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Memory and Discounting: Theory and Evidence

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Memory and Discounting: Theory and Evidence

Abstract:

Heterogeneous memory capacity has been neglected in economics literature, though it may have profound economic implications. Adopting the concept of "memory utility" proposed by Gilboa, Postlewaite and Samuelson (2015), we explore the relationship between memory capacity and individual discounting behavior by building a simple two-period model and comparing its predictions with experimental data. Both theoretical and experimental evidences confirm that memory capacity and discounting rates are positively correlated.

Keywords: Memory utility, intertemporal consumption, Individual Discounting Rates, time preference.

JEL Classification: C91, D90.

Introduction

Economic theory typically assumes that people discount future benefits compared to the same amount of benefit that they could enjoy immediately. Two main explanations, as discussed in the literature, for discounting behavior are impatience (i.e. a time preference) and fear of uncertainty in the future, e.g. risk of death (i.e. a risk preference). Andreoni and Sprenger (2012a, b) argue that time preference and risk preference are different and can be estimated separately, followed by the discussion by Andreoni and Sprenger (2015), Cheung (2015), Epper and Fehr-Duda (2015) and Miao and Zhong (2015).

In this paper, we argue that memory could play an important role in explaining discounting behavior. Memory plays an important role in our behavior as a key factor in shaping our decisions. Compared with psychological literature that has paid ample attention to memory, economic literature only explores this issue in a very limited way. Dating back to 1759, Adam Smith (2009, p. 152) already observed that "We can entertain ourselves with memories of past pleasures...."

which implies that past pleasant memories could yield current utility. Gilboa, Postlewaite and Samuelson (2015) recently developed a new concept known as "memory utility", which connotes that current utility depends not only on current consumption, but also on past consumption. Our work takes this idea very seriously by searching for empirical and experimental evidences for it. Ignoring the heterogeneity in memory capacity could lead to substantial bias particularly in estimation of discounting behaviors.

Adopting the concept of "memory utility", we attempt to explain the links between memory capacity and individual discounting behavior. If the pleasure enjoyed today generates long-lasting positive memories for the future, which is then added to future utility, an agent who maximizes his/her total utility during their lifetime should naturally allocate more consumption to earlier periods. Memory serves as a premium for consuming today rather than in the future. Therefore, our model predicts that the ability to memorize is positively correlated with discounting, which is supported by experimental data.

It is well-known that experimentally elicited discount rates are often higher than what seems reasonable for economic decision-making, and Andreoni and Sprenger (2012 b) attribute it to the present bias (Laibson, 1997, Benhabib et al. 2010, and Chark et al. 2015). However, the root of present bias is not yet well explained. The conjecture that memory capacity and discounting rates are correlated then could partly explain the present bias (Andreoni and Sprenger; 2012a, b), as the experiments are conducted for college student subjects, who are often young and have higher memory capacity due to selection.

This is not the first study looking at utility from memory and discounting. To our knowledge, utility from memory has been discussed by Loewenstein and Elster (1992), together with utility from anticipation. More recently, Gilboa, Postlewaite and Samuelson (2015) set up a complete theoretical framework for introducing memory utility to economic analysis. The purpose of studying this question is to understand a wide class of phenomena that seemingly confront standard economic theory on intertemporal consumption. For example, why do a young couple spend one quarter of their combined annual income on a wedding and honeymoon?

The answer provided by Gilboa, Postlewaite and Samuelson (2015) is that a wedding and a honeymoon are memory goods. While the consumption usually takes place when young, people derive utility from it when they recall it at later stages in their lifetime. Therefore, spending a large amount of money on these non-durable goods may be an optimal choice. However, memory utility may make it harder for people to postpone their consumption and to act as if they have higher discount rate. Their theoretical framework is further developed by Hai, Krueger and Postlewaite (2015) to explain the welfare cost of consumption fluctuations. Our paper argues one step further: if memory makes people behave as if they are more impatient, the elicited discount rate should be positively correlated with the memory capacity. The paper adopts the memory span test from the psychological literature (e.g. Miller 1956) to measure the individual memory capacity, which is then linked to discounting rates. The positive correlation between memory and discount rate found in our paper serves as a strong evidence for the existence of memory utility suggested by Gilboa, Postlewaite and Samuelson (2015).

