**Temporal discounting across adulthood: A meta-analysis**

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**Data:** Preregistration, synthesized data, and code used in the manuscript can be viewed and downloaded from <https://osf.io/ch9eg/>.

**Abstract**

Many everyday decisions involve tradeoffs between immediate satisfaction and long-term well-being. A number of empirical studies have examined adult age differences in decisions to accept a smaller, sooner reward instead of waiting for a larger, later reward, or temporal discounting. While some studies have reported a decrease in temporal discounting with age, many studies have reported no age effects on discounting or an increase in discounting with age. Based on these mixed findings, we predicted a nonsignificant or small negative effect of age on discount rates. We evaluated the reliability of the age effect on temporal discounting with a pre-registered systematic literature review and meta-analysis of existing studies examining temporal discounting in different age groups (e.g. younger adults vs. older adults) or in adult age-heterogeneous samples. Our initial search identified 2688 independent studies and after screening, we found 27 studies met our inclusion criteria. We also acquired 8 unpublished data sets directly from researchers. Across these 35 studies, we found no reliable relationship between discounting behavior and age. However, within these studies, we found heterogeneity in terms of experimental design (e.g. extreme-group vs. continuous age), incentives, (hypothetical vs. rewards), amount of delay (e.g. days, weeks, months, or years), and quantification of discounting behavior (e.g. proportion of immediate choices vs. parameters from a computational model).

Overall, the results suggest that age does not reliably explain individual differences in decision preferences and that discounting may remain stable across adulthood.

**Introduction**

Many everyday decisions involve tradeoffs between immediate satisfaction and long-term well-being. Should I get coffee now, or wait until after lunch? Should I purchase a new vehicle now, or wait until the end-of-the-year sales? Should I use a bonus at work to take my family on vacation now, or invest in my retirement? When faced with a potential delay, most people show a tendency to discount, or diminish the value of, future rewards. The degree to which people diminish the value of future rewards is known as an individual’s discount rate. Discount rates vary widely from person to person, and one question is whether these individual differences in discount rates persist as people get older. Do individuals have the same discount rate throughout their lives, or do the neurobiological and socioemotional changes associated with aging systematically change people’s discount rates?

Adult developmental theories suggest that because their future time is more limited than younger adults, older adults are more present-oriented (Lang & Carstensen, 2002; Carstensen 2006). It follows that because of their limited time horizons, older adults may view the future as more uncertain. This uncertainty may lead older adults to discount future rewards than younger adults (Trostel & Taylor 2001). However, there are several other theoretical reasons that one would predict the opposite relationship between age and temporal discounting. For instance, the illusion that time passes faster as we age (Block et al 1998?) could lead older adults to view a potential delay as subjectively shorter in duration. This subjectively shorter delay may make the delayed reward seem subjectively closer to older adults, and thus lead them to discount less. Likewise, studies have suggested that older adults may be better than younger at predicting their future emotions, or affective forecasting (citation). This enhanced ability to imagine and predict future states in older adults may make the future seem subjectively closer to them, and thus lead them to discount less (Löckenhoff, 2011). As posited by Löckenhoff, these two pathways could lead reduce discounting as people age.

The empirical literature on aging and temporal discounting is equally heterogeneous. While initial studies of temporal discounting and aging suggested the that people become more patient with age and discount less (Green et al., 1994), follow-up studies suggested that socioeconomic status was a stronger predictor of temporal discounting than age (Green et al., 1996). More recent behavioral studies are equally inconsistent, with studies reporting increased discounting with age (e.g. Read & Read, 2004), no discounting with age (e.g. Rieber & Mata 2015), and decreased discounting with age (e.g. Lockenhoff et al 2011). Similarly, neuroimaging studies have shown mixed results, with some finding less discounting in older adults (Eppinger et al., 2012) while others have shown no age differences (Samanez-Larkin et al., 2011; Seaman et al., 2018). These contradictory results make it difficult to summarize or draw conclusions about the impact of aging on temporal discounting.

