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Underestimation of money growth and pensions: Experimental investigations

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Abstract: *People underestimate long-term growth in savings because they linearise exponential growth – a phenomenon known as exponential growth bias (EGB). This bias has implications for multiple financial decisions, particularly those relating to pensions. We hypothesised that underestimation might be even more severe for regular savings relative to lump sums, because savers need also to estimate accumulation. The additional cognitive load could strengthen EGB, or individuals might underestimate accumulation in addition to EGB. Four experiments investigated: (1) whether underestimation of money growth is greater for long streams of regular savings than for lump sums; (2) whether underestimation occurs when questions are framed intuitively as the cost of delaying starting a pension; and (3) whether practice with a calculator designed to illustrate the cost of delay attenuates underestimation. Individuals were more likely to underestimate money growth from regular savings than from lump sums, because they failed to accumulate contributions in addition to displaying EGB. Underestimation was substantial and persistent. Practice with a calculator partially attenuated underestimation, primarily among individuals with higher educational attainment and without a pension. Overall, these findings imply that across multiple judgements, decisions and frames, individuals substantially underestimate money growth, reducing the attractiveness of saving.*

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1. Introduction

People tend to linearise exponential relationships when making intuitive judgements. This psychological phenomenon, first investigated by Wagneaar and Sagaria (1975), has become known as "exponential growth bias" (EGB). Many financial decisions are potentially prey to EGB, because compound interest means that both assets and debts grow exponentially. At its most simple, the phenomenon is consistent with evidence that individuals are intuitively inclined to underestimate both the benefits of saving (McKenzie and Liersch, 2011) and the costs of debt (Ranyard and Craig, 1993; Soll, Keeney and Larrick, 2013). Moreover, there is evidence that variation in EGB affects household financial outcomes (Stango and Zinman, 2009).

EGB may have a particular impact on decisions concerning pensions, given the durations over which saving for retirement takes place. If so, it is a matter of concern. Recent decades have seen a shift from defined benefit (DB) pensions to defined contribution (DC) pensions, which has been accompanied by the scaling back of state pension entitlements (OECD, 2015). These trends transfer responsibility for retirement planning from professionals and institutions to individuals (Baldwin, 2008; Poterba et al., 2007).

The decision to start a pension, and subsequent decisions such as when to start and what level of contributions to make, depend partly on the trade-off between the evaluation of money now and the evaluation of money in the future. A strand of research has investigated the link between pension contributions and intertemporal discounting. Hyperbolic discounting implies that people may strongly discount retirement income relative to current income (Laibson, 1997), albeit that this phenomenon can also be exploited to make committing to starting a pension or increasing contributions at a later date more attractive than acting immediately (Thaler and Benartzi, 2004). Although uncertainty about the future may contribute to it

(Gabaix and Laibson, 2017), strong discounting of future monetary amounts relative to equivalent current amounts is a separate phenomenon from systematic misjudgement of the future monetary amounts. By contrast, EGB implies that individuals systematically underestimate them. The distinction between these phenomena is supported by the finding that the individual-level correlation between intertemporal discounting parameters and EGB is low (Goda et al., 2015).

This paper investigates judgement of money growth in the specific context of investing in a pension, where linearisation of exponential growth over decades might lead to substantial underestimates of the benefits of saving. To this possibility, we add another.

EGB is typically investigated by testing individual judgements of what a monetary amount will be worth at a future date given the application of a specific interest rate. In the context of a pension, the situation is less straightforward. For one thing, returns on the underlying investment are uncertain and possibly volatile. Although potentially important, this variation is not investigated in the present paper. Instead, our focus is more straightforward. Pensions (and other forms of regular saving) consist of an accumulating stream of contributions to a fund. We hypothesise that regular saving might generate additional effects when estimating money growth, over and above those observed for lump sums. We consider three rationales. First, it is possible that the impact of EGB might be attenuated for estimates of growth on regular savings relative to lump sums over defined periods, because the regular contributions will earn interest for only half of the period, on average. Growth in the fund is partly a linear process of accumulation, not a purely non-linear one; the combination of linear and non-linear growth may be more accurately judged. Second, if estimating growth due to accumulation as well as interest increases cognitive load, the opposite may occur and underestimation could be more severe. Additional cognitive load could strengthen a mental shortcut such as linearisation of a relationship and so strengthen EGB. Third, individuals may also underestimate the accumulation of contributions over long periods. This could act simply as a separate, additional factor that results in greater underestimation for regular savings than for lump sums.

To the best of our knowledge, the only previous investigation to address the possibility of a different degree of underestimation for regular savings is McKenzie and Liersch (2011). This multi-experiment study asked questions that were specific to retirement saving. It tested both abstract judgements of money growth and decisions as to which of two individuals would be better off if one saved less but started saving earlier than another. The precise question asked is potentially important, as performance may differ when an exponential growth problem is placed in an everyday context rather than an abstract one (Christandl and Fetchenhauer, 2009). McKenzie and Liersch (2011) recorded strong underestimation for judgements of regular saving and showed that an intervention designed to highlight the exponential nature of money growth increased intentions to save. However, participants were mostly undergraduates, the tasks assumed high rates of return (10% and 5%) over a long period (40 years), and there was no direct comparison with performance for lump sums.

The present paper aims to build substantially on this and other previous work. In a series of experiments, we test the accuracy of estimations of money growth, directly comparing lump sums and regular saving, both in abstract and more intuitive everyday contexts. We compare non-expert and expert judgements and use samples of participants who are representative of adults who make relevant decisions about pensions. The samples are of sufficient size to permit some subgroup analyses by age, gender, educational attainment and whether the participant has a pension. Finally, we also test the impact of an intervention in which participants could use a pension calculator designed to illustrate the dynamics of money growth. The concluding section considers limitations, future research needs and the policy implications of our results.

2. Relationship to Previous Work

2.1 Understanding Exponential Growth

The counterintuitive nature of exponential growth has been understood anecdotally for centuries,[1] but was first studied experimentally by Wagenaar and Sagaria (1975). Asked to predict future values of exponentially growing quantities, people made linear estimations and then adjusted insufficiently for nonlinearity. For relationships with high exponents, underestimation occurs when questions are presented non-numerically, among trained professionals and among students educated about misperception of exponential growth (Wagenaar & Timmers, 1979). Thus, exponential relationships can cause difficulty even when individuals are aware of the non-linearity.

2.2 Exponential Growth Bias and Financial Decision Making

With respect to financial decisions, the exponents that drive key relationships are interest rates, investment returns and inflation. They are typically smaller than exponents tested in non-financial studies, notwithstanding periods of extraordinary returns or certain high-interest products such as payday loans. Nevertheless, evidence suggests that when dealing with interest rates or inflation a substantial proportion of the population does not understand that there is a nonlinearity to contend with at all (Lusardi and Mitchell, 2017; Song, 2015a). One way to measure EGB for returns is to present two savings scenarios and ask the participant which scenario at a given rate of return would result in greater savings by a given date. A

[1] Legend surrounding the invention of chess tells that the game was invented for the entertainment of a king who was so delighted with the game that he offered the inventor any reward. The inventor said he wanted only the number of grains of corn that could fit on a chess board starting with one on the first square, two on the second and doubling for each of the successive 64 squares. The reward at first seemed meagre but on calculating the final amount the king realised that this would equate to a twenty-figure sum and more corn than the kingdom could provide (MacDonell, 1898, from Levy and Tasoff, 2017).

large proportion of participants underestimate money growth (Eisenstein & Hoch, 2007; McKenzie and Liersch, 2011).