The rest of the paper is organized as the followings: Section 2 presents the theoretical framework, Section 3 reports the experimental evidence, and Section 4 concludes.

Theory

- **Benchmark**

We start from a basic two-period consumption model ($t = 0,1$) with a single commodity good. Our model is a simplification (special case) of the model of a two-good economy in Gilboa, Postlewaite and Samuelson (2015). The total utility for a consumer is

$$U = u(c_0) + \frac{1}{1+r} u(c_1) \tag{1}$$

with intertemporal budget constraint:

$$w_0 = c_0 + (1+i)c_1 \quad ; \tag{2}$$

where $u(c_0)$ and $u(c_1)$ denote the utilities at period 0, and period 1, which are respectively derived from consumption c_0 and c_1. w_0 denotes the total permanent income at period 0; and r and i are the discounting rate and market interest rate respectively.

Equation (2) is a typical overlapping generations model without involvement of memory goods.

- **Model with memory utility**

Following Gilboa, Postlewaite and Samuelson (2015), consumption at t does not only depend on the current consumption c_t, but also depends on the consumption in the past, which is defined as memory utility. Equation (1) can be rewritten as

$$U = u(c_0) + \frac{1}{1+r}u(c_1, c_0) \qquad (3)$$

If we assume $u(c_1, c_0)$ is additive, and specifically,

$$u(c_1, c_0) = u(c_1) + \rho u(c_0) \qquad (4)$$

where $\rho u(c_0)$ is the memory utility, the utility derived from the memory of $u(c_0)$ at period 1. Here ρ is defined as memory capacity, and $\rho > 0$. In the highly cited paper "The magical number seven, plus or minus two", Miller (1956) finds that human have limited and heterogeneous memory capacities. One can speculate that if a consumer has a better memory, his/her memory utility is higher.

Combining equations (3) and (4) yields

$$U = \frac{1}{1+r}[u(c_0) + \frac{1}{1+r+\rho}u(c_1)] \qquad (5)$$

When maximizing the utility in Equation (5) with the budget constraint of Equation (2), the observed discounting rate with memory utility for intertemporal choice becomes

$$r^* = r + \rho \qquad (6)$$

Equation (6) implies that when memory utility exists, consumers appear to make decision based on the Observed Discounting Rate r^* which involves in memory effects, rather than the market discounting rate, as memory utility cannot be observed. Particularly, the observed discounting rate is positively correlated with memory capacity. Thus, we have the following proposition:

Proposition 1:

When a consumer has memory utility, his/her (observed) discount rate is higher when his/her memory capacity is higher.

The current experimental literature finds that discounting rates are often unusually higher when the experimental subjects are college students. Proposition 1 could partly explain this phenomenon because students often have higher memory capacity than the general public, because they are young, well trained, and highly selected. One can speculate that better memory could lead to better school performance.

The current literature has studied in-depth both memory and discounting rates, but the linkage between them is still missing. The paper will later empirically study the linkage between the two variables via a simple experiment, and then verifies the proposition 1.

- **Risk Aversion**

The current literature also suggests that risk aversion is linked to discounting rates, as people fear of uncertainty in the future. However, Following Andreoni and Sprenger (2012b), we could further extend our theory by specifying a utility function with inclusion of risk aversions. We assume the CRRA (Constant relative risk aversion) utility function $u(c) = \frac{c^a}{\alpha}$, in which the relative risk aversion is measured as $\frac{1}{1-\alpha}$. When $\alpha < 1$, the consumer is risk-aversion; When $\alpha = 1$ he/she is risk-neutral; and When $\alpha > 1$ he/she is risk-loving.

Maximizing the utility in Equation (1) in the case of no memory utility yields

$$c_0^* = \frac{1}{1+(1+i)^{\frac{\alpha}{\alpha-1}}(1+r)^{\frac{1}{\alpha-1}}} w_0 \quad . \tag{7}$$

Analogously, maximizing the utility in Equation (5) in the case of memory utility under the budget constraint (2), we have

$$c_0^* = \frac{1}{1+(1+i)^{\frac{\alpha}{\alpha-1}}(1+r+\rho)^{\frac{1}{\alpha-1}}} w_0 \qquad (8)$$

Comparing Equation (7) with (8), we obtain $c_0^* > c_0$ for $\rho > 0$ and $\alpha < 1$ (risk-aversion consumer). That is

Lemma 1:

When there is memory utility, a risk-aversion consumer tends to allocate more budgets to the current period, compared with the case without memory utility.

