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Original article

Time-discounting and tobacco smoking: a systematic review and network analysis

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Abstract

Background: Tobacco smoking harms health, so why do people smoke and fail to quit? An explanation originating in behavioural economics suggests a role for time-discounting, which describes how the value of a reward, such as better health, decreases with delay to its receipt. A large number of studies test the relationship of time-discounting with tobacco outcomes but the temporal pattern of this relationship and its variation according to measurement methods remain unclear. We review the association between time-discounting and smoking across (i) the life course, from initiation to cessation, and (ii) diverse discount measures.

Methods: We identified 69 relevant studies in Web of Science and PubMed. We synthesized findings across methodologies and evaluated discount measures, study quality and cross-disciplinary fertilization.

Results: In 44 out of 54 studies, smokers more greatly discounted the future than non-smokers and, in longitudinal studies, higher discounting predicted future smoking. Smokers with lower time-discount rates achieved higher quit rates. Findings were consistent across studies measuring discount rates using hypothetical monetary or cigarette reward scenarios. The methodological quality of the majority of studies was rated as ‘moderate’ and co-citation analysis revealed an isolation of economics journals and a dearth of studies in public health.

Conclusion: There is moderate yet consistent evidence that high time-discounting is a risk factor for smoking and unsuccessful cessation. Policy scenarios assuming a flat rate of population discounting may inadequately capture smokers’ perceptions of costs and benefits.

Key words: time-discounting, time preference, smoking, cessation

Key Messages

- A potential reason why people smoke or respond poorly to cessation treatments is that they devalue, or 'discount', future rewards more than non-smokers and those who successfully quit.
- A large number of studies have tested this hypothesis but there is substantial variation in studies' methodologies and temporal patterns being analysed. We review the association between time-discounting and smoking across diverse methodologies, including studies of initiation and cessation.
- We find consistent yet moderate quality evidence that smokers more greatly discount the future than non-smokers. Higher discounting predicted future smoking and decreased cessation success; these findings were most consistent with discount measures based on hypothetical monetary or cigarette reward scenarios.
- Co-citation analysis revealed an isolation of economics journals and a dearth of studies in public health.
- Policy scenarios assuming a flat rate of population discounting may inadequately capture smokers' perceptions of costs and benefits.

Introduction

Tobacco smoking is a risk factor for a number of chronic diseases including cancer, lung diseases and cardiovascular diseases.¹ Many policy-makers have committed vast sums of money to help smokers quit, have increased taxes on cigarettes to raise prices and have mandated graphic labels on cigarette packages to inform smokers of the grave dangers to health.² Ultimately, however policy-makers attempt to reduce the prevalence of smoking, they influence people's behaviour. Thus, a critical question in public health is: 'Why do people engage in risky behaviours such as smoking despite evidence and knowledge of their consequences?'

One cognitive factor receiving increasing attention in risky behaviours such as tobacco use is the role of time-discounting. Time-discounting characterizes how individuals' preference for a reward decreases with the delay to its receipt.³ Most people tend to prefer smaller, immediate rewards to larger ones available after a delay—i.e. they 'discount' the value of future rewards.⁴ Importantly, time-discounting differs from 'time preference', which describes whether and how people consider events in the past, present and future when making decisions.⁵ Instead, time-discounting captures the degree to which people devalue rewards with every additional unit of delay—a parameter known as the 'discount rate'. There is robust evidence that discount rates vary according to multiple socio-economic characteristics and behaviours. For example, discount rates are found to be lower in older and more educated individuals with higher socio-economic status, whilst those who save less for retirement, who gamble and who are overweight have higher discount rates.^{6–10}

The health costs of cigarette smoking come at a delay whilst benefits are immediate. Thus, time-discounting may act as one important mediating, and potentially modifiable, factor linking environmental, social and life-course factors to risky unhealthy behaviours, including smoking.⁸