Survey data display correlations between EGB and consumers' financial literacy, long term savings and retirement planning. Stango and Zinman (2009) found that respondents who underestimated compound interest borrowed more money, saved less and favoured shorter maturities. Levy and Tasoff (2016) reported that respondents with EGB had lower accumulated assets over the life-course than unbiased respondents. They estimated that an unbiased participant would accumulate 55% – 90% more assets than a fully biased person, equivalent to $88,000-93,000 in their study. Goda et al. (2015) also found that individuals with high EGB have lower retirement savings.

2.3 Interventions for Exponential Growth Bias

Given the potential impact of EGB on financial decision making across the life-course, efforts have been made to find interventions that can attenuate it. Although Wagenaar and Sagaria (1975) showed that trained professionals can display EGB, financial studies have found that familiarity with compound interest and inflation can reduce EGB (Keren, 1983; Christandl & Fetchenhauer, 2009) and that some interventions to combat it can increase intention to save (McKenzie and Leirsch, 2011). Eisenstein and Hoch (2007) demonstrated that expert individuals often used the "Rule of 72" as a rule of thumb to estimate exponential growth.[2] Teaching the rule to previously naïve participants led to a higher proportion of correct answers to a question about savings. In a field study in China, a financial education intervention increased understanding of compound interest and subsequent contributions to a pension scheme (Song, 2015a). In a US field study, participants shown their projected

[2] If y is the number of years that it takes for money invested at interest rate i to double in value, then $y \approx 72/i$ (Eisenstein & Hoch, 2007).

retirement income during pension scheme enrolment made higher annual contributions than those in a control group (Goda, Manchester and Sojourner, 2014).

With the exception of McKenzie and Liersch (2011), who used a student sample, these studies intervened with individuals already enrolled in a pension plan. Arguably, however, EGB is likely to be equally, if not more, relevant to people with no pension. Individuals who do not have a pension and who exhibit EGB are likely to underestimate the benefit of saving at a younger age and to overestimate how long they can delay.

2.4 Failure to Accumulate Disaggregated Prices

We are unaware of any studies that have previously tested for an intuitive failure to accumulate pensions contributions accurately. However, there are other areas of economic life where individuals face the task of aggregating monetary sums in order to evaluate transactions. In a series of experiments, Gourville (1998) showed that temporally reframing prices as smaller regular amounts alters consumers' perceptions of value. In essence, products are viewed as better value when marketed using a "pennies-a-day" strategy, implying underestimation of the accumulated total cost. Similarly, a large volume of research (reviewed by Greenleaf et al., 2016) suggests that partitioning product prices into components (e.g., surcharges, shipping costs, handling fees, etc.) can systematically distort perceptions of total prices. Similar failure to combine monetary amounts may lead to underestimates of funds built up from accumulated pension contributions.

2.5 Hypotheses

We set out to examine judgements of money growth in laypeople and experts, making a direct comparison between growth of funds that receive regular contributions and growth of lump sums. Given the potential for effects to be context-dependent, we also aimed to assess whether underestimation is affected by the question context, framing the question in a narrative rather than abstract context, both in terms of time (“How long can I wait if I save more?”) or cost of delay (“How much more will I need to save if I start later?”). Given findings suggesting that underestimation can be reduced by intervention, a further aim was to test a calculator designed to combat underestimation of money growth.

With these aims and taking account of previous literature, we developed a series of hypotheses:

H1: Individuals will display greater underestimation of money growth when funds are built up by regular savings compared to lump sums.

H2: Underestimation of pension funds built up via regular savings will result from both EGB and failure to accumulate contributions.

H3: A money growth calculator designed to illustrate the underlying relationships in an intuitive context will reduce underestimation.

As we did not find previous studies that had addressed the impact of framing the question in terms of time or money, we did not have a directional hypothesis as to how these question formats would affect judgement.

3. Experiments 1A and 1B

3.1 Introduction

The aim of these two initial experiments was to perform a simple comparison of judgements of money growth in the general public and in an expert audience when asked to assess growth of a lump sum and of a fund subject to regular savings. Both studies employed convenience samples, were undertaken in lecture halls, and presented the problem as an abstract financial question. They were designed as initial tests to inform subsequent experiments, which were undertaken in controlled laboratory conditions.

3.2 Experiment 1A – General Public

3.2.1 Method

Participants were 77 members of the general public who were recruited to take part in a television programme entitled "My Money and Me", to be screened by Ireland's public broadcaster, RTÉ. The sample was selected by a production company from volunteers in the Dublin area and was designed to be broadly representative of the local population of consumers with respect to gender and age (18-75 years). The sample was plausibly subject to some selection bias, because respondents had volunteered to take part in a television programme on personal finance and therefore probably possessed an above-average level of interest in the matter.

Participants were asked the following two questions:

"You put €1,000 into an investment fund. You leave it in there for 5 years. The investment generates a return of 5% per year, which is added each year to your fund and all goes to you – no fees, charges or tricks. How much will you have in 5, 10, 15 and 20 years?" [Lump Sum condition].

"You put €1,000 into an investment fund every year. The investment generates a return of 5% per year, which is added each year to your fund and all goes to you – no fees, charges or tricks. How much will you have in 10, 20, 30 and 40 years?" [Regular Savings condition].

Respondents were encouraged to remain silent and not to confer. There was no time limit to consider each question. Respondents wrote their answers into a response booklet. Given the within-subjects design, the durations were altered slightly between the two questions to reduce overlap between the estimations while still allowing for comparability between conditions. The 10, 20, 30 and 40 year periods for regular savings also permitted comparison with the undergraduate student sample of McKenzie and Liersh (2011).

3.2.2 Results

A small number of non-responses were recorded (reaching a maximum of 8 for the final question regarding regular saving over 40 years). These were excluded from the analysis. The correct answers for the lump sum questions are €1,276, €1,628, €2,078 and €2,653 respectively. Because the distribution of responses was highly non-normal with substantial variance, we report the medians and inter-quartile ranges (IQRs). Answers were transformed into proportions of the correct answers (so that 1 reflected a perfect answer, less than 1 displayed underestimation, greater than 1 overestimation). Results are shown in Figure 1.

In the lump sum condition, participants were close to correct when calculating over 5 years (median 0.98, IQR 0.98 – 1.02). This level of performance was likely, because linearising the relationship gives an answer of €1,250 (0.98), which was the median response. Underestimation of growth on the lump became greater over longer durations, reaching 0.84 (IQR 0.75 – 1.18) at 20 years. Again, 0.84 equates to linearisation of the relationship. Among the minority of respondents who attempted to correct for the nonlinearity, there was a mixture of insufficient and excessive corrections, with 9 participants guessing more than double the correct amount.

