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# Does it all add up? New experimental evidence for 'undersum bias' as an impediment to precautionary saving

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# Does it all add up? New experimental evidence for 'undersum bias' as an impediment to precautionary saving

*Abstract*

Under-saving generates multiple sources of risk for consumer detriment, including insufficient income in retirement and exposure to high-interest debt when faced with a financial shock. Cognitive biases, such as present bias and exponential growth bias, have been proposed to explain under-saving for some consumers. Here we present novel evidence for an additional bias. 'Undersum' bias describes a systematic tendency for consumers to underestimate the accumulation of monetary amounts, even in the absence of compound interest. Evidence for its existence with respective to the cumulation of expenses has recently been replicated by independent research teams. In this chapter, we specifically discuss recent lab and field experiments demonstrating its implications for saving behaviour. Our evidence shows that undersum bias may demotivate saving as consumers fail to appreciate the benefits of starting to save sooner in life. We show that the bias interacts with exponential growth bias but is distinct from it. Evidence also suggests that undersum bias may also lead consumers to underestimate future expenditure and inaccurately judge the cumulative risk of facing a financial shock. This nascent evidence presents multiple opportunities for future research, to further investigate the implications of undersum bias for financial behaviours and to test ways to mitigate it.

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Increasing life expectancy is a testament to advancements in healthcare, technology, nutrition and overall living standards in multiple countries (e.g. Mathers et al. 2015). With aging populations and declining birth rates, however, come multiple challenges for policymakers and the public. Maintaining desired quality of life in older age necessitates not just investing in one's health early in life but also in one's finances. Unfortunately, human psychology is poorly equipped to prioritise long time horizons over shorter ones, particularly when doing so also requires integrating complex numeric information with multiple uncertainties. In this chapter, we present new evidence from lab and field experiments for a cognitive bias that can demotivate pension saving: 'undersum' bias, a systematic tendency to underestimate straightforward accumulation.

We are not the first to explore a behavioural phenomenon that impedes pension saving. Others have, quite thoroughly, outlined the implications of inertia (e.g., Choi et al., 2002), present bias and temporal discounting (e.g., Beshears et al., 2022; Hastings & Mitchell 2020), over-optimism (e.g., Mitchell & Utkus 2004), and so on. Many of these phenomena are not unique to pension saving, but some are particularly relevant. One such relevant bias, and one that is strongly linked to our thesis here, is 'exponential growth bias.' When tasked with predicting the future value of exponentially growing quantities (e.g., compounding interest), naïve consumers tend to project linear growth (Stango & Zinman 2009; Wagenaar & Sagaria 1975). Even sophisticated consumers, who appreciate sources of non-linearity, make insufficient upward adjustments in their linear projections (Christandl & Fetchenhauer 2009; Wagenaar & Timmers 1979). Exponential growth bias leads consumers to underappreciate the effect of compound interest, meaning they underestimate both the consequences of failing to repay debt with high interest rates and the benefits of saving (Levy & Tassoff 2017; Stango & Zinman 2009).

Exponential growth bias has clear implications for retirement savings, with consumers failing to appreciate the importance of starting to save earlier in life to exploit compound interest (Goda et al. 2019). There have thus been multiple attempts at designing interventions to help individuals better estimate exponential growth. These include instructions on heuristics to apply (Eisenstein & Hoch 2007), diagrams for use on pension benefit statements (McGowan & Lunn 2020) and financial education (Song 2015).

However, one assumption with much of the research on exponential growth bias is that underestimation occurs only once consumers must contend with the exponential function. If, for example, growth is merely linear, the cognitive effort required is far more straightforward and, it is assumed, that most consumers can anticipate growth in linear contributions reasonably accurately. This assumption is our starting point. What if there are biases that precede or exacerbate exponential growth bias, with implications then for retirement saving? To investigate this question, we first briefly review the evidence on "number sense" (i.e., the mental representations of numbers required for their integration).

**Number Sense**

People have an innate ability to form judgements of numerosity, but often imperfectly. Intuitive estimates of magnitudes tend to be noisy with representations that become increasingly compressed as the objective magnitude increases (Dehaene 1992). As a result, approximations of numerosity of both visual stimuli and mental representations of numbers (e.g., digits) follow a concave response function; estimates are biased downwards, with the strength of bias increasing as the degree of magnitude increases (Anobile et al. 2012; Dehaene et al. 2008).

Despite a wealth of evidence from psychophysics research showing underestimation in judgements of the numerosity of visual stimuli, evidence for whether similar effects occur when people must integrate series of numbers has only recently emerged. In perhaps the first empirical investigation of intuitive summation of numbers (excluding the impact of compound interest), Scheibehenne (2019) tasked participants with estimating the cumulative cost of grocery items. In a lab experiment, participants saw a series of trials, each with 24 grocery items and individual cost. Results showed that participants underestimated the total bill on two thirds of trials. The lab experiment was followed by a field experiment with greater ecological validity: shoppers in a supermarket were asked to estimate the total bill of their cart while waiting in line to pay. Given the real world implications for underestimating a shopping bill and the experience shoppers likely had with grocery shopping (perhaps purchasing very similar items every week), this experiment presented a more stringent test of intuitive summation. Again, however, the majority underestimated the total.

