Published in final edited form as:

Trends Cogn Sci. 2016 January ; 20(1): 64–74. doi:10.1016/j.tics.2015.09.005.

The malleability of intertemporal choice

Karolina M. Lempert, M.A. and

New York University 6 Washington Place, room 890 New York, NY 10003

Elizabeth A. Phelps, Ph.D.

New York University 6 Washington Place, room 890 New York, NY 10003 Nathan Kline Institute Orangeburg, NY

Abstract

Intertemporal choices are ubiquitous: people often have to choose between outcomes realized at different times. Although it is generally believed that people have stable tendencies toward being impulsive or patient, an emerging body of evidence indicates that intertemporal choice is malleable and can be profoundly influenced by context. How the choice is framed, or the state of the decision-maker at the time of choice, can induce a shift in preference. Framing effects are underpinned by: allocation of attention to choice attributes, reference-dependence and time construal. Incidental affective states and prospection also influence intertemporal choice. We advocate that intertemporal choice models account for these context effects, and encourage the use of this knowledge to nudge people toward making more advantageous choices.

Keywords

intertemporal choice; temporal discounting; framing; context; affect

Rethinking the stability of intertemporal choice

In stark contrast to what is predicted by traditional models of choice, nearly all decisions are strongly context-dependent. A choice between two alternatives will be influenced by what other options are available, how the options are described, and what options were previously available. In addition to behavioral evidence from numerous studies conducted over the last forty years [1,2], there is evidence of a neural instantiation of context-dependent value coding [3–5]. To date, studies demonstrating context effects on choice have been largely restricted to risky choices or choices between immediately available options. Most prominently, Kahneman and Tversky observed context-dependent risk attitudes and developed prospect theory [1] to describe them.

Corresponding author: Phelps, E.A. (liz.phelps@nyu.edu).

Much less scrutiny has been given to context-dependence in the domain of intertemporal choice. Intertemporal choices are decisions between rewards available at different points in time – most commonly, between smaller/sooner rewards and later/larger rewards. These decisions are prevalent in everyday life, and they range from the mundane (e.g., choosing to go out with friends or study for an exam) to the highly consequential (e.g., choosing to buy a car now or save money for your children's education). Intertemporal choices also go beyond the personal; preferences for future environmental gains correlate with preferences for future financial gains [6]. The study of these decisions is also of importance because maladaptive intertemporal choices underlie many societal and psychiatric problems, including addiction [7], obesity [8] and gambling [9].

It is generally thought that people are fairly stable in their intertemporal preferences [10–12], and it has been suggested that they may have a genetic component [13,14]. These preferences have even been proposed as a candidate behavioral marker for psychopathology [15,16]. However, research in the last decade or so has brought to light strategies and manipulations for shifting choices toward being more patient or more impulsive. In this review, we focus on describing and classifying these manipulations. We highlight two primary means by which intertemporal choice can be manipulated and discuss their implications for models of intertemporal choice and policy.

Measuring intertemporal choice

The most striking characteristic of intertemporal decisions is that people discount the value of future rewards as a function of the delay to receiving them. This is known as delay discounting, or temporal discounting. The extent to which people devalue future rewards varies. We will refer to the inclination to choose smaller/sooner rewards as 'impulsivity' and the tendency to choose later/larger rewards as 'patience,' at a between-subjects level. Although impulsivity has many meanings in the literature, we use this term here to mean that a person is relatively more impulsive if they are more likely to choose smaller/sooner rewards over later/larger rewards relative to other people or to their own choices in a different context. In this review, we only discuss studies that involve explicit choices between a smaller/sooner (usually immediate) and later/larger reward. We do not include studies that involve delay-of-gratification (in which it is possible to alter one's plan and choose the immediate reward at any time; e.g. [17]), or studies with very brief delays on the order of minutes or seconds. By extension, we limit our review to human studies, since the tasks performed by other species almost always utilize very short delays. Although different mathematical models have been used to characterize intertemporal choice (see Box 1), we are concerned mostly with the degree of discounting, so we include papers that fit data using various models, as well as studies that use nonparametric means of assessing discounting. Finally, although it may be problematic to assume linear value functions for rewards (see Box 2), most studies of intertemporal choice do, so we do not exclude studies on this basis.

Laboratory intertemporal choice tasks are typically comprised of a series of intertemporal choices made in rapid succession. These choices explicitly indicate the amount of both rewards and the immediacy with which they can be obtained. While this format allows researchers to estimate individual discount rates with precision, these decisions can be quite

different from those faced by individuals in daily life. This is important to bear in mind when considering the context effects described below; they may not all apply to real-world decisions. Nevertheless, discount rates measured in the laboratory are sound predictors of everyday behaviors, such as smoking [18], alcohol use [19], academic performance [20] and even texting while driving [21].

Framing effects on intertemporal choice

The way that intertemporal preferences are elicited can influence choice. In this section, we present mechanisms by which these framing effects could occur. Specifically, intertemporal choices depend on the allocation of attention to choice attributes, on the reference point, and on the construal of time.

Attention to attributes

Attention can be a powerful tool for manipulating choice. For example, 'delay' is considered a negative attribute of a future reward, but its magnitude can be considered a positive attribute (because it usually exceeds the value of the immediate reward). Therefore, drawing attention away from magnitude and toward delay should lead to more impulsivity.