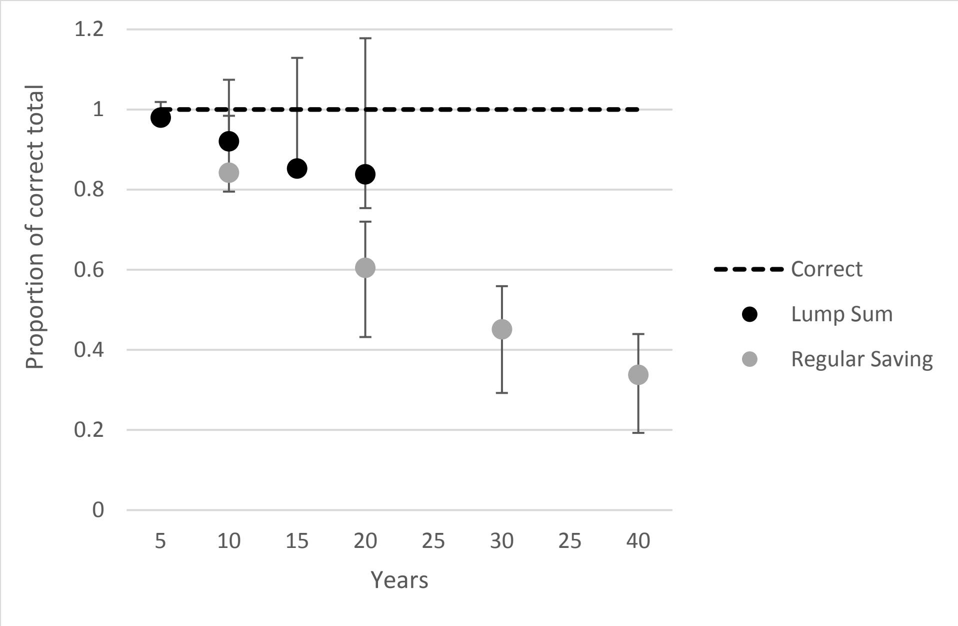

Figure 1. Median estimations and interquartile ranges from a sample of the general public of the value of a €1,000 lump sum and of a fund built through regular saving of €1,000 per year, each at 5% annual interest.

The correct answers for the regular savings questions are €13,207, €34,719, €69,761 and €126,840. The extent of underestimation was substantially greater in this condition. At 20 years duration the median was 0.60 (IQR 0.43-0.72), with only 7 participants overestimating the fund size. By 40 years duration it was just 0.34 (IQR 0.19 – 0.43), with only 4 participants overestimating. The 10 and 20 year periods permit direct comparison between conditions, although it is important to acknowledge that, in addition to the difference between lump sums and regular saving, there was a substantial difference in the scale of the fund size for the two problems (and therefore the scale of the answer). Median underestimation was greater in the regular savings condition compared to the lump sum condition for both 10 years and 20 years (sign test, $p = .002$ and $p < .001$ respectively).

3.3 Experiment 1B – Expert Sample

3.3.1 Method

We conducted a similar initial experiment on a sample that ought to have relevant expertise. The experiment took place at a national economics and psychology conference. Almost all participants (N = 39) were academic researchers with an interest in economic psychology, ranging from postgraduate students to tenured research professors. Participants answered two questions:

"In January 2017 you put €1,000 into an investment fund. You leave it in there for 30 years. The investment generates a return of 5% per year, which is added each year to your fund and all goes to you – no fees, charges or tricks. How much will you have at the end of 2046, 30 years later?" [Lump Sum condition].

"On the first of January, 2017 you put €1,000 into an investment fund. You deposit another €1,000 at the start of every year over the next 30 years. The investment generates a return of 5% per year, which is added each year to your fund and all goes to you – there are no fees, charges or tricks. How much will you have at the end of 2046, 30 years later?" [Regular Savings condition].

The problems were read aloud by the experimenter, after which participants were given just 30 seconds to write down an answer. They could not use calculators. These conditions were imposed because it was likely that some people in the room would be able to do the calculation formally and we were interested in their intuitive judgement. This was also the reason for posing just two problems, rather than eliciting estimations over multiple time periods.

3.3.2 Results

The correct answers are €4,322 for the lump sum question and €69,761 for the regular savings. The median response for the lump sum was €4,500 and the median response for the regular savings was €75,000. These answers were remarkably close to and, in fact, marginally above the correct answers. Transforming the answers into proportions of the correct answer, medians were 1.04 (IQR 0.58 – 3.93) for the lump sum and 1.08 (IQR 0.57 – 1.72) for regular savings. A sign test indicated no statistically significant difference in medians between conditions (p = .15). These results suggest that many individuals in this expert sample knew to adjust for the nonlinearity, resulting in an accurate median response, but could only do so very approximately, leading to an extensive range of responses.

3.4 Experiments 1A and 1B: Discussion

Two initial studies compared a general and expert audience in their ability to estimate money growth from lump sums and regular savings. As hypothesised (H1), a sample of the general public underestimated money growth substantially, and did so more for regular savings than for the lump sum. For regular savings the effect size was very large, with funds built up over 30 years estimated to be less than half the correct size. Despite differences between the studies in question wording, amounts, sample frame and country, the results for the regular savings condition in Experiment 1A is strikingly close to those of McKenzie and Liersch (2011, Experiment 1). In that study, undergraduates judged a fund built up through regular saving at 5% interest. They increasingly underestimated up to 40 years, when estimates were approximately one-third of the correct amount.

By contrast, the expert audience demonstrated that in an intuitive judgement taken in just 30 seconds, it is possible to overcome biases that drive systematic underestimation. The median response was unbiased despite the large variability in the responses, which confirms the inherent difficulty of intuitively estimating money growth over long periods. Among the expert sample, therefore, we observed a classic "wisdom of crowds" effect of the sort first documented in the seminal work of Galton (1907). Consequently, the expert sample also did not display greater underestimation for regular savings compared to a lump sum.

While providing suggestive confirmation of our main hypothesis, Experiments 1A and 1B were initial experiments with convenience samples. It is possible that the main effect of greater underestimation of money growth when judging funds built up via regular savings was partly influenced by other factors that were not systematically controlled. These could include the absolute scales of the answers, the one specific interest rate employed, the order of the questions (which was not counterbalanced), or the abstract nature of the task.

4. Experiment 2

Experiment 2 built on Experiments 1A and 1B in three ways. First, Experiment 2 employed less abstract and more intuitive questions concerning the decision to start saving for retirement. Second, by employing a counterbalanced, repeated measures design, Experiment 2 systematically manipulated the interest rate, size of the fund and the duration of saving. These manipulations were designed to give insight into the hypothesised psychological mechanisms behind underestimation (H2). If regular saving exacerbates EGB, it should have a greater effect at higher interest rates, because linearisation entails greater departure from the true relationship. If regular saving results in failure to accumulate amounts over long time periods, underestimation should be sensitive to the relative time periods over which saving takes place. Third, Experiment 2 studied the effect using a larger and more representative sample under more controlled conditions, permitting some sub-group analysis of responses.

When individuals consider starting a pension, they must determine when to start saving and how much to save. If they underestimate money growth, they may underestimate the cost of delay. However, the decision is often made by workers who expect to earn higher income or to come into wealth as they age, meaning that pensions contributions are more affordable. Typical examples are workers who consider whether to start saving now or to wait until their next promotion or pay increase, and individuals who expect to receive substantial inheritance. In these contexts, the problem may be conceived of as one of deciding how long to delay saving given the expectation of higher income and/or wealth. Thus, judgements of money growth can be recorded intuitively in either a monetary frame ("How much?") or a time delay frame ("How long?"). Experiment 2 split participants into two groups to test the accuracy of intuitions under these two frames, comparing lump sums and regular saving.