Scheibehenne (2019) did not refer to this tendency as 'undersum' bias. We encountered the term in a recent Working Paper by Goswami et al. (2022), which describes a series of experiments presumably undertaken during the same time period as we were testing the implications of Scheibehenne (2019) for pension saving. Goswami et al. (2022) provide a thorough exploration of the bias, replicating it across 10 experiments. They show that the bias emerges in multiple domains, not just shopping environments; that it emerges even under lessened cognitive load; and that it persists even if overestimation is incentivised.

For the remainder of this chapter, we present recent evidence from lab and field experiments, designed to inform policy, on the implications of undersum bias for precautionary saving behaviour specifically. We first present the evidence for the implications of undersum bias on pension saving. This evidence follows similar logic to Scheibehenne (2019) and Goswami et al. (2022), in that it pertains to a downward bias for intuitive summation. However, we also present evidence for how undersum bias might also extend to people's perceptions of the accumulation of risk, which may further inhibit motivations to save. We conclude with evidence for scalable interventions that seek to overcome these biases and point to avenues for future research.

## Evidence for Undersum bias

**Summation.** The experiments described in Scheibehenne (2019) are, we believe, the first to demonstrate a bias towards underestimation when people try to integrate sequences of monetary amounts. The field experiment is perhaps particularly convincing, as consumers are likely to have experience making similar purchases on a regular basis and might reasonably be expected to have an incentive to accurately estimate their grocery bill. Even more convincing is to see the same effect replicated independently, in supermarkets that serve higher- and lower-income consumers with shoppers offered cash incentives for accuracy (Goswami et al. 2022).

In McGowan et al. (2022), we set out to further replicate and extend the central finding of Scheibehenne (2019). In the first experiment, participants in an online experiment saw a series of monetary amounts and were incentivised to provide approximations of their total. The monetary amounts were presented to some participants as slot machine payouts and to others as bills (e.g., utility bills). Participants were tasked with estimating the total, as in Scheibehenne (2019), or with the simpler task of choosing whether the total of the sequence they had just seen was higher or lower than a referent amount. We varied also the length of the sequences, with either six or twelve amounts presented per trial. The experimental design was thus a 2 (framing: slot machine payouts or familiar household bills) x 2 (task order: judgements first or estimates first) x 2 (series length: six or twelve) mixed design, with the first two factors varying between-groups and the final varying within. Following a couple of practice trials, participants completed 24 incentivised trials.

Results demonstrated consistent underestimation of the total. On average, two-thirds of the incentivised trials were underestimated, closely similar to the level of accuracy observed by Scheibehenne's (2019) first experiment. Underestimation occurred in both the familiar frame (the bills) and the unfamiliar frame (slot machine payouts). Underestimation was also observed on both the difficult estimation task and the simpler forced-choice task and regardless of series length, although with some evidence for exacerbation on longer trials. Thus, this first experiment provides an additional independent replication of Scheibehenne's central finding of a bias towards underestimating the accumulation of monetary amounts.

The second experiment sought to replicate the first and tested further whether specific contextual factors could attenuate this undersum bias. Although there was no attenuation of the bias in the familiar compared to unfamiliar framing (i.e., bill vs. slot machine), we suspected that other framings might matter. Specifically, we tested two additional ones: unfamiliar household bills (the cost to feed exotic pets) and a savings frame (for a vacation). Results closely replicated the first experiment, with underestimation again observed on two thirds of all trials.

Thus, we had observed consistent underestimation of accumulation in a controlled environment, on a relatively simple task, with clear instructions and incentives. The motivation for testing undersum bias under these simplified conditions resulted from an earlier series of experimental tasks that we had run to inform pension policy. In these experiments, which were funded by the Pensions Authority in Ireland, we set out to test the accuracy of estimations of money growth from regular saving and lump sum investments (McGowan et al. 2019). These studies thus provide evidence for how undersum bias might manifest when consumers must also contend with compound interest.

In a first experiment, participants were presented with two straightforward saving scenarios. In the Lump Sum scenario, they were told that they had transferred €1,000 to an investment fund that generates a return of 5% per year. They were told to assume zero fees or other deductions would occur and were asked to estimate the growth of the fund. In the Regular Saving scenario, the only change was to incorporate saving an additional €1,000 every year. Results showed that, for the Lump Sum scenario, participants tended to linearise the growth and estimated a total of 84 percent the actual amount after 20 years. However, the underestimation was significantly greater when participants had to also consider the accumulation of regular savings, at just 60 percent the actual total.

A second experiment sought to more closely align with decisions individuals make when considering starting a pension: how much to save per month. In this 'match task' experiment, participants were again presented with hypothetical scenarios. Participants were given three pieces of information on one individual's retirement fund: the age at which they started to save, their monthly contribution and the annual interest rate (e.g., saving €130 per month from age 22 at 3% interest). Again, the task was simplified to ignore any fees, taxes, and so on. They were then informed about another individual who began saving at an older age (e.g., age 27) in a fund with the same interest rate. They were asked to estimate how much this individual would need to save per month in order to have the equivalent fund as our first saver at age 65. This was a difficult task and accuracy was incentivised in a performance-weighted lottery system.[1] Results showed that participants tended to underestimate how much extra the older saver would need to save per month in order to reach the same total by 65, suggesting again that they had underestimated the total pension saved by the younger saver.