Intuitively, consumers with memory utility could obtain more utility when more budgets are allocated to the period 0, which could then compensate the utility loss in period 1 through memory utility.

In addition, when $\alpha < 1$, Equation (8) also shows that

$$\frac{\partial c_0^*}{\partial \rho} > 0 .$$

This yields

Lemma 2:

A risk-aversion consumer with higher memory capacity allocates more budgets to the current period, and save less for the future when memory utility exists.

Also, the fact that more budgets are allocated to current period implies that the consumer has a higher discounting rate. Thus, Lemma 2 is consistent with Proposition 1. In practice, people tend to spend a lot of money on weddings and for tourism, particularly young people, because they could yield ample memory utility, which could contribute to later utility.

From the empirical perspective, Equation (8) demonstrates that risk aversion and discounting rate could be disentangled, and similar results are showed in studies of Andreoni and Sprenger (2012b).

However, both Equation (5) and Equation (8) shows that the true discounting behavior r cannot be disentangled from memory capacity ρ, as we only observed the discounting rate $r^* = r + \rho$. As proposed by Proposition 1, the observed discounting rate is positively correlated with memory capacity. This will be tested in the following experiment, where we develop a method to elicit the heterogeneity of memory capacity.

Experiment

- Measuring memory capacity

Psychological literature has distinguished three types of memory: sensory, short-term and long-term (Kassin 2006, pp.235) according to human information processing mechanism. Sensory memory records information from the senses for a very short time, for example, three seconds. However, sensations that do not draw attention tend to be forgotten, but those we notice are transferred to short-term memory. The short-term memory fades quickly, and only some information turns into long-term memory which can be stored for many years. The information process and the three types of memory are demonstrated in Figure 1.

Short-term memory is the critical chain linking sensory memory and long-term memory, and has been well studied in the literature. It is very difficult to measure sensory memory and long-term memory objectively. As the information processing time is very short for sensory memory, and very long for long-term memory, they cannot be measured accurately. In contrast, psychological literature pays attention to the study on short-term memory capacity. Figure 1 demonstrates that the short-term memory should be correlated with long-term memory capacity.

[Insert Figure 1 here]

Limited by attention resources, short-term memory can hold only a small number of items. In the famous memory span task test, Miller (1956) described the human short-term capacity as “the magical number seven, plus or minus two”. In other words, the average length of items that can be recorded in short-term memory is seven, with plus or minus two. His experiment has been replicated on many later occasions, and many studies have found that our short-term memory capacity is actually more limited than what Miller suggested (Cowan 2000). Such an experimental design is widely regarded as a good tool for measuring memory capacity.

Following Miller (1956), Baddeley (1992) and Cowan (2000), a *Memory Span Task* experiment is conducted in this study to measure memory capacity. Our subjects are college students, and are believed to have above average memory capacities. Specifically, we use a computer to generate 13 random number sequences, increasing successively from 2 digits to 14 digits (the number sequences are reported in Appendix 2). Each of the 13 number sequences are put separately on 13 PowerPoint slides, in an order of increasing number of digits, and are shown to the experiment subjects one by one. Each slide is shown for two seconds. Between every second slide a 10-second pause is provided for the subjects to write down the number on the previous slide on a notebook distributed by the experiment conductor. Memory capacity is measured by the number of digits in the longest number sequence a subject is able to write down, before the first mistake is made.

- Measuring discounting rates

Though individual discounting rates cannot usually be directly observed, Coller and Williams (1999) first developed an experiment to elicit this by comparing a list of different payment scenarios with different effective interest rates. Since then, the so-called multiple price list (MPL) is widely adopted in many experimental studies in eliciting time preference. Though some literature argues that time preference is often confounded with risk aversion (Holt and Laury 2002), the paper by Andreoni and Sprenger (2012a) and its comments suggest time preference can be elicited without risk preference. In the case of CRRA, Equation (8) in this paper demonstrates the very finding that risk aversion can be separated from time preference. Therefore, we did not combine the time preference elicitation task with the risk elicitation task.