4.1 Method

4.1.1 Participants

Participants were 96 Dublin consumers aged 19-65 recruited by a market research company. The sample was representative of the Dublin population, balanced by gender (47 female), age (M = 39.95, S.D. = 12.63), education (49 educated to degree and above) and working status. Participants were paid €30 for participation and had the chance to win €50 vouchers based on performance.

4.1.2 Materials

The experiment was computerised. Tasks were programmed in Python using the PsychoPy package (Peirce, 2007; 2009) and presented on 14" (1366 x 768) Dell laptops.

4.1.3 Design

The experiment had a 2 x 2 x 2 design. Two manipulations were orthogonal and between-subject: (a) monetary frame vs. time delay frame and (b) the interest rate of 7% vs. 3%. The lump sum versus regular saving manipulation was within-subject. All participants answered 8 questions, 4 with a lump sum savings situation and 4 with a regular savings situation, counterbalanced between participants. Saving durations and fund sizes were varied randomly over questions as described below. Each question presented a cartoon depicting a comparison of two scenarios (Figures 2a and 2b). In the top scenario, a monthly amount saved and a starting age was shown. In the bottom scenario, one of these pieces of information was missing, while the other was different. The task was to fill in the blank so that the total amount saved at 65 (including all interest earned) was the same.

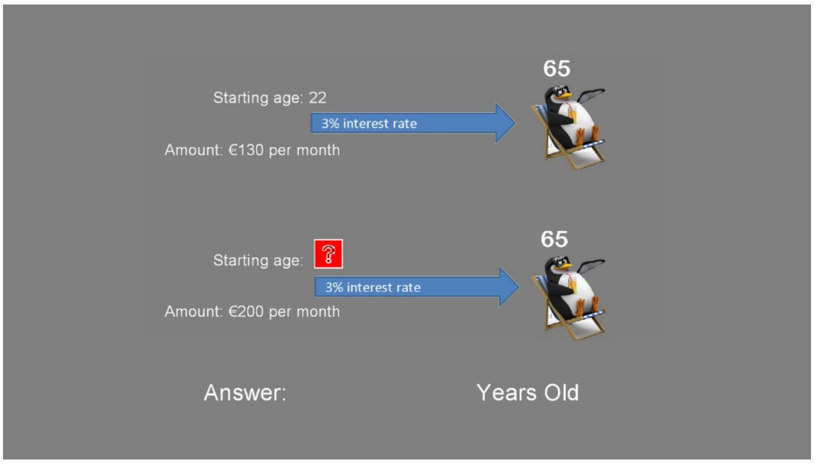

Figure 2a. Screenshot of one question in the time delay frame regular savings condition.

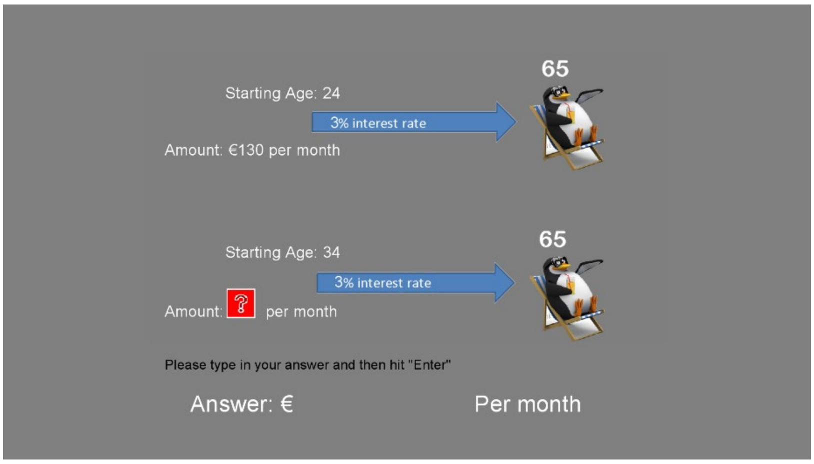

Figure 2b. Screenshot of one question in the monetary frame regular savings condition.

For the monetary frame (hereafter “Euro” task), the regular savings questions employed randomly selected monthly amounts from the range €100-€340 in intervals of €10, while the lump sum questions selected from €60,000 to €180,000 in intervals of €5,000. These ranges were based on the desire to keep the geometric progression of the range similar (near to three-fold), to keep numbers round and to maintain realistic monthly contributions and bequests (e.g., shares of executor house sales) for the local economy. These ranges generated overlapping rather than equivalent fund sizes for the regular savings and lump sum conditions. For each set of four questions and each participant, starting ages were drawn without replacement from one of two ranges (25, 35, 40, 50; or 25, 30, 40, 45) jittered by ±3 years. The second age displayed was then either 5 years or 10 years older. The correct answer in euros was calculated once these variables had been selected. For the time frame (hereafter “Years” task), the amount saved and starting age for the top scenario were selected as in the Euros condition. The correct answer was then randomly selected from the range 3 to 12 years, before the correct saving amount was calculated for the bottom scenario to match the fund size at age 65 for the top scenario. After a response was entered, a confirmation screen appeared. Participants could go back and change their answer or proceed to the next question.

4.1.4 Procedure

Participants completed the experiment in groups of five, all in the same Euro vs. Years condition, but with different questions and interest rates. After informed consent was obtained, the experimenter explained the task. S/he worked through an example cartoon on a projector screen; participants had the same example on their screens. For the Euros condition with regular saving, the example compared someone who started saving €225 a month from age 35 to someone who instead started at age 45. The experimenter explained that participants had to estimate how much the second person needed to save to have the same amount at retirement. For the Years condition with regular saving, the first scenario was the same and savings in the second scenario were €295 per month. The experimenter explained that participants had to estimate the age at which the second person needed to start save to have the same amount at retirement. The lump sum examples for the Euros and Years conditions used the same ages, but participants were told that saving consisted of a once-off lump sum of €115,000 or €150,000.

The experimenter acknowledged the difficulty of the task and made clear to participants that they were not expected to provide precise correct answers but to give their best guess. We explained that calculators had not been provided because we were interested in people's intuitions. Responses were incentivised. Participants were told that they would be rewarded for accuracy such that every answer in the top half of the sample, would earn an extra entry into a raffle for a €50 shopping voucher, which would have 10 winners.

There was no time limit on responses, but participants were encouraged to spend at least one minute on each question. When all participants had answered the first four questions, the experimenter explained the second half of the task which was either the regular saving or lump sum condition. The experiment took approximately 15 minutes.

4.2 Results

4.2.1 Scale of Underestimation

There were 384 responses in each task. In the Euros task, 29 (7.6%) amounts were lower than the starting amount of the earlier saver. In the Years task, 70 (18.2%) ages were younger than the starting age of the lower saver. These answers were not included in the analyses as they implied either mistyping of responses or failure to comprehend the question adequately.