This evidence for consistent underestimation of summation has at least two critical implications for retirement saving. First, and perhaps most obviously, people are likely to underestimate the importance of beginning to save early, even with small amounts. They are likely to judge doing so as being less effective than waiting until they can save a bit more per month, as they fail to appreciate how much they will accumulate by retirement. This underappreciation is indeed well documented but is typically attributed to exponential growth bias (e.g. Goda et al., 2019).

Our evidence suggests that undersum bias interacts with exponential growth bias but is distinct from it. In McGowan et al. (2019) we calculated the implied retirement fund from each response in the money-match task and plotted these as cumulative distributions, shown in Figure 1. If responses were noisy but unbiased, we would expect half the responses to lie below the dotted horizontal line denoting "Correct Response" in each condition, and half to lie above. Only in the Lump Sum 3% condition is the split close to even. In the other three conditions, the majority of responses demonstrate underestimation. The magnitude of underestimation is greater for Regular Saving (RS) compared to Lump-Sum saving (LS) and greater for the higher interest rate (7%) vs. the lower interest rate (3%). However, the magnitude and prevalence of underestimation in the 7%-RS condition is notably greater than the 7%-LS condition, and the difference between 7%-RS and 3%-RS is greater than the difference between both LS conditions. This interaction effect was confirmed in regression analyses. The implication is that individuals are likely to delay initiating retirement savings or contribute inadequately, missing out on the opportunity to harness the potential of both accumulation and compound interest.

*Figure 1 here*

The second implication is for how consumers might forecast their retirement expenditure. Accurately estimating future financial requirements is a fundamental challenge for effective retirement planning. Our evidence suggests that, where consumers attempt to do so, they are likely to produce underestimates of the expenses they will face. This underestimation may be particularly problematic in coming years as an increasing proportion of the population in multiple countries face continued mortgage repayments into retirements (e.g., Mayer 2017). Relatedly, undersum bias might interfere with peoples' consideration of unexpected expenses that can arise during retirement (such as unexpected healthcare costs or requiring additional home help).

**Risk.** Here we speculate on undersum bias manifesting also with respect to the probability of facing a financial shock. We have less direct evidence for its existence specifically with respect to saving behaviour, but there is strong evidence that people struggle to accurately estimate risk. People often underestimate the probability of bad outcomes while simultaneously overestimating their ability to handle ones that arise (Shepperd et al. 2017; Jefferson et al. 2017). A related literature links overconfidence with financial capabilities to early withdrawals from retirement funds (Lee & Hanna 2020). If these tendencies apply when considering the need to save for retirement, it is thus likely consumers will underestimate the likelihood of experiencing a financial shock when they are close to or in retirement.

That said, financial shocks tend to be low probability events and hence misjudging the likelihood of one individual shock may be detrimental for only a small minority of consumers. The issue arises, however, when considering the accumulation of multiple low-probability shocks. For example, the probability of needing to finance home repairs during any one year of retirement may be low, but the risk accumulates over time. Moreover, the individual probabilities of, for example, facing a market downturn that significantly devalues assets *or* of losing one's job in the years approaching retirement may be low, but each of these individual probabilities sum, giving a greater likelihood of facing at least one of these financial shocks. The same logic applies to all possible shocks. In other words, the disjunctive probability that at least one financial shock will be experienced is far higher than is likely to be perceived.

There is a wealth of literature from psychology showing that estimates of cumulative risk specifically are inaccurate and often biased (Kahneman & Tversky 1982; Knäuper et al. 2005; McCloy et al. 2010). Disjunctive probabilities in particular tend to be underestimated (Bar-Hillel 1973; Brockner et al. 2002). For example, many people fail to realise that although the probability of pregnancy when using contraceptives is very low, it accumulates over time and hence consistently increases (Doyle 1997). Evidence on intuitions about cumulative suggests that people's judgement appear closer to an averaging of risk rather than summation (Carlson & Yates 1989).

Underestimating the accumulation of financial shock probabilities thus poses an additional challenge for motivating retirement saving. Individuals may perceive their future financial security as less vulnerable than it is, and therefore target insufficient savings totals. For example, when deliberating about the need to make additional pension contributions today versus relying on fixed social security payments, the consumer may accurately reason that such social security payments will suffice to maintain a reasonable standard of living. But if she has failed to accurately estimate the probability of facing at least one financial shock, she will be left with less than expected for day-to-day needs. Even if she manages to account for facing financial shocks, undersum bias may then lead her to reason that she can procrastinate additional pension contributions and that saving a bit extra later in life is the equivalent to saving a bit less now. Can anything to be done to improve our saver's estimates?

**Interventions to Overcome Undersum Bias**

The experiments by Scheibehenne (2019), Gotswami et al. (2022) and McGowan et al. (2019, 2022) provide consistent evidence for a downward bias when consumers attempt to integrate sequential monetary amounts. A present-biased consumer seeking to justify procrastinating their pension contributions is thus likely to fail to appreciate the benefits of starting to save small amounts earlier in life compared to saving more later. This presents a challenge for policymakers seeking to ensure retirees have sufficient income saved. But what can be done to address this seemingly detrimental bias?