Over the past two decades, a growing body of scholarship has therefore begun testing whether time-discounting correlates with a range of smoking-related behaviours. Studies in this field analyse a range of temporal patterns, including the relationship of time-discounting with smoking initiation, smoking status and dependence at a fixed point in time and sustained cessation.^{13–15} Studies also employ a wide range of alternative discount measures, reflecting differences in research questions, data collection and data analysis across psychological and social sciences.¹⁶

Understanding the temporal relationship of time-discounting with smoking has important implications for epidemiologists by identifying a potential upstream determinant of persistent tobacco use, mortality and inequalities, and by providing insights that increase the effectiveness of cessation or upstream prevention interventions. Since time-discounting is also correlated with alcohol consumption and poor diet, modifying discount rates to prevent smoking can also provide possible 'spillover' benefits by reducing the risk of multiple risky behaviours and associated diseases.^{17,18}

Previous systematic reviews importantly helped to reveal the significance of time-discounting as a cognitive risk factor for smoking. These include a meta-analysis by MacKillop *et al.* that identified higher discount rates among smokers in 79% of the included studies, although the authors exclude studies of initiation and cessation and studies using non-monetary discount rate measures ($n = 19$ studies).⁹ These findings are consistent with a second review by Story *et al.* who also found that higher discount rates for money are associated with several unhealthy behaviours, including smoking ($n = 39$ studies), but excluded studies in social science.⁴ Hughes *et al.* explore possible bidirectionality of the relationship between smoking and discounting, reporting mixed results in experimental studies that test whether elevated time-discounting is a symptom of tobacco withdrawal ($n = 6$ studies).¹⁹

Previous reviews were relatively narrow in scope, as they do not synthesize temporal patterns of initiation and cessation and heterogeneity according to measurement methods. As MacKillop *et al.*⁹ concluded, there is a ‘need for a better understanding of the chronological relationship’ of time-discounting with smoking (p. 316). To address these gaps in the literature, our review analyses the relationship between smoking and time-discounting across the life course for the first time, from initiation through to cessation. We disaggregate studies by design and methodology to study variation in study findings according to discount rate measurement. We also analyse co-citation patterns to assess whether studies of time-discounting are currently being acknowledged in epidemiology and public health or are instead located in disciplinary siloes. As is being increasingly noted elsewhere, including a recent article in *IJE*, this is especially important in epidemiology and public health, as a failure to include work from other disciplines could lead to partial or incorrect conclusions.^{10–13} This also enables us to identify opportunities for future research in this cross-disciplinary area of epidemiology and behavioural economics.

Data and methods

Search strategy and study selection

We searched all journal fields (title, abstract, subject and full text) in Web of Science and PubMed using the terms described in Table 1. Searching across both databases enabled us to include studies published in journals from a range of disciplines, including economics, pharmacology and neuroscience. Both databases provide journal citation data that can be used for co-citation analysis.

Figure 1 shows a PRISMA flow diagram depicting study identification, screening and exclusion (see Supplementary Appendix 1, available as Supplementary data at *IJE* online, for full PRISMA statement).²⁰ The search yielded 727 unique articles, ranging from 1977 to mid-2015. Papers were excluded if they were (i) not in English, (ii) had been retracted or (iii) were not journal articles or were not yet published. We further excluded those that were not relevant to the study’s objectives, using criteria shown in Table 2. Briefly, the most common reasons were that they failed to study tobacco smoking (378 studies); failed to measure a time-discount rate (125 studies); or they alternatively performed economic cost–benefit analyses (70 studies). Next, we reviewed the bibliographies of previous reviews and book chapters on time-discounting and smoking, although this did not yield any additional studies. Screening and exclusion were conducted by the lead author (PB). Our final analytical sample included 69 studies, covering years 1990 to 2015.