The MPL method of Coller and Williams (1999) is adopted in this study for measuring individual discounting rates. Given a table, subjects are asked to choose between two options, A and B. Option A offers 3000 yuan at present, and B offers 3000 yuan plus an interest payments (the list of choices is reported in Appendix 1). The subjects make their choices from 10 rows in which A remains the same and the interest payment for B is increasing. The switching point from A to B is used to calculate the subjects' discount rate. Then we could calculate the yearly interest rates (YIR) and effective yearly interest rates (EYIR) respectively. The questions about time preference are hypothetical. Subjects do not receive the money they choose in their answer form. Coller and Williams (1999) conducted 6 sessions in their experiment, including both real and hypothetical payments. They find that the discounting rates for hypothetical payments are lower, but their results might be not robust because the sample size is relative small.

- <u>Experiment implementation</u>

Our data was collected in March-May, 2015 at Nanjing Agricultural University, Jilin Agriculture University, and Jilin University of Finance and Economics in China. We have 587 participants. All subjects are university students, and are recruited by our research partners in these three universities. Such a large sample could yield a robust result from a statistical perspective. The experiments are conducted in the following steps:

<u>Step 1:</u> Collect basic demographic information, such as age and gender of the subjects.

<u>Step 2:</u> Ask the subjects to elicit individual discounting rates using the table in Appendix 1.

<u>Step 3:</u> Show the 13 slides with the number sequences of the memory span task to elicit heterogeneities of individual memory capacity.

This experiment is also combined with a dictator game, but that was run after the experiment. The total duration of the whole session is typically around 40 minutes, and the subjects receive their payoffs based on their decision in the dictator game.

After deleting abnormal samples, for instance inconsistent answers in eliciting the individual discounting rates, we obtain 552 effective observations.

Experimental Results

Table 1 reports the descriptive statistics of the experimental results. The average age of the subjects is 20.71 years, with a standard deviation of 2.17 years. The percentage of male participants is 26.24%. The average number of correct numbers in the memorizing task is 9.31 out of 14, with a standard deviation of 1.78. It is higher than the finding of Miller (1956). However, it is comprehensible as the participants are college students who should have better memory capacity after training and selection of the college-entrance exams in China. Without considering censoring effects, the YIR (yearly interest rate) is 25.06%, with a standard deviation of 12.66%. Corresponding, the EYIR (effective yearly interest rate) is 28.20%, with a standard deviation of 15.30%. The discounting rates seems slightly higher than the results in Coller and Williams (1999), who report that YIR and EYIR fall in the intervals 17.5-20% and 19.1-22.1% respectively. But they are comparable because the samples in our study are young college students.

[Insert Table 1 here]

To obtain a quick overview of the relation between discount and memory, we plot the average discount rate at each memory level. Figure 2 shows this plot. There is strong indication of a positive correlation between the two variables. We also show the average discount rate by age and gender. There is an indication of a negative correlation between age and discount rate, and the average discount rate is higher for men than for women.

Next, we regress the discount rate on memorizing ability, age and gender.

$$Discount\_Rate = \beta_0 + \beta_1 memory + \beta_2 male + \beta_3 age + \epsilon \quad (9)$$

In the econometric model, $Discount\_Rate$ can be proxied by YIR and EYIR.

Coller and Williams (1999) proposes that there is a censoring mechanism in the MPL method. For instance, there are 19 subjects selected all “A” choices, which means that their discounting rates are smaller than 5%; while there are 38 subjects selected all “B” choices, which implies that their discounting rates are greater than 50%. We adopt the interval regression method proposed by Amemiya (1973) to estimate Equation (9). Both the results for YIR and EYIR are reported in Table 2.

[Insert Figure 2 and Table 2 here]

The results for the YIR and EYIR are similar, except that the coefficients for EYIR are slightly larger. It makes sense that the EYIR is higher than YIR. The likelihood ratio tests for model specification are highly significant (1%). It indicates that the interval regression models fit the data very well.

The coefficients for Memory are 0.76 and 0.92 respectively for YIR and EYIR models, and they are statistically significant at 5%. It proves our hypothesis that memory capacity is positively correlated with the discounting rates. Controlling other variables, an increase in one digit in memory span test, the discount rate will increase by 0.76%.

The coefficients for the Male dummy variable are 5.28 and 6.43 respectively for YIR and EYIR, and both statistically significant at 1%. It implies that the discounting rate for the male is 5.3% higher than female.