In a third experiment, McGowan et al. (2019) tested a potential debiasing tool. For the main task in the experiment, participants were again presented with two individuals, but this time the task was easier. They were shown full information (age at which they started saving and monthly contributions) for both individuals and told the annual interest rate was 5%, with no withdrawals, fees or deductions. For example, they were told that John started saving €280 per month at age 32 whereas Charlie started saving €560 per month at age 44. Their task was to judge whether John or Charlie is likely to have saved more by age 65. Consistently choosing the older saver (who always saves more per month) would be evidence of undersum bias (with exponential growth bias).

However, before completing this task, half the participants were randomised to use a computerised, interactive calculator designed to debias their estimates of money growth. On one side of the screen, participants could input a starting age and monthly contribution amount. On the other side, they input a an (older) age only, and the calculator generated the monthly amount required for both saving plans to have the same fund size at 65. Hence, the calculator answered the question: “If I start saving later, how much would I need to save per month?” Participants were walked through some examples before freely using the tool for a set amount of time. In the experiment, the younger had saved more by age 65 on exactly half the trials.

Results of the main task showed strong bias towards thinking that saving more per month later in life would accumulate a higher total than saving less earlier. The level of accuracy was generally high, with 2,448 of the 3,240 trials answered correctly (76%). Overall, 81 percent of responses were correct when the older saver was the correct response, but accuracy fell to 70 percent for 'younger correct' trials.[2] Figure 2 shows that the gap narrowed most dramatically on the difficult trials, whereas the easy trials were subject to a ceiling effect in performance.

However, participants who had used the debiasing tool prior to engaging with the task displayed a diminished bias. This is illustrated in Figure 2, which plots the proportion of trials answered correctly by difficulty level for the control condition and the calculator condition. The trials where the older saver had more saved at age 65 are marked by squares; circles denote the proportion correct when the younger saver had more at 65. The two messages from the Figure are that there is consistent underestimation of final fund size, as the 'older correct' trials have a consistently higher hit rate. We attribute this to a combination of EGB and undersum bias. The second is that the money calculator reduced the bias, as shown by the smaller (older correct – younger correct) gap. Although the tool did not fully mitigate the ingrained tendency to underestimate, just a few minutes of using our interactive calculator had more than halved the bias.

*Figure 2 here*

The interactive debiasing calculator was designed for scalable implementation; it could be easily adapted on any consumer website. However, despite incentivising participants in our lab experiment, we couldn't be certain that the tool would work in the "real world" or indeed whether it would alter real saving behaviour even if it did mitigate relevant cognitive biases. And so, we set out to test the tool in a field trial (Timmons et al. 2022).

The aim of the field trial was to encourage precautionary saving (i.e., "rainy day" saving) and it was conducted on a sample of over 160,000 retail bank customers. The trial was commissioned by Ireland's Competition and Consumer Protection Commission, who had identified under-saving as a target behaviour for improving financial wellbeing in Ireland and we partnered with a high-street retail bank, Bank of Ireland. Following a review of relevant literature and analysis of existing survey microdata, we settled on two interventions that sought to motivate precautionary saving. The first incorporated McGowan et al.'s (2019) debiasing calculator.

The target account was the bank's "GoalSaver" account. Similar to a pension saving account, the account required customers to set up an automatic, monthly payment (i.e., direct debit) of between €20 and €2,000. There were two arms to the trial. The first was a communications campaign, in which customers who had consented to receiving communications from the bank were issued emails to encourage saving (we discuss these communications in greater detail below). The second was a test of "organic" traffic to account's web application form (i.e., customers who accessed the form unprompted). For both arms, we tested a "behaviourally-enhanced" version of the bank's existing application form.

We first applied minor changes to the form, including changing the order in which questions were asked (e.g., we moved the savings start date question to earlier in the form) and incorporating basic financial advice on relevant questions (e.g., to choose to start saving soon after a regular pay date). The primary change, however, was the debiasing calculator. Consumers had first input their target savings total (i.e., their goal), following financial advice to aim to save to cover three months of expenses. Consumers randomised into the treatment group were asked whether they would like to use the interactive calculator to help them figure out how much to save per month. Those who opted in were asked to input into the calculator either a target date for reaching their goal or to input how much they were considering to save per month. The calculator then generated the missing value (i.e., how much to save per month or when they would reach their savings goal, respectively), factoring in the low level of annual interest at the time of the study (0.25%). Consumers could use the calculator as much as they liked.

Results showed a positive effect of the enhanced application form on the number of accounts opened over the six-month trial period. In the sample of over 160,000 who received the email communication, 0.29 percent of the control group opened the target savings account, but this increased to 0.37 percent of those with access to the enhanced savings form (i.e., a 27% increase in accounts opened).[3] The effect was even stronger among organic traffic to the web application form: the enhanced form boosted the conversion rate from 3.4 percent to 4.7 percent (a 38% increase). Google Analytics data from the web form showed that significantly more of those who ultimately opened the account had used the debiasing calculator (63.0%) compared to those who did not ultimately open the account (56.5%).