Because of this theoretical and empirical heterogeneity, we decided to investigate adult age-related differences in temporal discounting. The goal of this study was to systematically gather and summarize the existing research in a meta-analysis that was pre-registered on the Open Science Framework at <https://osf.io/e4anc/> and ResearchGate at <https://www.researchgate.net/project/Age-differences-in-temporal-discounting>. We predicted a non-significant or very small negative effect of age on time discount rates (i.e., older adults discount less than younger adults). We also sought to identify and test potential moderators related to the way temporal discounting was quantified in empirical studies. Our analysis followed two main steps. First, we conducted a systematic literature search following the PRISMA guidelines. Consequently, we identified potentially relevant studies for the meta-analysis, defining relevant studies as original research articles that either compared temporal discounting in younger and older adults or correlations between age and temporal discounting in an adult sample. We also solicited unpublished results via decision-making listservs, online preregistrations, and follow-up emails to authors presenting unpublished results at decision making conferences. After identifying 28 empirical studies, we used meta-analytic methods to summarize the relationship between age and temporal discounting.

Next, in exploratory analyses, we selected potential moderators to test for an influence on the relationship between age and temporal discounting. The first potential moderator was experimental design; specifically, we classified studies on whether they treated age as a continuous variable or a grouping variable. Prior studies have shown that extreme-group designs can bias estimates (Preacher et al 2005). The second potential moderator identified was whether the incentives used were real or hypothetical. While there are strong correlations between different real and hypothetical incentives (e.g. Seaman et al 2018), the use of real rewards (versus hypothetical rewards) has been shown to reduce discount rates (e.g. Coller & Williams, 1999). The third potential moderator identified was the amount of delay (e.g. days, weeks, months, or years). Prior work has shown that the amount of delay can vary discount rates (e.g. Rieger & Mata, 2013?). The final potential moderator identified was the quantification of discounting behavior (e.g. parameter estimation or proportion of delayed options chosen). Again, although prior studies have found a strong correlation between parameter estimates and proportional measures (e.g. Seaman et al., 2018), parameter estimation may be more sensitive to small effects than proportional measures. Each of these potential moderators was tested in a separate analysis.

**Methods**

*Literature search*

We conducted a systematic review of the literature on January 2, 2019 to identify original empirical articles that estimated adult age differences in temporal discounting. Our procedure is illustrated in a flow diagram based on the PRISMA guidelines (Fig. x) and a detailed description follows:

1. We used the digital databases PsycINFO, PubMED and Web of Science (WOS) core collection database for our literature search with a combination of keywords related to time preferences (e.g., delay of gratification, delay discounting, temporal discounting, intertemporal choice, inter-temporal choice, delay aversion). The keywords also included the names of frequently used questionnaires or tasks to measure temporal discounting. These instruments had to be noted in the general literature reviews of temporal discounting (Cross, Copping, & Campbell, 2011; Pauli-Pott & Becker, 2015; Sharma, Markon, & Clark, 2013). We also included terms concerning age differences or aging (e.g., aging, older adults, elderly, age differences).
2. In addition, we performed a literature search in PsycINFO, PubMED and Web of Science (WOS) for articles citing the original paper reporting any of the discounting measures mentioned in general literature review described above (The Kirby questionnaire (Kirby & Maraković, 1996; Kirby, Petry, & Bickel, 1999), Delay Discounting Task (Coller & Williams, 1999), and Delay of Gratification Task (Mischel, Shoda, & Rodriguez, 1989)).
3. Papers cited in the reviews on aging and decision making were individually searched in either *Pubmed* or cross referenced (Brown & Ridderinkhof, 2009; Hsu, Lin, & McNamara, 2008; Lim & Yu, 2015; Löckenhoff, 2011; Mather, 2006; Peters, Hess, Västfjäll, & Auman, 2007; Spreng, 2016).
4. After undertaking the first three steps, we checked the references of the articles found through the searches above.
5. In December 2017 we emailed to list serves for unpublished results or data. (Society for Judgment and Decision Making; European Association for Decision Making);
6. In April 2017 we uploaded our preregistration on the Open Science Framework and ResearchGate, advertising our efforts and asking for any additional references, results, or data.

Most of these procedures were outlined in our preregistration. Details of the search can be found on our OSF repository at <https://osf.io/ch9eg/>. The keyword search (Point 1 above) resulted in the following numbers of hits: Pubmed (167), PsycInfo (152), and WOS (714). The article citation search (Point 2 above) resulted in the following number of hits: Pubmed (801), PsycInfo (598) and WOS (2603). All papers retrieved were collected in a Zotero group and then uploaded into the online software, Covidence. (cite Covidence). In the literature review process, we used Covidence for the abstract and full-text screening, but also for extracting the relevant data for our analysis. All articles were first screened by abstract and studies were excluded if they clearly did not meet the inclusion criteria listed below. If the information was ambiguous, the study was included for full-text screening. For example, if the age range was not explicitly stated in the abstract (e.g., undergraduates) the study was included for the full-text screen. At all stages there were two individuals performing the screening (ZF & SA). In case of a conflict a third independent individual (KS) resolved the issue by going through the disagreed studies.