Table 1. Search terms

‘time preference’ smoking
‘time preferences’ smoking
‘time-preference’ smoking
‘time-preferences’ smoking
delay discount smoking
delay discounting smoking
delay-discount smoking
delay-discounting smoking
discount rate smoking
inter temporal smoking
inter-temporal smoking
intertemporal smoking
time discount smoking
time discounting smoking
time-discount smoking
time-discounting smoking
‘time preference’ tobacco
‘time preferences’ tobacco
‘time-preference’ tobacco
delay discount tobacco
delay discounting tobacco
delay-discount tobacco
delay-discounting tobacco
discount rate tobacco
inter temporal tobacco
inter-temporal tobacco
intertemporal tobacco
time discount tobacco
time discounting tobacco
time-discount tobacco
time-discounting tobacco

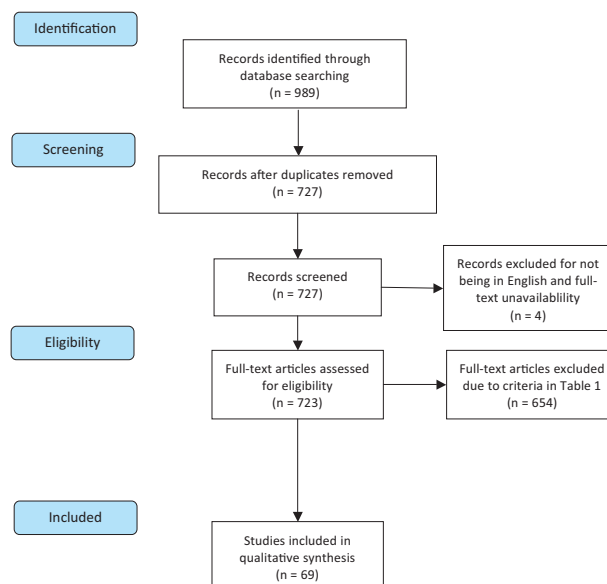


Figure 1. PRISMA flow diagram.

Notes: PRISMA flow diagram following Moher *et al.* 2009. Please see Web Appendix 1 for full PRISMA statement.

Table 2. Study exclusion

Analyses economic costs and benefits
Studies animal subjects (e.g. rats)
Not an empirical study (e.g. systematic review, book chapter, commentary)
Does not measure time discount rates
Article unavailable (e.g. poster or conference abstract, has been retracted, not yet published)
Cannabis not tobacco smoking
Not in English
Outcome variable not smoking initiation, smoking cessation, smoking abstinence, smoking status or quantity of cigarettes consumed per day

Data extraction and analysis

We extracted title, author, journal, abstract and year for each paper, as well as research question, methodology, sample size, sample demographic, discounting measure (e.g. real or hypothetical rewards, hyperbolic or exponential discounting), smoking variables (e.g. smoker status, dependency, abstinence, cessation success) and main results (see [Supplementary Appendix 2](#), available as [Supplementary data](#) at *IJE* online, for study coding). We analysed study results by performing a qualitative synthesis rather than a meta-analysis in order to explore heterogeneity across different methodologies.

We then used an adapted version of the Quality Assessment Tool for Quantitative Studies (developed by the Effective Public Health Practice Project)²¹ to assess the methodological quality of the included studies ([Supplementary Appendix 3](#), available as [Supplementary data](#) at *IJE* online). Studies can have between six and eight component ratings, with each component score ranging from 1 (low risk of bias; high methodological quality) to 3 (high risk of bias; low methodological quality). An overall rating for each study was determined based on the component ratings.

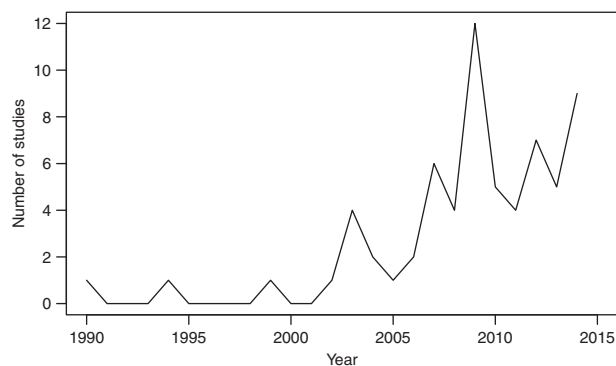
Co-citation data were collected from Web of Science and PubMed and analysed using VOSviewer version 1.6.1 and network clustering algorithms.²² Sixty-five journals were included based on having at least 10 citations.