We were further able to test whether the treatment influenced the amount saved per month. Although intuitively an intervention to mitigate undersum bias should result in consumers showing greater appreciation for saving more per month, our (pre-registered) hypothesis for this analysis was non-directional. We reasoned that although the enhanced form should increase appreciation in the importance of saving, any increase by some participants could be offset by an increase in the proportion of lower income consumers (who were a target population) completing the form or indeed from consumers who otherwise might have procrastinated saving from realising the benefits of starting to save lower amounts earlier. In other words, increasing the participation rate could reduce the average amount saved, because at the margin of saving behaviour are lower-income individuals. Indeed, results from the communications campaign arm showed a slight but non-significant increase in monthly deposits among the treatment group (€250 per month versus approx. €225 per month). In the organic arm, however, those who accessed the enhanced form saved *less* per month (€200 per month versus €280 per month among the control).

Available socio-demographic data provided some insight into this tendency towards lower monthly deposits. Modelling the association between consumer income and treatment group showed that the enhanced form had substantially stronger effects on consumers with lower income; there was a 120 percent increase in account openings among the lowest income group, with the strength of the effect declining monotonically to zero among the higher income group. Hence, the reason for lower deposits in the organic traffic is explained by consumers having less disposable income to save.

The communications arm of the trial also tested an intervention designed to overcome our more speculative manifestation of undersum bias – the under-accumulation of the risk for financial shocks. This treatment was based solely on informing consumers about the risk of financial shocks. We developed an infographic to communicate the risk of facing a financial shock in a given year, based on principles from the psychological literature on risk communication (e.g., Spiegelhalter 2017). The infographic was assigned at random to half of the banks customers in the communications arm and featured three animated GIFs (Graphic Interchange Formats; see Figure 3). The first GIF employed natural frequencies to communicate the proportion of the public who face a financial shock in a given year (6 in 10). The second showed a grid of people experiencing different types of shocks via icons (e.g., a car icon to indicate car problems). The end sequence of the animation showed that only a minority had avoided any financial shock. The third GIF illustrated that 3 in 10 face more than one shock per year. The data for the infographic were accurate and based on responses to a 1,000-person survey run to inform the trial. The email ended with a ‘Call to Action’ to open a savings account, but cookies allowed us to track whether customers randomised into the treatment group accessed the savings form at a later date. The control communication was the bank’s planned email about the importance of saving for financial wellbeing, which also incorporated GIFs relevant to saving but did not feature information on the risk of financial shocks.

*Figure 3 Here*

The risk accumulation treatment was manipulated orthogonally to the application form treatment, in a 2 (form: behaviourally-enhanced vs. control) x 2 (email: cumulative risk vs. financial wellbeing) between groups design in the communications arm. This design allowed us to isolate the effect of this novel communication treatment. Results showed that, compared to the control group, those who received the risk accumulation communication were significantly more likely to have opened a savings account at the end of the trial. The effect was size was comparable to the effect of the debiasing calculator, albeit slightly weaker (20% increase in uptake; 0.35% of treated customers opened an account vs. 0.29% in the control group). Although we hoped for an additive effect of the treatments (i.e., a stronger effect among those who received the risk communication and accessed the enhanced application form), none was observed. This perhaps indicated a ceiling in the ability for behavioural interventions to increase savings account uptake.

Of course, it was important in the trial to not just assume customers had benefitted from increased savings account uptake. We further assessed the evidence in the trial for negative spillovers. We had access to indicators of debt in the partner bank (i.e., any credit products or arrears on their current account) as well as any other savings accounts held with the same bank.

Importantly, the partner bank offered the highest interest rate at the time of trial, meaning participants were unlikely to take out accounts from other institutions. Fortunately, we observed no evidence for negative spillovers. (In fact, there was suggestive evidence that participants in the treatment groups were less likely to hold any form of debt at the end of the six month period, perhaps implying that the precautionary savings account was functioning as intended).

Both of our treatments (the debiasing calculator and the cumulative risk communication) targeted undersum bias, albeit different manifestations of it. To our knowledge, these treatments are the first to successfully increase precautionary savings rates in a country with widespread access to banking infrastructure. Of further note is that the relative effect sizes we observed are far larger than typical for successful "nudge" type interventions. We observed increases in account uptake of between 20 and 40 percent, compared to a standard relative effect size of just 8 percent (DellaVigna & Linos, 2022).

These interventions are also the first to target undersum bias in the field. We provide evidence that the debiasing calculator is beneficial for consumers (although we cannot perfectly isolate its effect given the combination of lighter-touch interventions). We also provide evidence that underestimating the cumulative probability of a financial shock leads to undersaving. This idea is novel and not previously tested in a financial context. Future research could test ways to improve it.

**Future Research**

The behavioural economics literature on pension saving has thus far focused complex psychological phenomena, such as hyperbolic discounting and exponential growth bias. The cognitive ability to intuitively generate accurate approximations of summation seems, by comparison, deceptively simple. As such, undersum bias appears to have been overlooked.

Evidence for its existence has emerged relatively recently, with core papers still in working paper format at the time of writing. Interestingly, there is almost a "multiple discovery" component to undersum bias, whereby evidence has emerged independently from different research teams during a similar time period. The nascency of this evidence presents multiple avenues for future research.

