunately, the "Inter-university Consortium for Political and Social Research" (ICPSR) provides a file which will solve our problem. It lists *all* the deaths which occurred in 1992 and for each of them it gives the age, marital status, cause of death and many other characteristics. The downloaded (and inflated) ASCII file has a size of 333 Megabyte.

Fig. 10 shows that in the summer months (i.e. in the 2 or 3 months following May–June) there appears to be a transient excess mortality of married persons. Moreover this excess mortality does not exists for ages over 35.

It must be kept in mind that for a fraction of the death certificates of married persons who die shortly after their marriage the new marital situation may not have been updated. The death registration procedures may also be different from state to state, but one should not be too surprised to see a May–June peak in the deaths of single persons.

4.6. Comparison of the three methodologies

Each of the three methods that we used has its merits and its shortcomings.

- The first set of data had the advantage of existing for a census of the 19th century. This gave us the opportunity to check whether the effect exists over a broad time range.
- The second set of data allowed us to probe different lengths of time between marriage and death.
- The results obtained through the third method were more "noisy" than those of the two other methods,[7] but this approach had the merit of suggesting that there may indeed be a tall and sharp death rate peak within one or two months after marriage.

[7] This is of course partly due to the fact that in this approach we did not use a logarithmic scale. When it is the age which is the independent variable the death rate differences for successive age intervals are so large that the random fluctuations become invisible.

Table 2
Studies of the widowhood effect according to the number of deaths of widowed persons.

Reference (first author)	Year of paper	Age	Deaths of widowed persons
Mendes De Leon [37]	1993	>65	22
Bojanovsky [38]	1979, 1980	Any age	181
Young [36]	1963	>55	906
Schaeffer [39]	1995	>40	934
Helsing [40]	1981	Any age	4,032
Kaprio [35]	1987	Any age	7,635
Martikainen [41]	1996	>40	9,935
Boyle [34]	2011	Any age	14,630
Mellström [42]	1982	Any age	360,000
Thierry [31]	1999	>35	819,000

Notes: The Bojanovsky studies differ from the others in the sense that it considered only death by suicide. The study by Young et al. was continued by Parkes et al. [30].

4.7. The effects of cohabitation, divorce and birth giving

For the marriages which were preceded by a period of cohabitation the transition single-to-married should be smoother. As cohabitation before marriage becomes more widespread, the effect measured in this section will become weaker. What is the percentage of marriages which fall into this category? Currently (that is to say in 2015) in the United States, 33% of the marriages are preceded by cohabitation.[8]

Actually, cohabitation is not the only factor which can affect the death rate of newly married persons. Divorce and birth giving are two others.

When, in its early days, a marriage sours, separation and divorce may provide a way out. One century and a half ago, although divorce already existed, it was fairly uncommon. As a result this safety valve was not often used and, due to familial and social pressure, it was probably used even less in the months immediately following the marriage.

At the end of the 19th century the maternal mortality following childbirth was 50 per 1000 births [29]. In addition it was probably not uncommon for the first birth to occur 9 months (or may be even less) after marriage. In order to quantify the contribution of this purely medical factor to the mortality spike, one would need to know the distribution of the dates of first births with respect to the date of the marriage.

In short, one should not be surprised to find at that time a much taller mortality spike than nowadays. A comparison of the situations in 1880 (Fig. 8a) and 2008–2010 (Fig. 8b) shows indeed a considerable reduction of the effect. At age 40 the death ratio (recently married)/married was 23 in 1880, but in 2008–2010 it was reduced to 4.

5. Transient mortality shock after widowhood

The death of a spouse results in a drastic change in living conditions. The "Transient Shock" conjecture would lead us to expect a mortality spike in the months following widowhood. The transition from single to married status implies (i) a change in individual living conditions (ii) a re-arrangement of ties: weakening of the ties with parents and strengthening of the ties with the spouse. Similarly the transition from married to widowed status implies (i) a change in individual living conditions (ii) a severance of the bond with the spouse and possibly a strengthening of the links with relatives or friends. In addition there is the psychological dimension of the bereavement process.