In the Euros task, underestimation was indicated by inputting an amount for the later saver that was lower than required to generate an equivalent fund at age 65. In the Years task, underestimation was indicated by inputting an age for the later saver that was older than required to generate an equivalent fund. The first column of Table 1 provides the probabilities that participants underestimated money growth by task and by whether the condition was regular saving or lump sum. Participants tended to underestimate in both conditions but were more likely to do so in the Euros task and in the regular saving condition in both tasks. The remaining columns quantify the effect according to the impact on the fund size at age 65. As in Experiment 1A (Figure 1), the median underestimation for regular saving translates into an approximate doubling of underestimation relative to the lump sum. To assist comparison of effect size with Experiment 1A, note that the median delay in starting saving in both tasks was 7.5 years. Hence, despite the different samples and tasks, the degree of underestimation is similar. Assuming a constant rate of underestimation over years, over 30 years the underestimation recorded in Experiment 2 would translate into underestimation of 0.44 (Euros task) and 0.62 (Years task), compared to 0.45 in Experiment 1A.

Comparison of the interquartile ranges indicates that although the Years task generated less bias, responses were if anything less accurate than in the Euros task. (Indeed, if the discarded data are included the interquartile range for the Years task was greater for both conditions.)

Table 1: Probabilities of underestimation of money growth and resulting impact on funds by task and condition

Condition	Probability of Underestimation	Median proportion of fund at 65	25th percentile	75th percentile
		Euros Task		
Regular Savings	.744	0.815	0.668	0.999
Lump Sum	.671	0.902	0.774	1.054
		Years Task		
Regular Savings	.589	0.886	0.667	1.095
Lump Sum	.554	0.949	0.817	1.061

4.2.2 Euros Task

To perform significance tests and to examine how underestimation of money growth varied with different properties of specific trials, we estimated generalised linear (GLM) models with a logistic link function at the trial level, separately for the two tasks. The dependent variable was whether the response implied underestimation of money growth, with a random effect for the individual tendency towards underestimation (i.e. a “random intercept” model). Results for the Euros task are shown in Table 2.

Model (1) specifies the following independent variables: regular savings vs. lump sum, size of the fund at age 65 for the top scenario (log transformed to remove right skew), interest rate (3% vs. 7%), years to retirement of the younger saver (standardised to aid comparison of coefficients, mean = 28.7, sd = 8.7) and the delay in starting saving (5 vs. 10 years). The main hypothesis is strongly confirmed: underestimation was more likely in the regular saving condition than in the lump sum condition ($p < .001$). Underestimation was more likely when the interest rate was 7% rather than 3%, and when there was a 10 instead of a 5-year gap between the two starting ages ($p < .001$ in both cases). Model (2) tests key interactions. If the additional cognitive load in the regular saving condition induces stronger EGB, then the condition should have a positive interaction with the interest rate, which determines the strength of nonlinearity. If regular contributions over long periods are not fully accumulated, then for a fixed delay in starting saving, the regular savings condition should have a negative interaction with years to retirement, because the difference in accumulation between the two starting ages becomes proportionately smaller (e.g., the additional accumulation for starting at 25 and saving for 40 years versus starting at 35 and saving for 30 years is one-third again, while for starting at 45 versus 55 years it is double). Model (2) finds evidence for both mechanisms ($p < .05$ for the interaction with the interest rate and $p < 0.001$ for the interaction with years to retirement). Model (3) added background information: gender, educational attainment and age. None of these was significant and, as expected given randomisation, controlling for these variables did not alter any of the abovementioned effects.

Most importantly, the primary hypothesis held with strong statistical significance across all models. We performed some additional robustness tests. Most notably, we tested the sensitivity to the range of fund sizes, since although controlled for in the model these were not perfectly matched between the regular saving and lump sum conditions.[3] The ranges of fund sizes had a 73% overlap. The results in Table 2 are not altered meaningfully by rerunning the regressions for only the overlapping ranges, or for only narrower ranges of fund sizes, or if the fund size is left untransformed.

[3] Note that given the arithmetic and nonlinearity, it is not possible to match the fund sizes without inducing differences between the geometric progression of the ranges of regular savings and lump sums. We opted for overlapping ranges of lump sums in order to control for any effect in the analysis.

Table 2. GLM models predicting likelihood of underestimation of money growth in the Euro task.

Dependent variable: Pr(Underestimate)	(1)	(2)	(3)
Regular saving	2.742***	3.586***	3.602***
	(.632)	(.763)	(.766)
Ln(Fund)	1.968***	3.388***	3.380***
	(.496)	(.694)	(.695)
7% interest (vs. 3%)	1.759*	.127	.667
	(0.725)	(.974)	(1.055)
Years to retirement (standardised)	-1.187***	-1.133**	-1.126**
	(.306)	(.396)	(.356)
10-year gap (vs. 5-year)	1.504***	1.707***	1.705***
	(.390)	(.427)	(.427)
Regular saving * 7% interest		2.075*	2.021*
		(.904)	(.903)
Regular saving * Years to retirement		-1.502***	-1.515***
		(.396)	(.398)
Male			-.363
			(.752)
High education			1.003
			(.910)
Participant age			-.018
			(.034)
Constant	-25.746***	-43.271***	-43.163***
	(6.263)	(8.712)	(1.55)
Random effect: Var (constant)	2.622	3.695	3.531
	(1.111)	(1.585)	(1.015)
Individuals	48	48	48
Observations	355	355	355

† $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

4.2.1 Years Task

The equivalent analysis was undertaken for the Years task and results are presented in Table 3. The main difference is that instead of a variable indicating the difference in starting years for saving, a variable is specified for the difference in saving contributions, which enters as the log of the proportionate difference (either regular amounts or lump sums). The results are not sensitive to the form of this variable, which was logged to remove skew.

Model (4) again confirms the main hypothesis: funds built up from regular savings were more likely to be underestimated than lump sums (p < .001). The size of the effect was similar to that recorded for the Euro task. Underestimation was more likely for larger funds (p < .001) and when there were fewer years to retirement (p < .01). However, the interest rate did not have a statistically significant impact for the Years task.

Table 3. GLMM predicting likelihood of underestimation of money growth in the Years task.

Dependent variable: Pr(Underestimate)	(4)	(5)	(6)
Regular saving	2.662***	3.640***	3.272***
	(.679)	(.829)	(.806)
Ln(Fund)	2.127***	2.329***	2.033***
	(.499)	(.559)	(.549)
7% interest (vs. 3%)	0.012	0.902	.743
	(0.615)	(0.801)	(.785)
Years to retirement (standardised)	-.793**	-.435	-.315
	(.295)	(.332)	(.325)
Additional saving (ln(ΔS/S))	-.212	-.598	-.584
	(.342)	(.385)	(.374)
Regular saving * 7% interest		-1.254*	-1.197 †
		(.638)	(.627)
Regular saving * Years to retirement		-.638*	-.572 †
		(.320)	(.316)
Male			-.447
			(.416)
Degree			-1.321*
			(.571)
Participant age			-.056**
			(.021)
Constant	-27.434***	-30.796***	-23.796**
	(6.301)	(7.109)	(6.971)
Random effect: Var (constant)	1.250	1.399	.850
	(.592)	(.656)	(.500)
Individuals	47	47	47
Observations	314	314	314

† $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Model (2) tests the hypothesised interactions. The regular savings condition had a negative interaction with the interest rate (p < .05) – the opposite of that hypothesised. It is important to observe from the pattern of coefficients that this interaction does not imply that underestimation was significantly greater for the 3% than the 7% rate in the regular saving condition, but that the effect of the interest rate difference was significantly reduced relative to the lump sum condition. The negative interaction with the number of years to retirement was as hypothesised ($p < .05$), consistent with a failure to account fully for the accumulation of regular savings contributions. Model (3) adds background characteristics. Unlike the Euros task, underestimation was less likely among those educated to degree level and older people. Similarly to the Euros task, the main effect was strongly statistically significant in all specifications and effects are robust to limiting the analysis to mid-range fund sizes.