First, and perhaps most straightforwardly, there is considerable scope for further exploring the implications of undersum bias for saving behaviour. Scheibehenne (2019) exclusively investigated shopping behaviours, whereas both McGowan et al. (2022) and Goswami et al. (2022) also focused primarily on spending behaviours. McGowan et al. (2019) investigated undersum bias with respect to pension saving, but undersum bias was not the primary target. The implication here is that further studies are required to explicitly investigate the implications of undersum bias for saving behaviour. There are multiple potential angles, for example by focusing on whether undersum bias demotivates saving due to an underestimation of forecasted expenditure, an underestimation of forecasted saving accumulation, or both.

Second, and relatedly, our speculation that undersum bias may also apply to how people consider the risk of financial shock has important implications for precautionary saving, but our evidence is admittedly circumstantial. Direct testing of this hypothesis using controlled, diagnostic laboratory studies is needed.

Third, there is considerable scope for developing interventions to help consumers overcome the bias. McGowan et al. (2019) and Timmons et al. (2022) provide evidence that interactive calculators may help. But their effect appears to diminish the bias rather than mitigate it entirely. Policymakers and other stakeholders interested in helping consumers make welfare-improving decisions would thus benefit from investing in research to develop boosts and other tools to help mitigate undersum and other relevant biases (e.g., Hertwig & Grüne-Yanoff, 2017).

These boosts and other interventions would in turn benefit from controlled diagnostic experiments to identify relevant psychological mechanisms (Lunn 2019).

**Conclusion**

Ensuring desired quality of life in retirement requires consumers to estimate the kinds of expenses they will face and how to accumulate a sufficient pension fund to cover those expenses. Bias in these estimates produces asymmetric risk. If consumers apply a precautionary principle and save too much, they might simply afford more luxuries later in life at the expense of present needs and wants. However, saving too much does not appear to be a prevalent policy problem. Instead, consumers in multiple countries save too little and we present evidence for a bias that might help to explain why. Undersum bias, as coined by Goswami et al (2022) and first observed by Scheibehenne (2019), describes the systematic tendency to underestimate accumulation. Our evidence shows that it matters not only for estimating the accumulation of expenses – and the potential for financial shocks – but also for how regular savings accumulate. Consumers are thus likely to underestimate their expenses later in life but also reason that saving earlier will have less of an impact than it in fact will, event without incorporating compound interest. We also present initial evidence for interventions to help consumers overcome the bias, including a boost to help consumers figure out how much to save per month in the form of an interactive online calculator and a communication tool to help consumers more accurately estimate the risk they will face financial shocks. Despite these implications for late life, research on undersum bias is, however, in its infancy, with further investigation likely to be fruitful for those interested in facilitating precautionary saving for the future.

**References**


Anobile, G., Cicchini, G. M., & Burr, D. C. (2012). Linear mapping of numbers onto space requires attention. *Cognition*, *122*(3), 454-459.

Bar-Hillel, M. (1973). On the subjective probability of compound events. *Organizational behavior and human performance*, *9*(3), 396-406.

Beshears, J., Choi, J., Laibson, D., & Maxted, P. (2022, May). Present bias causes and then dissipates auto-enrollment savings effects. In *AEA Papers and Proceedings*, *112*, 136-141.

Brockner, J., Paruchuri, S., Idson, L. C., & Higgins, E. T. (2002). Regulatory focus and the probability estimates of conjunctive and disjunctive events. *Organizational behavior and human decision processes*, *87*(1), 5-24.

Carlson, B. W., & Yates, J. F. (1989). Disjunction errors in qualitative likelihood judgment. *Organizational Behavior and Human Decision Processes*, *44*(3), 368-379.

Choi, J. J., Laibson, D., Madrian, B. C., & Metrick, A. (2002). Defined contribution pensions: Plan rules, participant choices, and the path of least resistance. *Tax Policy and the Economy*, *16*, 67-113.

Christandl, F., & Fetchenhauer, D. (2009). How laypeople and experts misperceive the effect of economic growth. *Journal of Economic Psychology*, *30*(3), 381-392.

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition*, *44*(1-2), 1-42.

Dehaene, S., Izard, V., Spelke, E., & Pica, P. (2008). Log or linear? Distinct intuitions of the number scale in Western and Amazonian indigene cultures. *Science*, *320*(5880), 1217-1220.

Doyle, J. K. (1997). Judging cumulative risk 1. *Journal of Applied Social Psychology*, *27*(6), 500-524.

Eisenstein, E. M., & Hoch, S. J. (2007). Intuitive compounding: Framing, temporal perspective, and expertise. *Unpublished manuscript*.

Goda, G. S., Levy, M., Manchester, C. F., Sojourner, A., & Tasoff, J. (2019). Predicting retirement savings using survey measures of exponential-growth bias and present bias. *Economic Inquiry*, *57*(3), 1636-1658.

Goswami, I., Greenberg, A. E., & Schley, D. (2022). Undersum bias. *Available at SSRN 3954282*.

Hastings, J., & Mitchell, O. S. (2020). How financial literacy and impatience shape retirement wealth and investment behaviors. *Journal of Pension Economics & Finance*, *19*(1), 1-20.

Hertwig, R., & Grüne-Yanoff, T. (2017). Nudging and boosting: Steering or empowering good decisions. *Perspectives on Psychological Science*, *12*(6), 973-986.