*Inclusion criteria*

We used the following eligibility criteria:

1. studies must report results based on a behavioral measure of temporal discounting involving real or hypothetical rewards, or results based on a self-report questionnaire of temporal discounting behavior;
2. studies must report a temporal discounting outcome (e.g. proportion of choices, k parameter, area under the curve, indifference points) concerning at least one comparison between a group of younger (ca. 18-35 years) and older (ca. 65-85 years) individuals, reporting the outcome for each age group (mean, standard deviation) in numerical or graphical format, at test statistic that can be used to compute an effect size corresponding to age-related differences, or this information is attainable from the authors; or
3. studies must report a correlation between age and at least one measure of temporal discounting in an adult sample (i.e., majority of respondents are older than 18) and a minimum age range of 25 years, or this information is attainable from the authors;

*Exclusion criteria*

We limited our analyses to those studies that focus on the effect of age on temporal discounting. Studies or measures were excluded if:

1. the sample was a subsample of another included study;
2. the sample primarily consists of patients with cognitive-impairment (e.g. Parkinson’s, Alzheimer’s, or Mild Cognitive Impairment) or other disorders that are known to influence cognition (e.g. depression, ADHD, addictive disorders);
3. the measure examines probability or effort discounting or combines temporal discounting with probability or effort discounting;
4. a reward other than monetary reward was used (e.g. juice reward); or
5. the study was not included in a peer-reviewed publication (e.g. thesis or book chapter).

Title and abstract screen resulted in <641> references which were then subjected to full-text screening. This resulted in a total of <31> studies for inclusion in our analyses. Reasons for exclusions, along with numbers of studies excluded for those reasons, can be seen in Table 1. In addition to the systematic literature search, direct contact with researchers (Points 5 and 6) resulted in <blank> unpublished data sets. Collectively, a total of <num> independent publications were included (see Figure 1 which will be PRISMA flow chart).

Most of these procedures were outlined in the preregistration. However, there were a few changes we made to our procedures as we began the systematic review. First, the Web of Science database search, as well as an expanded list of keyword search terms were added (see Appendix for full list of search terms) to the search criteria. Second, we expanded the exclusion criteria to explicitly exclude addictive disorders like drug or alcohol addiction and pathological gambling. We also excluded studies using non-monetary rewards. Third, book chapters and dissertations were excluded, with the reasoning that they are not peer reviewed. Fourth, we excluded any study which we could not access through the University of Basel or Duke University libraries and were not freely available online.

*Analyses*

Statistical analyses were carried out using the metafor package in R (Viechtbauer, 2010). We analyzed all temporal discounting outcomes (e.g. proportion of delay options, k values, area under the curve, indifference points) that were used in more than one study. To estimate the effect of age on temporal discounting, for each study we calculated either:

1. the Fisher’s *z* transformation of the standardized mean difference (*d*) in discounting between two age groups; or
2. the Fisher’s *z* transformation of the correlation *(r*) between age and discounting.

Given the wide variation in methodology and in the reported outcome measures, the measures of effect size (Fisher’s *z*) were entered into a random-effect model as it assumes between study variance unlike the fixed-effect model. Furthermore, we used funnel plots to examine publication biases and run exploratory meta-regressions to examine the potential moderator variables.

**Results**

* add Roni Setton’s unpublished group data and Corinna’s most recent pub that is under review

The meta-analysis suggests that there are no significant age differences in temporal discounting (estimate, 95% CI: ub, lb). Figure 1 presents a forest plot with the effect size (Fisher’s *z*) and respective 95% confidence intervals (CI) for each study included in the meta-analysis. A significance level of 0.05 can be inferred when zero is not contained within the 95% confidence interval.

We also attempted to assess whether methodological differences could account for some of the heterogeneity in the effects reported.

**Discussion**

Return to SST – perhaps because most studies focus on monetary rewards, which are potentially not as salient as social rewards – we don’t see discounting. We would see it for social rewards (Seaman et al., 2016 study). Work in that YA discount more for $ than OA (but same for juice (primary rewards) – Jimura et al)?

Gains vs losses – only a handful of studies examined discounting for losses. Reason to believe older adults may discount more for losses (SOC theory).