Results

First, we describe trends and disciplinary origins of the reviewed literature. Next, we review the findings from our methodological quality assessment, analyse the main findings by study question and review the different methods used to measure discount rates.

Trends in and types of publications on time-discounting and smoking

[Figure 2](#) plots the annual number of studies included in our analysis. There was a marked increase in the number

**Figure 2.** Number of time-discounting and smoking studies published per year, 1990-2014.

Notes: graph shows the number of studies published per year that were not excluded based on the screening and exclusion criteria in [Table 2](#). Studies from 2015 not included as search was conducted part way through the year.

Table 3. Quality assessment scores

Criterion	Strong	Moderate	Weak
Study design	1	68	0
Confounders	5	63	1
Blinding	0	69	0
Data collection	51	16	2
Representativeness I	1	3	64
Representativeness II	4	10	3
Data analysis	69	0	0
Reporting	45	22	2
Overall rating	1	65	3

Notes: Total studies for representativeness scores do not sum to 69 as 1 article was not eligible for scoring on 'Representativeness I' and 52 articles were not eligible for scoring on 'Representativeness II'.

published each year after 2003, when the majority (88.4%) were published.

Among the 69 articles included in our review, 54 were cross-sectional studies of smoking prevalence, 11 were studies of cessation and relapse, and 4 studied initiation and the life course. Sample sizes ranged from 30 to 42,863, with a mean of 1,171, albeit right skewed (median $n = 80$). Sixty-two out of the 69 included studies were conducted in the USA and 7 studies were conducted in Japan.

[Table 3](#) describes the results of the quality assessment of these papers. Most studies were 'weak' in representing the general population, tending to rely on college students. However, data collection and reporting quality tended to be high.

Time-discounting and smoking initiation

We first evaluated studies looking at initiation, principally occurring among youth. Three longitudinal studies found high discounting corresponded to greater likelihood

of initiation. Kang and Ikeda, using the Japanese Household Panel Survey on Consumer Preferences and Satisfaction ($n = 10\,638$), found that each standard deviation increase in discount rates was associated with a 4.5 [95% confidence interval (CI): 4.1–4.7] percentage point higher probability of becoming a smoker as well as greater daily cigarette consumption of 1.5 per day (95% CI: 1.22–1.67).²³ Anokhin *et al.*²⁴ used a longitudinal twin design, drawing on repeated interviews with individuals at ages 12 and 14 across three birth cohorts. The authors reported an association of greater preference for immediate rewards with smoking at age 14 ($\chi^2 = 8.76, p = 0.003$) but not at age 12, independently of genetic factors.²⁴ Audrain-McGovern *et al.*, using a prospective longitudinal cohort study ($n = 947$) similarly reported that each standard deviation increase in delay discounting increased the odds of smoking initiation by 11% [odds ratio (OR): 1.11, 95% CI: 1.03, 1.23] in youths aged 15–21.²⁵

Two retrospective cross-sectional studies found that time-discounting was linked to initiating smoking at younger ages²⁶ and smokers' children had higher discount rates than did non-smokers'.²⁷ A cross-sectional study by Reynolds and Fields reported that adolescents experimenting with smoking reported higher discount rates than non-smokers.²⁸

Time-discounting and smoking prevalence

Next, we investigated current smoking behaviour, including 54 cross-sectional studies. Forty-four out of 54 found evidence that discounting increases the likelihood of being a smoker and consuming cigarettes more frequently and in greater quantities.^{13,14,26–56} Several studies identified potential modifying characteristics. Seven studies reported results that varied according to gender and cigarette consumption levels, with stronger associations of time-discounting with smoking among men and more dependent smokers.^{57–63} Seven studies found that people with other substance use or mental health problems had stronger associations of smoking and time-discounting, including cocaine-dependent smokers,⁶⁴ those with depressive symptoms,⁶⁵ heavy drinkers,⁶⁶ obese persons⁶⁷ and individuals with gambling problems,⁶⁸ compared with smokers without these symptoms.^{69–73}