Jefferson, A., Bortolotti, L., & Kuzmanovic, B. (2017). What is unrealistic optimism?. *Consciousness and Cognition*, *50*, 3-11.

Kahneman, D., & Tversky, A. (1982). Variants of uncertainty. *Cognition*, *11*(2), 143-157.

Knäuper, B., Kornik, R., Atkinson, K., Guberman, C., & Aydin, C. (2005). Motivation influences the underestimation of cumulative risk. *Personality and Social Psychology Bulletin*, *31*(11), 1511-1523.

Lee, S. T., & Hanna, S. D. (2020). Financial knowledge overconfidence and early withdrawals from retirement accounts. *Financial Planning Review*, *3*(2), e1091.

Levy, M. R., & Tasoff, J. (2017). Exponential-growth bias and overconfidence. *Journal of Economic Psychology*, *58*, 1-14.

Lunn, P. D. (2019). Nudger beware: Diagnosis precedes remedy. *Journal of Behavioral Economics for Policy*, *3*(S), 23-26.

Mathers, C. D., Stevens, G. A., Boerma, T., White, R. A., & Tobias, M. I. (2015). Causes of international increases in older age life expectancy. *The Lancet*, *385*(9967), 540-548.

Mayer, C. J. (2017). Housing, mortgages, and retirement. *Evidence and innovation in housing law and policy*, *203*.

McCloy, R., Byrne, R. M., & Johnson-Laird, P. N. (2010). Understanding cumulative risk. *Quarterly Journal of Experimental Psychology*, *63*(3), 499-515.

McGowan, F. P., & Lunn, P. D. (2020). Supporting decision-making in retirement planning: Do diagrams on Pension Benefit Statements help?. *Journal of Pension Economics & Finance*, *19*(3), 323-343.

McGowan, F. P., & Lunn, P. D. (2020). Supporting decision-making in retirement planning: Do diagrams on Pension Benefit Statements help? *Journal of Pension Economics & Finance*, *19*(3), 323-343.

McGowan, F., Denny, E., & Lunn, P. (2022). Consistent underestimation in the intuitive summation of monetary amounts. *Available at SSRN 4021708*.

Mitchell, O. S., and Utkus, S. P. (2004). 'Lessons from behavioral finance for retirement plan design.' In Mitchell, O. S. and Utkus, S. P., eds., *Pension design and structure: New lessons from behavioral finance*. Oxford, UK: Oxford University Press, pp. 82-94.

Scheibehenne, B. (2019). The psychophysics of number integration: Evidence from the lab and from the field. *Decision*, *6*(1), 61.

Shepperd, J. A., Pogge, G., & Howell, J. L. (2017). Assessing the consequences of unrealistic optimism: Challenges and recommendations. *Consciousness and Cognition*, *50*, 69-78.

Song, C. (2020). Financial illiteracy and pension contributions: A field experiment on compound interest in China. *The Review of Financial Studies*, *33*(2), 916-949.

Spiegelhalter, D. (2017). Risk and uncertainty communication. *Annual Review of Statistics and Its Application*, *4*, 31-60.

Stango, V., & Zinman, J. (2009). Exponential growth bias and household finance. *the Journal of Finance*, *64*(6), 2807-2849.

Timmons, S., Robertson, D., & Lunn, P. (2022). Combining nudges and boosts to increase precautionary saving. *Available at SSRN 4143489*.

Wagenaar, W. A., & Sagaria, S. D. (1975). Misperception of exponential growth. *Perception & Psychophysics*, *18*, 416-422.

Wagenaar, W. A., & Timmers, H. (1979). The pond-and-duckweed problem; Three experiments on the misperception of exponential growth. *Acta Psychologica*, *43*(3), 239-251.

**Endnotes**

[1] Specifically, for each response in the top half of the sample in terms of accuracy, the participant got an extra draw into the lottery for a €50 voucher.

[2] The average accuracy rate on easy trials was 89%, for medium trials it was rising to 82% and 67% for the difficult trials where the smaller fund size was approximately one-tenth smaller than the larger one at age 65.

[3] Although saving rates are low, we were assured by our partners at the bank that such absolute effects are normal for communications campaign; we couldn't know, for example, how many customers had even opened the email.