Although a more "plausible" effect than the marriage shock, the widowhood shock is much more difficult to study statistically. The effect is difficult to measure for the simple reason that the deaths of young widowed persons are much rarer than the marriages of young persons. Of course, the death of elderly widowed persons are not rare but in that case it is difficult to separate the mortality due to aging from the mortality due to the widowhood effect. In other words, for elderly widowers the effect is blurred by a high level of "background noise".

Many studies have attempted to analyze the widowhood effect. Several of them are summarized in Table 2.

Not surprisingly, the most successful study so far has been the one by Thierry [31]. As shown in Fig. 11, it gives clear evidence of a mortality spike in the first year after the death of the spouse.

Unfortunately, because the data that Xavier Thierry has been using gave only the year of widowhood (and not the exact date), this study cannot tell us what happens during the first months of widowhood. Some of the papers listed in Table 2 (e.g. Refs. [33–36]) tried to obtain estimates at the semester level. However, due to the small size of the samples, the evidence is not really conclusive; for instance the Boyle, Kaprio and Young results are not consistent with one another. The sample collected by Frisch et al. [43] may have been large enough for this investigation but (despite the title of their paper) the authors did not try a monthly longitudinal analysis. We will leave this question open for a further investigation.

8 It can be added that about 50% of the young adults aged 20–40 are cohabiting but only about one half of them will eventually get married.