Time-discounting and smoking cessation

We then investigated the link of quitting success with time-discounting. Three longitudinal studies report that high time discounters were less successful in cessation. Ida *et al.* found that a 1% increase in the discount parameter at baseline resulted in a 10% increase in the chance of smoking relapse after a 5-month follow-up.⁷⁴ Similarly, Goto *et al.* reported a hazard ratio for relapse of 1.17 (95% CI: 1.10–1.24).⁷² Yoon *et al.* found that baseline time-

discounting predicted smoking relapse at 24 weeks post partum among a sample of women who spontaneously quit smoking after discovering they were pregnant.⁷⁵

We also looked at whether discounting modified the effectiveness of cessation interventions. Six studies found that higher time-discounting was linked to less successful abstinence in a cessation intervention, including nicotine replacement therapy, cognitive behavioural therapy and abstinence-contingent monetary rewards.^{26,53,61–63} For example, Krishnan-Sarin *et al.*¹³ found that, following a 4-week, high-school-based cessation programme in which participants received weekly monetary rewards if they abstained, individuals with higher discount rates at treatment onset were less likely to have remained abstinent from smoking at the end of the 4-week programme ($F = 2.67, p < 0.05$). Two studies, however, found no impact of discounting on the effectiveness of cessation interventions.^{76,77}

Heterogeneity by discipline and discount measurement

Figure 3 shows journal co-citation patterns revealing four main journal clusters: economics, neuroscience, psychology and pharmacology disciplines. The most highly cited journal is *Psychopharmacology*. The psychology and pharmacology journals have the strongest tendency for co-citation, the neuroscience cluster has a slightly weaker tendency for co-citation and the economics cluster is the most isolated.

Supplementary Appendix 3 (available as Supplementary data at *IJE* online) describes our review of heterogeneity in study findings according to the method used to measure time-discounting. The main methodological differences hinged on whether surveys asked respondents to value hypothetical or potentially real rewards. Studies measuring discount rates using hypothetical money or cigarette rewards tended to find more consistent results, reporting positive associations of time-discounting with adverse smoking behaviour in at least 80% of studies. Results with real or potentially real monetary rewards were less consistent.

Discussion

Our systematic review highlights several important findings on the relationship between smoking and time-discounting. First, cross-sectional studies consistently report a significantly greater likelihood of smoking, as well as greater quantity and frequency of consumption, among those with high time-discount rates. The association with smoker status was consistent across hypothetical discount rate measures. Second, the small number of longitudinal studies consistently reported a positive association between time-discounting and the likelihood of initiating smoking. Third, smokers with lower time-discount rates achieved higher quit rates and prolonged abstinence with smoking cessation

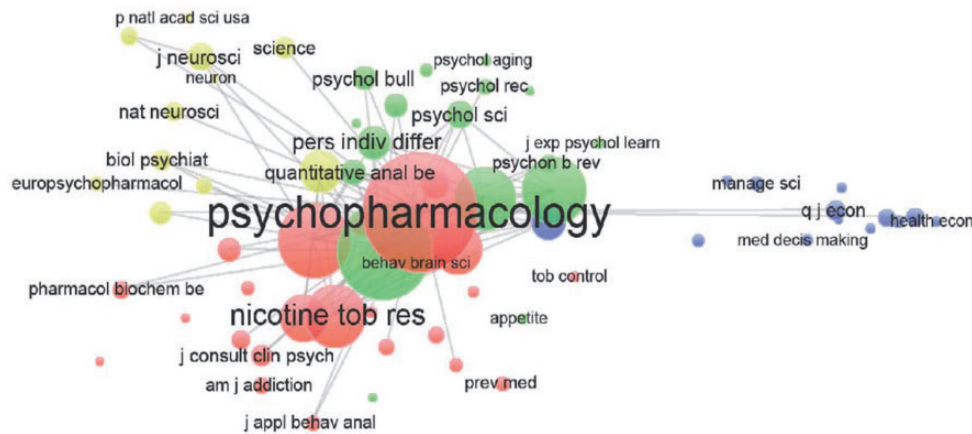


Figure 3. Co-citation of journals.