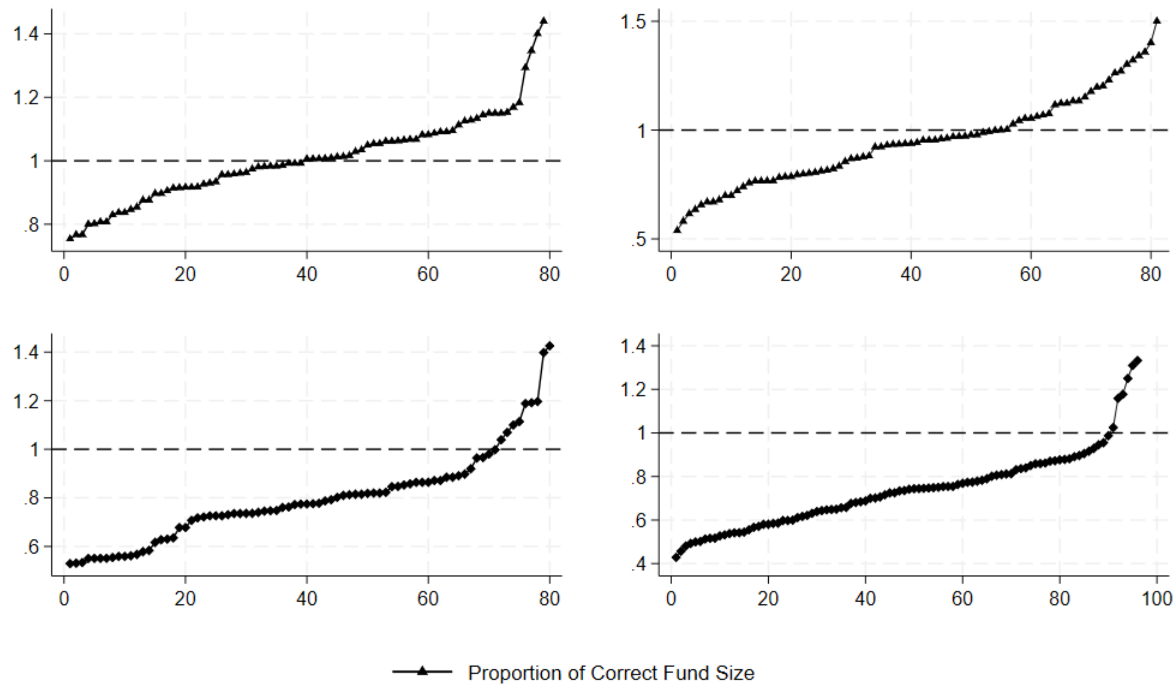


**Figure 1.** Four cumulative Distributions of Fund Sizes derived from responses in the Money-Match task. Left column is Lump Sum (LS) Conditions, right is Regular Saving (RS). Top row is 3% interest rate condition, bottom row is 7%. The difference between the two LS lines can be attributed solely to EGB. The RS lines illustrate more prevalent and severe underestimation, which can be attributed to undersum bias.

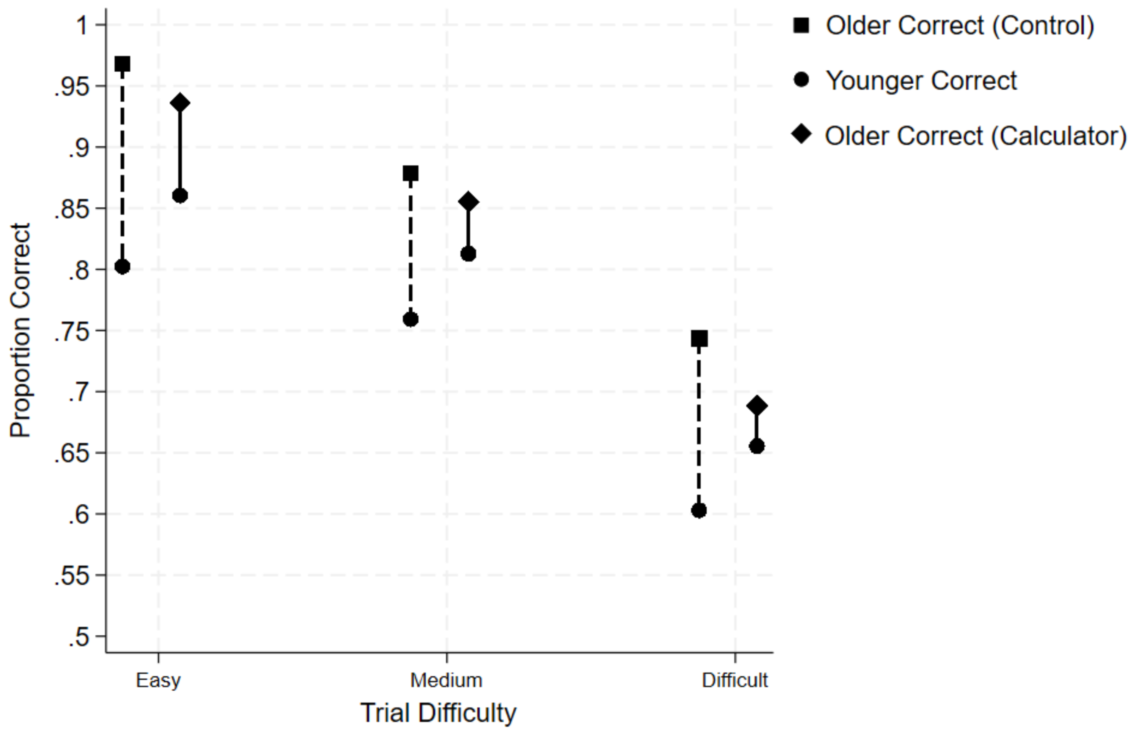


**Figure 2.** Proportion correct by trial type and trial difficulty for Control and Money Calculator conditions. The Money Calculator reduced the extend of underestimation, as illustrated by the higher proportion correct on 'Younger Correct' trials.


**Figure 3.** GIFs used to communicate the risk of financial shocks in randomised controlled trial on saving behaviour. Source: Timmons et al. (2022).