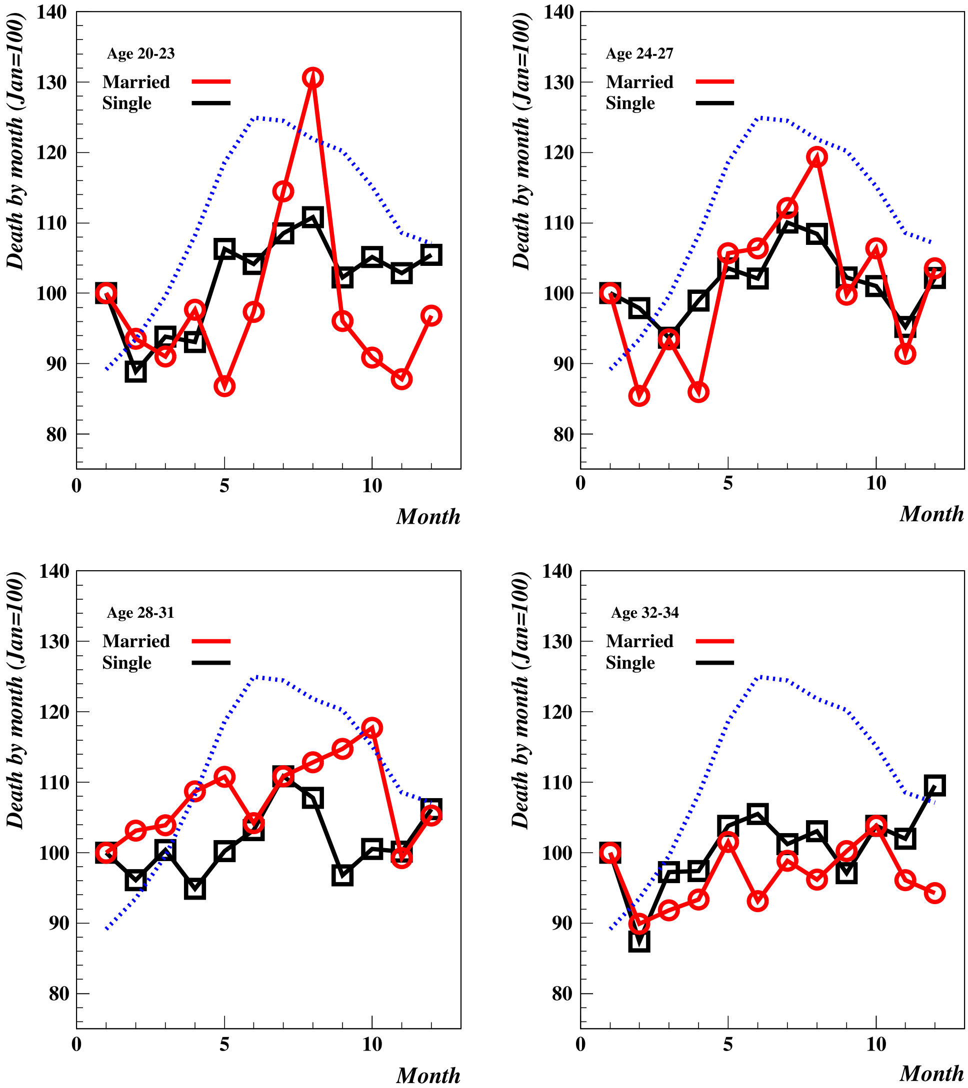

Fig. 10. Is there a transient mortality spike in the months following marriage? Horizontal scale: month (1–12) of 1992. Vertical scale: Number of deaths by month for single (black line with squares) and married persons (red line with circles) respectively. The panels show successive age groups. In each age groups there are several hundreds deaths (the smallest number, namely 182, is in the 20–23 age group of married persons). The (blue) dotted curve shows the monthly number of marriages. It can be added that as for the 32–34 age group, the age group 35–44 (not shown) does not display any peak either. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: [44] Mortality detail file for 1992 issued by the CPSR (Consortium for Political and Social Research). The file comprises all deaths that occurred in the US in 1992 (altogether there were 2,179,187 deaths).

6. Conclusion

We have examined the effect on mortality rates of sudden transitions in personal condition. Several of the transitions considered in the first part of the paper consisted in the severance of various social ties. Three of these cases are summarized in Fig. 12.

The next step would be to build a mathematical model. However, we believe that one should not hurry to do that without a more thorough understanding. So far, we have an overall grasp of the transient shock effect but there are several points which remain unclear, for example the relaxation mechanism. In almost all cases for which sufficiently detailed data were available (birth, arrest, marriage) the death rate seems to decrease as a power-law instead of an exponential. We would like to confirm this effect by studying additional cases and, if confirmed, we would like to understand the mechanism behind it.

The question of modeling versus factual observations can be seen in a broader perspective. In the first years of econophysics (1995–2005) many models were proposed often without much (if any) empirical underpinning. This remark