4.3 Discussion

Experiment 2 reinforces the main finding of Experiment 1 that funds derived from regular savings are underestimated by approximately twice as much as those derived from lump sums. The consistency of this effect across two different samples and three tasks is striking. The negative interaction of this main effect with the number of years to retirement in both tasks supports the view that, in addition to failing to account for exponential growth, individuals substantially underappreciate the accumulation of savings. The implication is that a third factor, in addition to intertemporal discounting and EGB, contributes to an intuitive failure to appreciate the benefits of saving.

A mixed picture emerged with regard to whether regular saving also increases EGB, since underestimation was stronger (relative to the lump sum condition) at the higher interest rate in the Euros task, but weaker in the Years task. In general, underestimation was also less likely in the Years task and less sensitive to the interest rate. One possibility is that the Years task, which frames the problem as "How long can I delay?", is simply a more intuitively accurate frame for considering the problem. Arguably, however, this view is at odds with the fact that while responses in the Years condition were less biased than those in the Euros condition, they were less precise. With hindsight, therefore, we think a more plausible alternative is that the lower likelihood of underestimation was due to anchoring. It is understood that in multiple contexts individuals often fail to adjust sufficiently away from an original figure (Jacowitz and Kahneman, 1995). In the Euros task, any anchoring effect associated with adjusting the saving amount presented in the top scenario would have reduced the response, leading to greater underestimation. For the Years task, by contrast, any anchoring effect associated with adjusting the age of starting saving presented in the top scenario would also have reduced the response but, by contrast, led to less underestimation. If failure to adjust responses sufficiently from the anchor presented in the top scenario was a factor, this might also have generated a partial floor effect that reduced the overall impact of the interest rate. However, this mechanism would not explain the negative interaction between the regular saving condition and the interest rate. Considering this interaction alongside the fact that the impact of regular saving on underestimation was of similar magnitude in both Years and Euro tasks, it seems reasonable to infer that the main mechanism through which regular saving produces underestimation of money growth is not via strengthening EGB. Rather, the consistent interaction with the number of years to retirement indicates a failure to accumulate regular amounts fully over extended periods.

5. Experiment 3

The scale of intuitive underestimation recorded in Experiment 2 presents a challenge for policymakers tasked with increasing saving rates. Experiment 3 tested the efficacy of a potential debiasing tool for regular saving. The tool took the form of a calculator that gave the cost of waiting to save, either in time or years. This is a worthwhile endeavour given evidence that individuals can learn nonlinear monotonic functional relationships through feedback (Busemeyer et al., 1997). Clearly the expert sample in Experiment 1B had learned, on average, to adjust. The difficulty is to try to induce learning quickly enough to be of use in an everyday scenario. Given the possibility arising from Experiment 2 that framing the problem as how much people can delay starting to save, we developed and tested two versions of the calculator, one based on the monetary frame and one on the time delay frame. The experimental design was straightforward. Participants were given a short period in which they could use the calculator to gain a feel for the underlying functional relationships, as they might if they were to encounter such a calculator on a website. We then collected responses that tested for underestimation.

Rather than a judgement task, Experiment 3 used a binary choice task similar to the method of Eisenstein and Hoch (2005). Participants were shown two saving scenarios for named individuals, one of whom had started saving at a younger age and one of whom started later but saved more. The use of this task meant that in addition to testing the impact of the calculators, we could confirm that underestimation of regular savings occurs in choices as well as judgements and obtain an alternative measure of the scale of underestimation.

5.2 Method

5.2.1 Participants and Materials

Participants were 180 Dublin consumers aged 22-68 (M = 42.46, S.D. = 13.11, 91 female, 109 working full time) recruited by a market research company. As before, the sample was representative of the Dublin population. Roughly equal numbers of participants had a degree level of education or above (49%) and slightly more than half reported having a pension (56%). Participants were paid €30 for participation and had the chance to win €50 vouchers based on performance. Materials were as in Experiment 2.

5.2.2 Design

Participants were divided into three groups of 60: Euros calculator, Years calculator and control (no calculator). Each completed 18 trials, split into three levels of difficulty. There were three “easy” trials, six “medium” trials and nine “difficult” trials per participant. In the difficult trials, the incorrect scenario had approximately 90% of the accumulated wealth of the correct answer at retirement. For the medium questions, the figure was 70% and for the easy trials, 50%. The interest rate on savings was always 5%. These figures were chosen based on the results of Experiment 2 and pilot testing, with the aim of obtaining an accuracy of approximately 75 – 80 % correct.

Over a sequence of choice trials, there is a danger that participants begin to process cues that relate the current pair of scenarios to previously presented pairs, rather than responding according to a comparison only of the current pair. For instance, if the age difference appears large relative to previous age differences, they may decide that the younger saver is likely to have the larger fund without comparing with the contributions difference. To minimise the first problem, we calculated the difference between the funds in two ways. The highest fund was randomly selected from a range such that, given the level of trial difficulty, both funds at age 65 would be between €220k and €550k – a realistic level for the local economy. On half the trials, the ages were randomly selected from ranges and the contributions then calculated to match the required fund sizes. On the other half, the contributions difference was randomly selected and the ages then calculated to match the required fund sizes. Thus the correlation between these differences and the correct answer was minimised. The ranges were: 28 – 45 years of age; 1 – 19 years age difference (mean = 7.3, sd = 4.0) ; €145 – 995 monthly savings contribution; €5 – 650 difference in contributions (mean = €194, sd = 131).

A further potential problem might arise if on the earlier trials participants repeatedly decide that the older saver will have a larger fund, because they might adjust their criterion to generate a 50-50 ratio of responses. To counter this, trials were presented in randomised orders that were perfectly matched across the three groups, such that one participant in each group faced exactly the same sequence of trials. This design did not remove the possibility that participants moved their criterion, but did ensure no differential effect across groups. The potential for the bias to reduce over consecutive trials could then be accounted for in the analysis (see below).

5.2.3 Procedure

For the two calculator groups, the experimenter initially explained how the calculator worked. The layout of the Euros calculator is shown in Figure 3a; the Years calculator is shown in Figure 3b. The experimenter worked through four examples with participants and told them what values to input. Participants then had four minutes to use the calculator as much as they wished. When this time elapsed, the second stage of the experiment started. On each binary choice, printed at the top of the screen was the question: "Who will have more saved at 65?" Two savings scenarios were shown side by side underneath the question (see Figure 4). The participant had to decide who would have more saved at 65 and click on the green button underneath. There was no time limit and feedback was not provided. Some background information was collected at the end of the experiment, which in total lasted 15 – 20 minutes.