Notes: Bubble sizes correspond to the relative magnitude of each journal's citations in other journals (minimum 10 citations per journal; $n = 65$ journals). Proximity of bubbles corresponds to the frequency with which journals are cited together in other journals. Colours reflect communities identified by VOS clustering. Produced in VOSviewer Version 1.6.1.

treatment. Fourth, the methodological quality of studies in time-discounting and tobacco smoking was predominantly 'moderate', largely due to a strong reliance on convenience sampling and the small number of longitudinal studies. Fifth, co-citation analysis revealed an isolation of economics journals and a dearth of studies in epidemiology and public health.

Our review has several limitations. Due to methodological variation between studies, it was not possible to perform a meta-analysis or to calculate pooled effect sizes. To address this limitation, we have structured the review according to the type of smoking behaviour being analysed, permitting comparisons at different stages of smoking from initiation to cessation. This systematic review also points to several limitations in existing research. First, the bulk of studies is cross-sectional, precluding ascertainment of a clear causal link between smoking and discounting. There is potential bi-directionality in cross-sectional studies, where nicotine exposure increases time-discounting rather than vice-versa, e.g. by inhibiting cortical regulation mechanisms or by impacting the sensitivity of the brain's reward system.^{52,78} Previous studies not included in our review found that (i) those seeking smoking cessation had lower discount rates, creating potential selection bias that is unaddressed in experiments analysing voluntary participants,²⁵ and (ii) time-discounting significantly decreased at a 12-month follow-up among smokers who successfully quit.⁷⁹ Conversely, there is also evidence that short-term withdrawal from smoking increases time-discounting.⁸⁰ This suggests a potentially complex aetiology, where time-discounting is a risk factor for smoking, yet abstinence increases time-discounting in the short run but causes a reduction in discounting in the long run. Future research should address these limitations and clarify the causal link between smoking and discounting.

Second, there was also a strong reliance on convenience sampling, limiting external validity and leading to a 'moderate' quality rating for the majority of studies in this field. Most studies were also conducted in the USA and Japan. There is variation in time-discounting and its association with smoking between different age groups,²⁴ suggesting that a reliance on local student populations comprising young adults is a limit to external validity.

Third, as revealed by co-citation analysis, there is a dearth of studies in epidemiology and public health. Additionally, the field of economics is relatively isolated. This suggests that the findings identified in our review are not currently acknowledged in public health and in epidemiology despite their important implications. For example, it is possible that epidemiological studies which do not account for the potential contribution of time-discounting to multiple behaviours may attribute an observed health outcome to smoking rather than other risky behaviours such as diet, physical inactivity and excess alcohol consumption.

Few studies analysed the life-course origins of discount rates in order to test whether these explain the social patterning of smoking.²⁷ Studies in sociology and social psychology indicate the importance of social and environmental factors for both smoking and discounting, e.g. via their effects on cognitive function. Poor cognitive function is linked to higher discounting and is hampered by stress, leading Bickel and colleagues, in a recent review, to highlight the potential role of stress-related socio-economic factors such as poverty in influencing unhealthy behaviour via increased discounting.⁸ Research into the life-course determinants of cognitive function highlights the additional roles of language development, home learning environments, parenting style and beliefs, and health (maternal health, birth weight and breastfeeding).^{81–83} The social