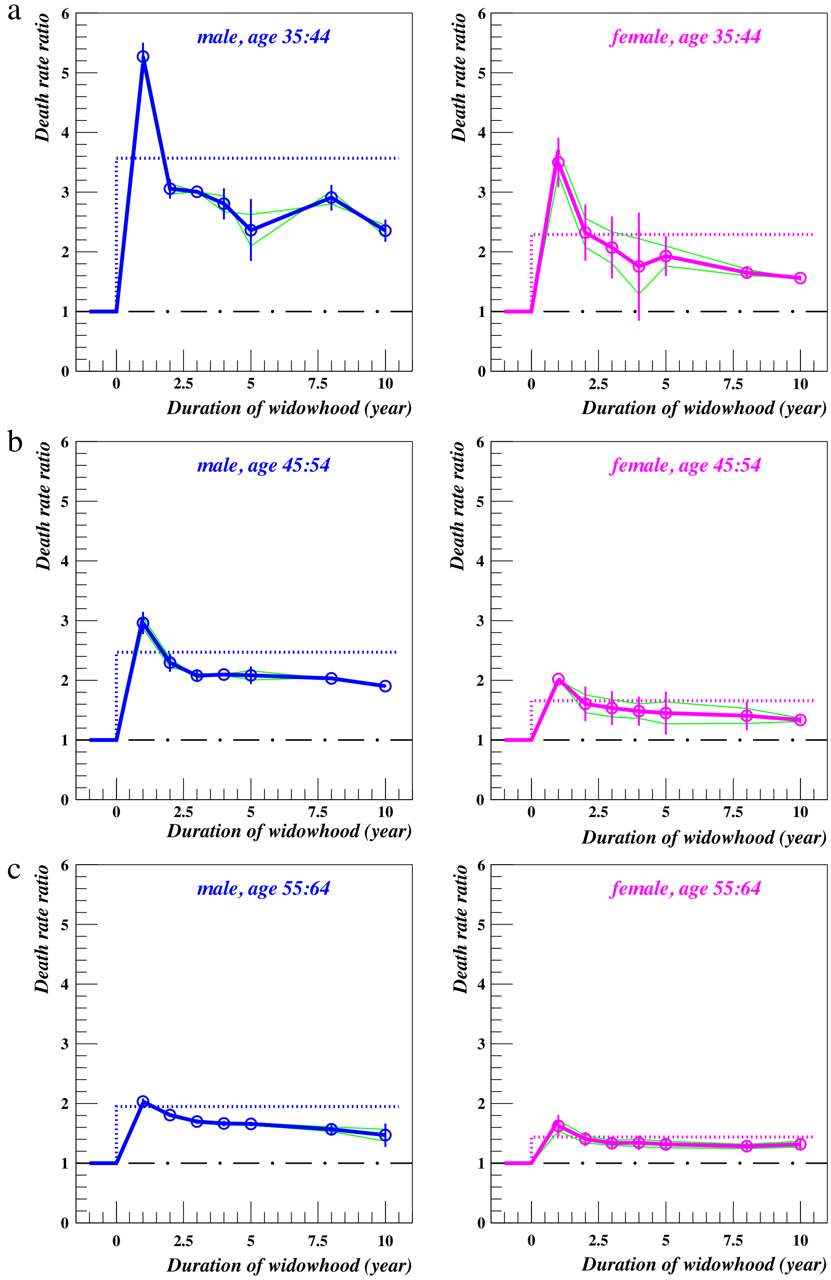

Fig. 11. Response functions of widowed persons following death of spouse as a function of the length of time t spent in widowhood. The response function gives the death rate ratio $w(t)/m$ where $w(t)$ is the death rate of persons who have been widowed for t years and M is the death rate of married persons. As expected from the results given in Part I [1] the amplitude of the spike is highest for young widowers. The two thin (green) lines are separate curves for the periods 1969–1974 and 1989–1991 respectively; the thick lines correspond to their averages and the error bars refer to the dispersion of the thin lines. For the purpose of comparison, the dotted curves show the average death rate ratios $w(t)/m$ for all persons irrespective of their time in widowhood. The phenomenon is basically the same for men and women; the response functions differ in amplitude but not in shape. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: Response functions: computations by the authors based on tables 4 and 5 of Xavier Thierry's paper [31]. Dotted curves: 35–44: Richmond and Roehner [1, Table 5, USA]; 45–54 and 55–54: Vallin et al. [32, Table B and D, p. 318 and 320].

applies especially to non-financial papers. Such models may have been interesting mathematically but could hardly be considered as being good "physics". Fortunately, in recent years (2005–2015), econophysicists became much interested in the analysis of data records pertaining to a broad range of phenomena. As illustrations of the diversity of their interests one can mention some of the papers published by Marcel Ausloos and his collaborators [45–48]. The present paper tries to follow suit in the same direction.

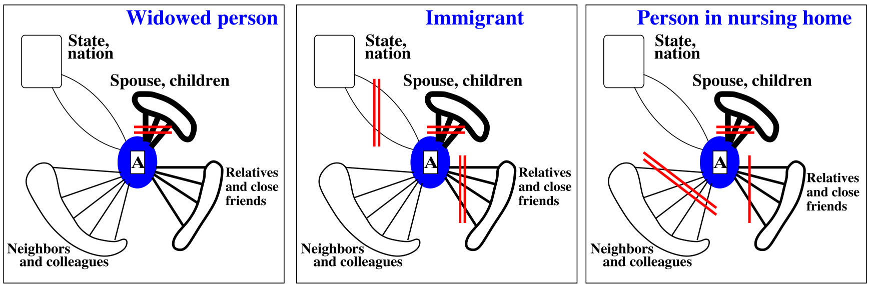

Fig. 12. Summary of cases of ties severance considered in the paper. The figure schematizes the links that connect a person *A* to the rest of the society. The two (red) parallel lines indicate severance of the corresponding links. For a person in nursing home the connection with spouse and children may be only partially broken depending on the location of the nursing home. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