Figure 3a. Euros Calculator

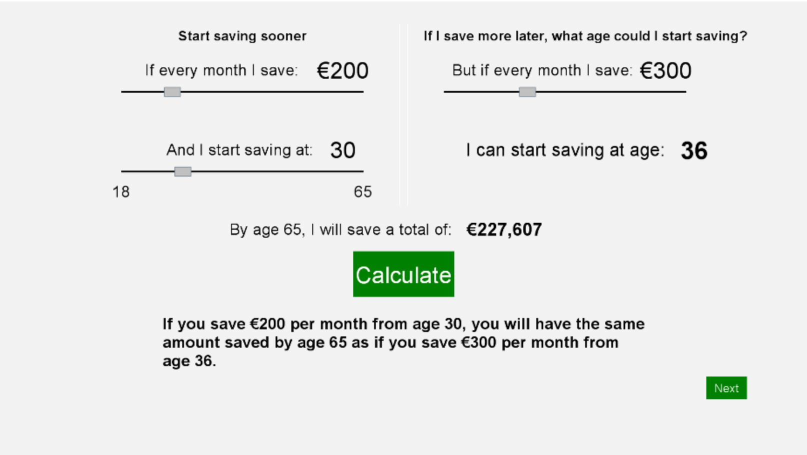

Figure 3b. Years Calculator

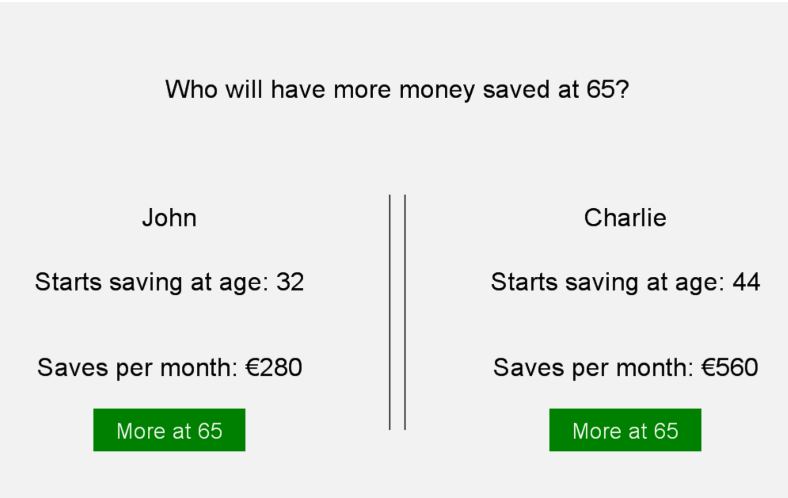

Figure 4. Example Binary Choice

5.3 Results

Of the total 3,240 answers, 2,448 (76%) were correct. The average number of correct trials per participant was 13.6 (S.D. = 2.08). For easy trials the error rate was 11%, rising to 18% in medium trials and 33% in difficult ones. There was a strong bias in favour of the older saver, indicating substantial underestimation of money growth. Overall, for trials favouring the older saver, 81% of responses were correct; for the trials favouring the younger saver the equivalent figure was 70%. There was no overall differences in correct responses between conditions (76%, 76%, 75% for control, Euros and Years conditions respectively), but there was a difference in underestimation. As shown in Figure 5, which shows how these descriptive results varied by condition and level of difficulty, the bias towards the older saver was apparent in all conditions and at all levels of difficulty, but was substantially reduced in the Euros condition relative to the other two.

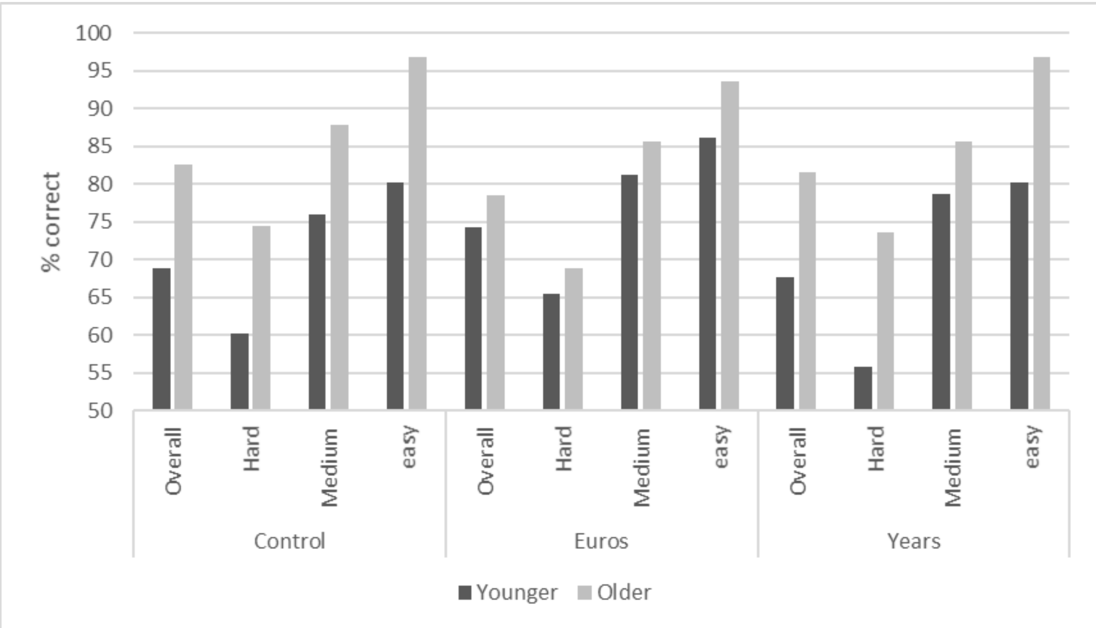

Figure 5: Correct response by condition and whether the younger saver had the larger fund at age 65.

We fitted GLMs with logistic link function to the individual trial data, assuming normal variation between participants in the likelihood of giving a correct answer. Results are shown in Table 4. Model (1) confirms that the bias towards the older saver was highly statistically significant ($p < .001$). The size of the bias can be intuitively approximated by comparison to the coefficients for trial difficulty, since the levels of difficulty were separated by differences in the fund size at age 65 of 20% and 40%. This approximation implies that underestimation of fund size was somewhat in excess of 20% for the control condition. Given the mean age difference of 7.3 years, the degree of underestimation in this choice experiment is hence comparable with the very substantial effects recorded for judgements in Experiments 1 and 2 (perhaps even marginally stronger). The interaction with the Euros condition is statistically significant ($p < .01$) and reveals that the use of the Euros calculator more than halved the bias, consistent with the descriptive data in Figure 5. By contrast, the Years calculator had essentially no effect.

Model (2) adds a variable for the log of the trial number and its interaction with whether the younger saver corresponded to the correct answer.[4] This interaction is significant, suggesting that the extent of underestimation reduced over trials. The coefficients imply a reduction in the extent of bias of approximately one third over the 18 trials. Since no feedback was given, this result probably reflects participants realising that they were strongly favouring the older saver and altering their decision criterion accordingly. If so, the true extent of bias may even be underestimated by the approximation above. Importantly, however, the inclusion of this variable does not alter the primary variation by condition (and further tests suggested no interaction between the Euros condition and the trial number).

[4] This effect is not sensitive to whether the trial is logged or not, but the model fit is superior with the log transformed variable - earlier trials had a bigger impact than later ones.

Table 4. GLM predicting correct answer in binary choice task between savers of different starting age and contribution level.