patterning of these environmental factors corresponds to social gradients in smoking, suggesting that all could contribute to smoking behaviour via their knock-on effects on time-discounting. Whilst all longitudinal studies controlled for a small number of socio-demographic characteristics, adjustment for multiple socio-economic characteristics was less common. Three of the six longitudinal studies adjusted for education, one study controlled for employment status and one study adjusted for income. There is therefore possible omitted variable bias across the majority of longitudinal studies, with just one out of six studies adjusting simultaneously for age, education and employment status.⁷⁵ In our review, one study also identified different associations of time-discounting with smoking at different ages.²⁴ Thus, there may exist a 'critical juncture' in the life course, at which point time-discounting emerges as a risk factor for smoking. Future research should address this limitation in the literature by identifying the social and life-course determinants of time-discounting. This will be important to identify policy implications for potential upstream rather than technical interventions that mitigate the risk of smoking, whilst also identifying the social groups for whom cessation interventions may be least effective.

Our review identified that the cross-sectional association between time-discounting and smoker status was consistent across studies using hypothetical monetary and cigarette measurement methods. Previous studies identify a correlation between discount rates measured using hypothetical monetary rewards and measures using real and appetitive rewards including cigarettes, although discount rate estimates tended to be smaller for hypothetical rewards.¹⁶ Thus, discount rate estimates using hypothetical cigarette or monetary rewards may underestimate discount rates for real cigarettes. Yet, our review identified a consistent correlation with smoker status across hypothetical cigarette and monetary rewards. There is therefore evidence of measurement specificity concerning the scale of discount rates but not the correlation with smoker status. This suggests that hypothetical measures are suitable for future research on time-discounting and tobacco use.

There is nevertheless a need for further research to test the construct validity of currently utilized discount rate measures. The majority of existing studies focus on discount rates for one reward at a time (cigarettes, money, health) whilst the theoretical mechanisms underlying the link with smoking behaviour involves a trade-off between two different rewards: cigarettes and health. There is also potential confounding in assessing time-discounting with risk-aversion if delayed rewards are viewed as more uncertain⁵⁰ yet a small proportion of studies accounted for this possibility. Further, insights from behavioural economics also suggest that gains are discounted more steeply than losses.^{84–86} There is a need for future research to better identify the specific types of

discounting (risk vs delay, gains vs losses, cigarettes vs money) that increase risks of smoking, increase during abstinence and decrease the likelihood of successful cessation.

Despite these limitations, our review identified evidence that high time-discounting is a risk factor for smoking, including initiation and unsuccessful cessation. This has important implications for tobacco interventions. Although tobacco-related mortality and initiation have begun to decline in many countries, there are still important challenges that need to be addressed. Inequalities in tobacco initiation and mortality remain stable in many countries.⁸⁷ Tobacco use continues to rise in some contexts, particularly low- and middle-income countries.⁸⁸ Cessation programmes have not always been effective, benefitting some groups more than others.^{89,90} The findings from our review show that time-discounting can potentially help epidemiologists, policy-makers and public health practitioners understand these trends and develop interventions that can tackle such issues. First, interventions which assume a flat rate of discounting across population groups may fail to capture smokers' perception of costs and benefits over time. There appears to be a critical window during initial withdrawal when discount rates may increase. Second, higher discount rates may be a common cognitive risk factor, as a so-called 'trans-disease process', playing a role in several unhealthy behaviours including hazardous alcohol consumption and binge eating.⁹¹ There may be scope to identify policies and interventions that influence discount rates, with a specific focus on elevated rates during initial withdrawal, as a useful target for intervention that simultaneously reduces the risks of multiple chronic non-communicable diseases.¹⁸ For example, Radu *et al.* find that discount rates can be reduced by re-framing intertemporal choices from 'nothing now but more later' to 'something now but nothing later'.⁹² In addition, working memory training has been found to decrease the degree to which individuals discount delayed monetary rewards.⁹³ Interventions that address differences in time-discounting cannot replace existing interventions but they may offer a complementary approach that can inform how other interventions are communicated to reduce initiation, increase cessation and minimize inequalities.

Supplementary Data

Supplementary data are available at *IJE* online.

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