Finally, the coefficients for age are -1.07 and -1.28 respectively for YIR and EYIR, and both statistically significantly at 1% as well. It implies that the young people have higher discounting rate, even though the memory capacity is controlled. Recalling the concept of "memory utility", young people could have long time to enjoy the memory utility if more expenses are allocated to young age.

Conclusion

Adopting the concept of "memory utility" proposed by Gilboa, Postlewaite and Samuelson (2015) , that current utility depends not only on current consumption but also on past consumption, we explore the relationship between memory and discounting behavior by building a simple two-period model and by comparing its predictions with experimental data. The model predicts that in most cases, the strength of memory capacity should be positively correlated with discount rate, which is well supported by the experimental data. Our work, as an extension of Gilboa, Postlewaite and Samuelson (2015), somehow confirms the validity of the new concept "memory utility" at the same time.

The current literature for experimental economics only controls observed heterogeneities, such as gender and age, but some internal and unobserved differences, such as memory capacity, have not been well studied. They doubtlessly could regulate human decision-making. For instance, neglect of the memory capacity heterogeneities could bias the experimental results, or could make the results difficult to explain.

The literature often attributes the usually high discounting rates in experimental studies to unexplainable present bias. Our finding that memory capacity and discounting rates are positively correlated then could partly explain the present bias, as the experimental subjects often are college student subjects, who usually have higher memory capacity due to young age and high selection.

For future extension of our research, it may be useful to compare memory utility for positive versus negative experiences. Chew et al. (2014) find that people have a strong tendency to forget negative past events and exhibit false memory in favor of positive events. If memory capacity is influenced by the nature of the event, it may also be translated to different observed discount rate.

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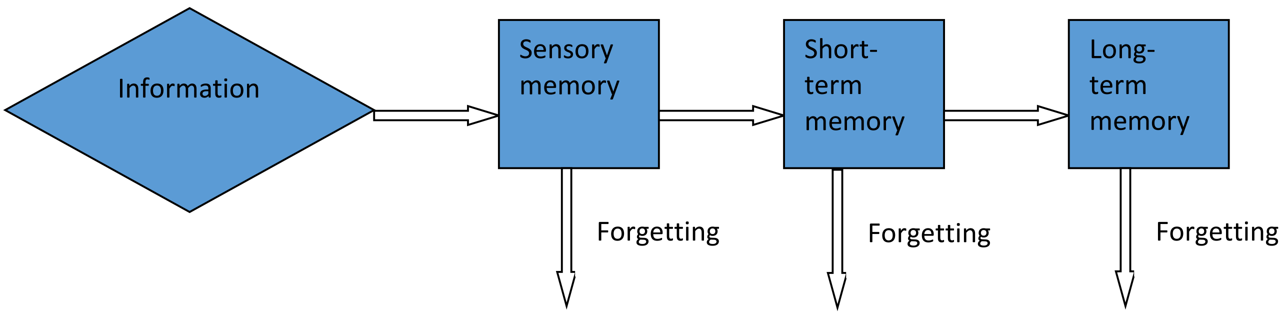