Dependent Variable: Correct Answer	(1)	(2)	(3)
Younger correct	-.833***	-1.472***	-1.443***
	(.153)	(.153)	(.153)
Condition (Ref = Control)			
Euro calculator	-.281	-.282	-.255
	(.174)	(.174)	(.169)
Years calculator	-.085	-.085	-.123
	(.178)	(.178)	(.172)
*Younger correct * Condition*			
Younger correct * Euros	.567**	.569**	.573**
	(.213)	(.214)	(.213)
Younger correct * Years	.024	.023	.021
	(.213)	(.214)	(.214)
Difficulty (Ref = Easy)			
Medium	-.572***	-.567***	-.568***
	(.163)	(.163)	(.163)
Difficult	-1.483***	-1.494***	-1.493***
	(.151)	(.152)	(.152)
Ln (Trial)		-.147†	-.143
		(.089)	(.089)
Younger correct * Ln (Trial)		.315**	.302**
		(.114)	(.114)
Male			.022
			(.097)
Age			.007
			(.004)
Degree			.405***
			(.113)
Pension holder			.306**
			(.099)
Constant	2.644***	2.952***	2.297***
	(.187)	(.264)	(.336)
Random Effect: Var (Constant)	.139	.139	.073
	(.052)	(.052)	(.044)
Individuals	180	180	180
Observations	3,240	3,240	3,240

† $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Model (3) adds background variables. As expected given randomisation, the inclusion of these variables leaves the coefficients estimating the main experimental effects essentially unchanged. It also reveals that participants educated to degree level and those with a pension were more likely to give correct responses. Given these findings, further analysis (not shown in Table 4) explored three-way interactions to determine whether the two calculators had differential effects by background characteristics. This analysis indicates that the debiasing effect of the Euros calculator was confined to participants (49%) with a degree, since the three-way interaction (Younger correct * Euros calculator * Degree) is statistically significant ($\beta = 1.164$, se = .441, $p < .01$), while the equivalent coefficient for those without a degree is close to zero ($\beta = .062$, se = .278). The equivalent three-way interaction for participants (56%) with a pension is negative, implying that the debiasing effect of the Euros calculator may have been stronger for those without a pension, although in this case statistical significance is marginal ($\beta = -.826$, se = .429, $p = .05$).

5.4 Discussion

The findings of Experiment 3 further confirm, using another type of task, that individuals intuitively underestimate funds built up through regular savings. The experiment also again recorded a very large effect size, suggesting that individuals intuitively believe that there is no cost to saving a higher amount later when, in fact, it reduces the final fund size by 10 – 50%.

Nevertheless, Experiment 3 revealed that the opportunity to use a calculator designed to make explicit the monetary cost of delaying saving can significantly and substantially reduce underestimation. No equivalent effect was found for a calculator framed according to how long a person who planned to save more later could delay starting to save. The data also suggest that the beneficial effect of the calculator was specific to people with higher educational attainment and stronger for those who do not have a pension. Care is need here, however, since these effects were not hypothesised in advance and while the former is highly statistically significant, the latter is only marginally so.

6. General Discussion

This multi-experiment study investigated underestimation of money growth using three different types of task, involving different question modalities, abstract reasoning, narrative scenarios, numeric judgements and binary decisions. The experiments were incentivised and employed representative samples of adults in a region with high levels of educational attainment by international standards, with around half holding at least a primary degree. In each experiment, a very substantial intuitive underestimation of money growth was recorded for funds built up through regular contributions, as is the case for a standard defined contribution (DC) pension. Over time periods of three decades or more, this underestimation implies that individuals, on average, believe the size of the accumulated fund will be less than half its actual size. By making the direct empirical comparison with growth of lump sum deposits, the current investigation shows that the scale of underestimation involved is greater than has been understood from previous work on exponential growth bias (EGB). Our findings suggest that in addition to the failure of intuition to account for the nonlinearity of money growth, individuals fail to appreciate the degree to which small regular contributions accumulate over long periods of time. Thus, despite the fact that accumulation of regular savings is a linear process, underestimation is greater when funds are built up from regular savings. It is important to understand that each of these effects applies over and above any effects of intertemporal discounting.

In their paper on EGB and household finance, Stango and Zinman (2009) noted that classic economics and behavioural economics texts had, at that time, omitted EGB as a psychological consideration for economics. While this has been somewhat remedied in recent years, the intuitive underestimation of money growth is perhaps underappreciated relative to other more prominent biases, such present bias. Goda et al. (2015) showed that EGB and present bias are uncorrelated and that both act independently on levels of retirement savings. Other studies have also demonstrated a negative correlation between levels of EGB and retirement savings (Goda et al., 2015; Levy & Tasoff, 2016; McKenzie & Liersch, 2011; Stango & Zinman, 2009). However, most studies assess the effects of EGB using questions that relate to growth of lump sums or failure to understand the principle of interest compounding. Our findings show that underestimation for regular savings is even greater.

Given its clear relevance to important financial decisions with economy-wide implications, we hope that the extent of underestimation of money growth recorded here prompts further investigation of this bias, its effects and how it might be mitigated. The scale and consistency of the effects that we report, coupled with the demonstration that it is possible to counter the bias, have straightforward policy implications. Most individuals are likely to underestimate the benefits of starting to save for their retirement early and, therefore, evidence supports policy interventions designed to improve judgment and increase saving. Nevertheless, underestimation of money growth and the inaccuracy of judgements more generally may be difficult to tackle and will require an empirical focus. This paper and the body of literature on which it builds offer methods that can be exploited to pre-test interventions for effectiveness on representative or target samples.

Individuals tend to be unaware of biases and overconfidence exacerbates the effects of EGB on retirement savings (Goda et al., 2015). A number of studies have implemented interventions to try to highlight awareness and thus attenuate EGB. These range from teaching individuals rules of thumb for growth of lump sums at different interest rates (Eisenstein & Hoch, 2007) to financial education campaigns (Song, 2015b) to individualised projections of retirement income (Goda et al., 2014; McKenzie & Liersch, 2011). Some interventions have shown promising effects for increasing retirement contributions. Arguably, however, the group that are in greatest need of assistance are those who intend to start saving for retirement but who delay, because they underestimate the cost of doing so. In this context, our findings do suggest that it may be possible to "debias" people, at least partially. An expert sample, on average, did not underestimate money growth from regular saving. Underestimation was attenuated (among individuals with educational attainment to degree level) after people were given the opportunity to view examples displayed on a calculator that made explicit the Euro cost of delaying starting regular saving. There appears, therefore, to be scope for designing effective interventions to counter this strong bias in intuition.

There are, naturally, limitations to the present experiments and important areas for further investigation. Our experiments are all hypothetical. They were each conducted assuming a constant interest rate and with nominal amounts and no consideration of inflation. Another limitation is that the paper's sole focus is on underestimation of money growth. Previous work has shown an interaction between individual time and risk preferences and EGB (Königsheim, Lukas, & Nöth, 2018). Future studies could combine measurement of these biases to investigate mediators of the effect. It is possible that this, or any one of the above factors highlighted might interact with the main effects we report and alter some of the implications. Nevertheless, the questions employed in this study had objectively correct answers and rewards for getting them right. Thus, regardless of how the effects may interact with other elements of financial reasoning, we are confident that they highlight clear intuitive mistakes in financial judgement.

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