Does our ‘number sense’ lead to financial mistakes?

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It is no accident that our visual perception is so precise. Evolution has never tolerated inaccurate perceptions that could lead to fatal mistakes. Those who misjudged the distance when swinging from one tree branch to the next - our ancestors' siblings - didn’t get the chance to pass on their genes.

Today, inaccurate judgment can still harm well-being, but the risky areas have changed. One such area is financial decision-making. The need to allocate monetary resources over (often long) periods of time is a very recent problem in human history. In fact, it is so new that no reliable intuition has yet been developed to solve it with ease and precision.

A distorted number sense

Accumulation, the process by which quantities build up over time, is at the core of most financial problems: saving, borrowing, or deciding whether to pay for a product upfront or in a series of instalments. For example, people often choose recurring payments for goods and services - think of mobile phone contracts and car finance arrangements, and digital services like Netflix or Spotify.

Traditional models of consumer choice assume that people simply calculate total costs of this kind without error. But we're not that good in practice. Evidence from neuroscience and psychology suggests that the humans have a ‘number sense’ that is subject to error (Dehaene, 2011). Research on intuitive accumulation calculations shows we are prone to underestimation in a systematic way (Scheibehenne, 2019). And economic studies that reframe prices from yearly (e.g. €365 per year) to daily prices (€1 per day), the so-called "pennies-a-day technique", often find that the daily frame increases our willingness to purchase goods (Gourville, 1998). This could be due to underestimating the accumulated daily cost. Similarly, research showing that splitting product prices into smaller components increases demand hints at underestimation of the total price (Greenleaf, Johnson, Morwitz & Shalev, 2016).

Why do we seem to underestimate accumulation? One theory is that the ‘mental number line’ in the brain does not devote the same amount of space to representing each number (Dehaene, 2007). Instead, more neurons are devoted to the precise coding of small quantities, because these appear most often in the world around us. Relatively fewer neurons code larger numbers, meaning their representation is ‘fuzzier’. One possibility for why the accumulation bias leans towards underestimation is that it is less costly than overestimation. For instance, hunter-gatherers who overestimated the total amount of berries in their area might starve. In contrast, underestimating the total might lead to a surplus at the end of the year - and maybe an excuse to have a party!

Guessing instead of calculating?

Understanding the accuracy of accumulation intuitions also matters for economic theory: do financial choices reflect true preferences, or might they be mistakes in disguise? This matters because changing people's preferences is not the job of economists. But if people are making a mistake instead of acting on their preferences, then there is greater scope for policy intervention.

Whenever consumers are asked to choose between options whose costs are not spread over the same amount of time, it is possible that apparent impatience – a desire to get the most for the least cost *now* (even if that option is more expensive in the long run) - actually reflects underestimation of the total costs. An example will make this clearer:

Imagine you're considering a two-year phone contract. Option A bundles a 'free' phone with services (i.e. calls, texts, data) and costs at €50 per month (total cost €1200). Option B allows you to buy the phone separately for €500 and purchase a €20 per month services contract (total cost €980). If you pick A, maybe you do so because of a rational preference for consuming more now (after all, the future is uncertain). Paying €50 rather than €520 in the first month leaves you more income for current consumption, even if it costs you €220 more overall. Alternatively, the choice of option A could be driven by underestimating the accumulated costs of the 'free phone' contract. As mentioned above, the policy implications are different, depending on the cause.

But why doesn't everyone grab a calculator to solve problems like this? It would certainly remove the risk of mistakes, but it's a slow route that asks a lot of us. Opting for deliberative decision-making (versus using shaky intuitions) requires all of the following factors to be true:
- realising our own risk of error,
- knowing that a calculator will help,
- adequate maths skills to use the calculator as intended (tricky if interest rates are involved),
- enough time to use the calculator before having to make the decision.

None of these factors are trivial, so many people will just follow their biased intuitive judgment - their gut feeling - when making financial decisions. Financial wellbeing is such a vital factor to overall health and happiness that it is important to understand such intuitions. Decision tools can then be developed to work with and correct these intuitions.

Underestimating our retirement savings: a series of experiments

In my research, I want to find out if intuitive decision tools actually help improve the way people think about their retirements savings. In recent decades, responsibility for retirement planning has shifted from employers and institutions to individuals (Baldwin, 2008). One documented reason that individuals undersave is that they suffer from the exponential growth bias (EGB), which is jargon for underestimating the power of compound interest (Stango & Zinman, 2009). But when the savings plan involves making regular payments over time, savers also need to estimate accumulation of these regular instalments, before even thinking about the effect of compound interest. I hypothesised that this could be a factor independent of EGB that leads to individuals not realising the true financial cost of delaying saving for retirement.

I conducted a series of controlled laboratory experiments on a representative sample of 280 Irish adults (McGowan, Lunn, & Robertson, 2019). The groups were balanced by age, gender and working status to match the wider population. The experimental designs allowed separate measurement of EGB and accumulation bias. One group of participants was asked to think about the following question: "How much more will I need to save if I start saving later in life?" For the second group, I framed the cost of delay in terms of time: "How long can I wait to start saving if I commit to saving more when I do start?"

In the first judgment task experiment (n =100), participants were shown two saving scenarios (e.g. Peter saves €200 per month from age 30 at 3% interest). However, in one scenario either the amount saved or the age at which the saving started was missing. The participant's task was to 'fill in the blank' so that the total amount saved by retirement was the same in both scenarios. In both frames, we recorded substantial EGB and also considerable degrees of accumulation bias.

In the second experiment (n=180), the task was simpler: participants were asked to look at two scenarios and to answer the question: "Who do you think saved more at retirement?" The individual in the first scenario had started saving at a younger age. In the second scenario, saving had started later in life, but they saved more per month.

Before answering, two of the three groups got to use a decision tool (a type of calculator) that was designed to help them understand the dynamics of money growth. One version of the decision tool framed the cost of delay in terms of money; the other in terms of time (for instance, you can afford to start saving three years later if you

commit to saving €200 more per month). The control group used no decision tool. Results showed that only the decision tool that highlighted the monetary cost of delaying saving caused a significant reduction in the tendency to underestimate savings. But the results also suggested that its beneficial effect was specific to people with higher educational attainment. In addition to displaying EGB, individuals failed to appreciate the degree to which small regular contributions accumulate over long periods of time. Overall, the results suggested that there is scope for decision tools to help, but they must be carefully designed to be accessible to all.

The process of accumulation is embedded in nearly all financial decisions. As my PhD progresses, I aim to further analyse the psychological mechanisms underlying accumulation bias in a laboratory setting, and then move towards applied settings in the field. Ideally, my findings will help policymakers design environments in which consumers are less likely to make costly mistakes, but instead swing successfully between financial trees.

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