Figure 1: Information Process and Memory

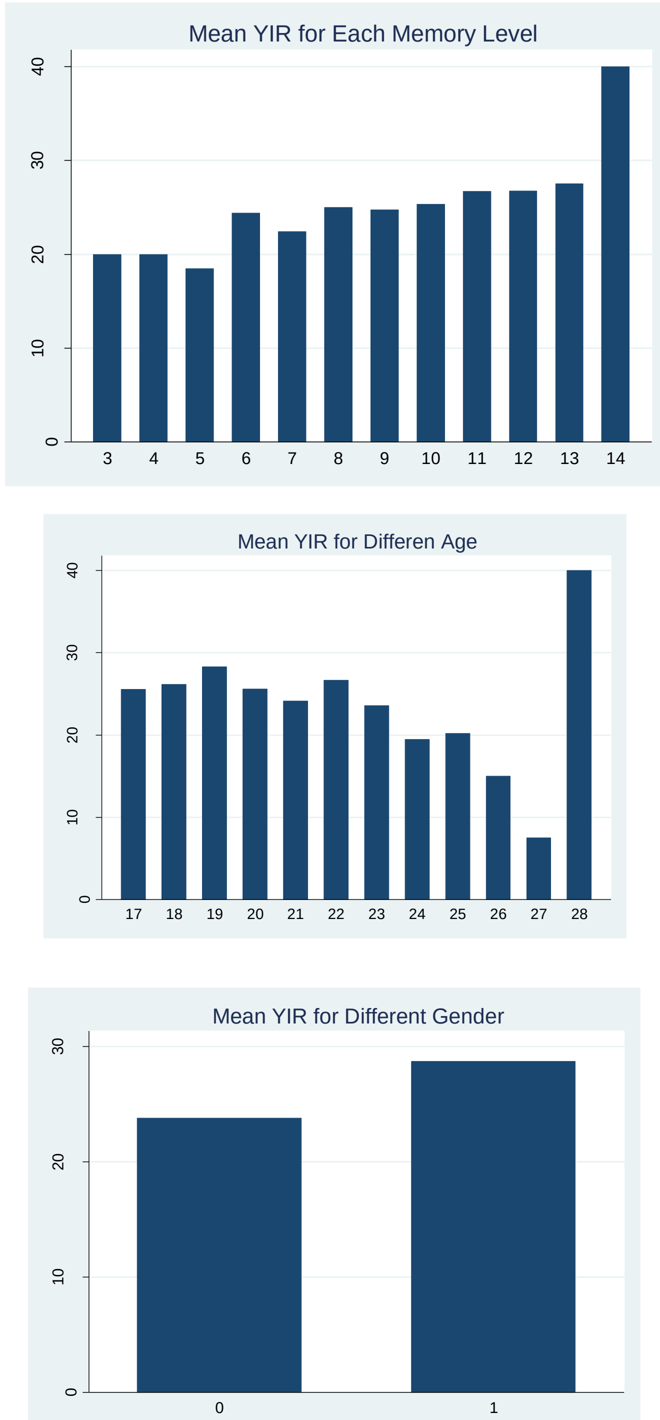

Figure 2: The average discount rate for each memory level, age and gender.

Table 1: Descriptive statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
Age	Age	20.71	2.17	17	28
Male	Male=1, Female=0	0.26	0.44	0	1
Memory	No. of Maximum Digits of Memorized Number	9.32	1.74	3	14
yir	Yearly Interest Rate (%)	25.06	12.66	0	50
eyir	Effective Yearly Interest Rate (%)	28.20	15.30	0	60.18

Table 2: Regression results for the experimental results

	YIR		EYIR	
	Coeff.	t-ratios	Coeff.	t-ratios
Memory	0.76	2.44*	0.92	2.41*
Male	5.28	4.27**	6.43	4.24**
Age	-1.07	-4.29**	-1.28	-4.17**
Intercept	41.56	6.78**	47.65	6.34**
LR test for Model Specification	chi2(3) = 41.61**		chi2(3) = 40.32**	

Notes: * and ** denotes significant levels at 5% and 1% respectively.

Appendix

Appendix 1:

Task to elicit time preference.

Suppose you are going to receive an amount of money around 3000 yuan. There are two options for you to receive it: Option A allows you to receive 3000 yuan in one month, and Option B allows you to receive 3000 yuan plus some interest payment in seven months. Please make a choice between A and B in the 10 pairs of choices below:

	Option A	**Option B**	**Yearly Interest Rate**	**Effective Yearly Interest Rate**	**Your Choice**	
	In 1 month Amount	In 7 months Amount	(%)	（%)	（Circle A or B）	
1	3000	3075	5	5.09	A	B
2	3000	3152	10	10.38	A	B
3	3000	3229	15	15.87	A	B
4	3000	3308	20	21.55	A	B
5	3000	3387	25	27.44	A	B
6	3000	3467	30	33.55	A	B
7	3000	3548	35	39.87	A	B
8	3000	3630	40	46.41	A	B
9	3000	3713	45	53.18	A	B
10	3000	3797	50	60.18	A	B

Appendix 2:

Instructions for memory measurement task

Now you are going to watch 13 slides in a sequence. On each slide there is a number. Please write down the numbers on the slides in the right sequence.

Numbers on the slides:

69, 929, 1021, 34634, 943453, 7374885, 69358267, 699875725, 6655803001, 26656897198, 661518840995, 1285246589042, 91431501977497.

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