References

[1] P. Richmond, B.M. Roehner, Effect of marital status on death rates. Part 1: High accuracy exploration of the Farr–Bertillon effect, Physica A (2016).
[2] W. Farr, 1859, 1975: Influence of marriage on the mortality of the French people (12 p.). Transactions of the National Association for the Promotion of Social Science 1858–1859, 504–520. The paper was republished in 1975 in "Vital statistics, a memorial volume of selections from reports and writings of William Farr". Scarecrow Press, Methuen (New York).
[3] L.-A. Bertillon, Mariage, in: Dictionnaire Encyclopédique des Sciences Médicales, [Encyclopedic Dictionary of the Medical Sciences], Vol. 5, 2nd ed., 1872, pp. 7–52.
[4] L.-A. Bertillon, France, in: Dictionnaire Encyclopédique des Sciences Médicales, [Encyclopedic Dictionary of the Medical Sciences], Vol. 5, 4th ed., 1879, pp. 403–584.
[5] B. Gompertz, On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies, Philos. Trans. R. Soc. 115 (1825) 513–585.
[6] Mortality Statistics 1910 (published in 1912): Bulletin 109. Bureau of the Census, Government Printing Office, Washington, DC.
[7] G. Klutke, P.C. Kiessler, M.A. Wortman, A critical look at the bathtub curve, IEEE Trans. Reliab. 52 (1) (2003) 125–129.
[8] B. Beach, How long do disk drives last? Provides data covering a 4-year period at the cloud storage company Backblaze, 2013. The website: https://www.backblaze.com/blog/how-long-do-disk-drives-last/.
[9] F.E. Linder, R.D. Grove, Vital Statistics Rates in the United States, 1900–1940, United States Printing Office, Washington, DC, 1947.
[10] D.J. Wilkins, The bathtub curve and product failure behavior. Part I: The bathtub curve, infant mortality and burn-in. Hot Wire 21 (November 2002).
[11] Child mortality statistics. Published annually by the British Office of National Statistics, this publication (now available on Internet) provides statistical data on stillbirths, infant deaths and childhood deaths occurring annually in England and Wales.
[12] Mortality statistics: review of the Registrar General on deaths in England and Wales. Series DHI, Number 16. Her Majesty's Stationary Office, London.
[13] Registrar General 1971: Statistical Review of England and Wales. Part III. Office of Population Censuses and Surveys. London.
[14] L.M. Hayes, J.R. Rowan, National Study of Jail Suicides: Seven Years Later, National Center on Institutions and Alternatives, Alexandria, Virginia, 1988.
[15] B.M. Roehner, A bridge between liquids and socio-economic systems: the key role of interaction strengths, Physica A 348 (2005) 659–682.
[16] G. Sattar, Rates and causes of death among prisoners and offenders under community supervision, Home Office Research Study, 2001, p. 231.
[17] O. Camargo, G.H. Preston, What happens to patients who are hospitalized for the first time when over sixty-five years of age, Am. J. Psychiatry 102 (2) (1945) 168–173.
[18] T. Locoh, L'entrée en maison de retraite. Etude auprès d'établissements de la région parisienne. [Admission into nursing homes. A study of institutions located in Paris and the surrounding area.], Population 27 (6) (1972) 1019–1044.
[19] R.D. Grove, A.M. Hetzel, Vital Statistics Rates in the United States, 1940–1960, United States Printing Office, Washington, DC, 1968.
[20] C.S. Aneshensel, L.I. Pearlin, L. Levy-Storms, R.H. Schuler, The transition from home to nursing home. Mortality among people with dementia, J. Gerontol. Ser. B: Psychol. Sci. Soc. Sci. 55 (3) (2000) 152–162.
[21] J.S. Kayser-Jones, Old, Alone, and Neglected. Care of the Aged in the United States and Scotland, University of California Press, Berkeley, 1981.
[22] C.K. Aldrich, E. Mendkoff, Relocation of the aged and disabled. A mortality study, J. Am. Geriatr. Soc. 11 (3) (1963) 185–194.
[23] E.C. Killian, Effect of geriatric transfers on mortality rates, Soc. Work 15 (1) (1970) 19–26.
[24] S. Weyerer, A. Wiedenmann, Economic factors and the rates of suicide in Germany between 1881 and 1989, Psychol. Rep. 76 (1995) 1331–1341.
[25] J.T. Nagle, Suicides in New York City During the 11 Years Ending Dec. 31, 1880, Riverside Press, Cambridge, MA, 1882.
[26] B.M. Roehner, Driving Forces in Physical, Biological and Socio-Economic Phenomena, Cambridge University Press, Cambridge, 2007.
[27] J. Bertillon, Les célibataires, les veufs et les divorcés du point de vue du mariage. [Attitude with respect to marriage of non-married, widowed and divorced persons.], Rev. Sci. France l'Etrang. 8 (33) (1879) 776–783. [Jacques Bertillon was the eldest son of Louis–Adolphe Bertillon].
[28] IPUMS: Integrated Public Use Microdata Series, University of Minnesota, Minneapolis.
[29] G. Chamberlain, British maternal mortality in the 19th and early 20th century, J. R. Soc. Med. 99 (11) (2006) 559–563.
[30] C.M. Parkes, B. Benjamin, R.G. Fitzerald, Broken heart. A statistical study of increased mortality among widowers, Br. Med. J. 1 (1969) 740–743.
[31] X. Thierry, Risques de mortalité et de surmortalité au cours des 10 premières années de veuvage. [Excess mortality during the first 10 years of widowhood.], Population 54 (2) (1999) 177–204.
[32] J. Vallin, F. Meslé, T. Valkonen, Tendances en matière de mortalité et mortalité différentielle. Editions du Conseil de l'Europe, Strasbourg. An English version was published under the title "Trends in mortality and differential mortality", 2001.
[33] J. Bojanovsky, Wann droht der Selbstmord bei Verwitweten? [After becoming a widower when is the likelihood of committing suicide largest?], Schweiz. Arch. Neurol. Neurochir. Psychiatr. 127 (1) (1980) 99–103.
[34] P.J. Boyle, Z. Feng, G.M. Raab, Does widowhood increase mortality risk? Testing for selection effects by comparing causes of spousal death, Epidemiology 22 (1) (2011) 1–5.
[35] J. Kaprio, M. Koskenvuo, H. Rita, Mortality after bereavement. A prospective study of 95,647 widowed persons, Am. J. Public Health 77 (3) (1987) 283–287.
[36] M. Young, B. Benjamin, C. Wallis, Mortality of widowers, Lancet 2 (1963) 254–256.
[37] C. Mendes de Leon, S. Kasi, S. Jacobs, Widowhood and mortality risk in a community sample of the elderly. A prospective study, J. Clin. Epidemiol. 46 (6) (1993) 519–527.
[38] J. Bojanovsky, Wann droht der Selbstmord bei Geschiedenen? [After a divorce when is the likelihood of committing suicide largest?], Schweiz. Arch. Neurol. Neurochir. Psychiatr. 125 (1) (1979) 73–78.
[39] C. Schaeffer, C. Quesenberry, S. Wi, Mortality following conjugal bereavement and the effects of a shared environment, Am. J. Epidemiol. 141 (12) (1995) 1142–1152.

[40] K.J. Helsing, M. Szklo, G.W. Comstock, Factors associated with mortality after widowhood, Am. J. Public Health 71 (1981) 802–809.
[41] P. Martikainen, T. Valkonen, Mortality after the death of spouse. Rates and causes of death in a large Finnish cohort, Am. J. Public Health 86 (8) (1996) 1087–1093.
[42] D. Mellström, A. Nilsson, A. Odén, A. Rundgren, A. Svanborg, Mortality among the widowed in Sweden, Scand. J. Soc. Med. 10 (1982) 33–41.
[43] M. Frisch, J. Simonsen, Marriage, cohabitation and mortality in Denmark: national cohort study of 6.5 million persons followed for up to 3 decades, Int. J. Epidemiol. 1 (2013) 13.
[44] Mortality detail file for 1992 (ICPSR 6798) 2001:Published by the US National Center for Health Statistics. It is the user guide of an electronic file of *all* the deaths that occurred in the United States in 1992.
[45] R. Lambiotte, M. Ausloos, Endo- vs. Exogenous schocks and relation rates in book and music "sales", Physica A 362 (2006) 485–494.
[46] M. Ausloos, R. Lambiotte, Time-evolving distribution of time lags between commercial airline disasters, Physica A 362 (2006) 513–524.
[47] M. Ausloos, Punctuation effects in English and Esperanto texts, Physica A 389 (2010) 2835–2840.
[48] M. Ausloos, Econophysics of a religious cult. The Antoinists in Belgium [1920–2000], Physica A 391 (2012) 3190–3197.