It has been suggested that, when making choices, people attend to reward magnitude by default [22]. They routinely underweight time and duration [22,23], and so, decisions involving time may be especially susceptible to contextual influences. For example, when participants are asked to attend to the time at which they will receive a future reward, they become more patient when considering shorter delays, and more impulsive when considering longer delays. Asking participants to attend to the amount of a future reward, on the other hand, does not change discounting behavior [22], suggesting that they were already focused on the amount.

In addition to explicitly instructing participants to attend to the delay between options, it is also possible to alter attention by changing the way that reward magnitudes are presented. One example of this is the 'decimal effect.' When rewards are framed as rounded numbers (e.g., $9.00 today vs. $11.00 in one week) rather than decimals (e.g., $8.44 today vs. $10.32 in one week), individuals tend to be more impulsive [24]. Although the authors suggest that increased positive affect in response to rounded numbers drives more impulsivity in this condition, this result can also be explained via attention. More attention and deliberation are required to process numbers with decimals, thus drawing the decision-maker's attention to the magnitudes and away from the delay. This makes the delayed reward seem more attractive. In the rounded numbers condition, relatively more attention is drawn to the difference in delay between options, thus making the immediate reward seem more favorable. Further research is needed to test this hypothesis.

Attention can also be drawn toward the opportunity cost (see Glossary) associated with selecting the immediate option [25], resulting in choice of the later/larger option. One such manipulation is the 'hidden-zero effect' [26,27]. Most experimental intertemporal choices are presented this way: "$10 today OR $22 in 30 days." However, one can also explicitly state the default outcomes associated with each choice: "$10 today and $0 in 30 days OR $0

today and $22 in 30 days." This 'explicit-zero' condition leads to reduced discounting, since seeing the default outcomes leads one to focus on the unpleasant future consequences of selecting the immediate reward [26]. This interpretation is reinforced by evidence showing that the subjective value of immediate rewards is significantly decreased with explicit-zero framing, but the subjective value of delayed rewards does not change [27]. A related study showed that using investment language increases patience [28]. If participants are told that the larger/later outcome is the result of an investment of the smaller/sooner option, they are more patient, presumably because this reminds them of the opportunity cost of impulsivity.

In sum, choices can be framed so that attention is drawn away from the magnitude of rewards, and toward the delay between rewards or the opportunity costs associated with the options. These differences in attention allocation lead to differences in decision-making.

Reference-dependence

Intertemporal choices can also be framed so that one option (either the smaller/sooner or larger/later reward) is considered the 'reference point' or 'default,' and so, individuals are biased to choose it. One essential discovery in behavioral economics was that risky choices are reference-dependent [1,29]. That is, individuals evaluate options based on whether they are perceived as a gain or loss relative to a reference point, and people dislike the prospect of a loss more than they like the prospect of a gain. This loss aversion is at the root of economic phenomena that previously seemed to be anomalies (such as the status quo bias, the endowment effect and the default bias [30]). Reference points most likely influence the allocation of attention to attributes, but in this section, we focus on how asymmetric processing of gains and losses can lead to changes in intertemporal choice as well.

The delay/speedup asymmetry effect, for example, exploits reference-dependent valuation in intertemporal choice [31]. When individuals are asked if they would prefer to receive an immediate reward now, or to wait to receive a larger reward later, they tend to be impulsive. On the other hand, if they are first given the option of receiving a future reward and then told that they could 'speed up' its delivery, they choose to be more patient. In the first, "delay" case, people perceive that they already have the immediate reward, so the loss of it looms larger than the potential gain of the delayed reward. In the "speedup" case, subjects perceive the delayed reward as being theirs, so they will want to keep it. Because loss aversion is a powerful motivator, it will take more money for an individual to give up the reward that is framed as the default, even if it is the delayed reward. This effect could also be accounted for by query theory [32,33]: the delay scenario invites people to think of reasons (i.e., 'query their memories') why they should 'keep' the immediate reward first, and the speedup scenario encourages people to think of why they should retain the delayed reward first. Indeed, forcing people to change the order of these thoughts can diminish reference-dependence [32].

Notably, a reference point can be manipulated even without explicit instruction or choice framing. In one study with hypothetical rewards, individuals were more patient when making decisions about a $500 delayed reward when they had just made choices about a $50 delayed reward, than if they had just made decisions about $5000 [34]. This is because

people exhibit more patience for larger rewards, and $500 appears larger following $50, than following $5000.

In a recent study, we found that it is not even necessary to change reward amounts to induce reference-dependence. Simply changing which reward value was more likely to change from trial-to-trial changed choices. When immediate rewards were relatively stable and delayed rewards were more variable, participants were more likely to select immediate rewards. Conversely, when immediate rewards were more variable, individuals were more patient [35]. This suggests that the more stable reward in the choice environment might be perceived as the default option, and people tend to choose it more often. It is possible that the primary mechanism behind reference-dependence in this case involves emotional arousal (Box 3). To explain these effects, it was proposed that reference points may be determined on the basis of expectations [36,37], which can be derived from the recent history of offers. If an outcome exceeds an expectation, it is perceived as a gain; if it is less than expected, it is seen as a loss. Thus, valuation can change if the experimenter simply controls the recent history of choices in the task. These results are especially relevant for interpreting findings from intertemporal choice tasks, but are less applicable to choices made in isolation.

All valuation is relative, and valuation in intertemporal choice is no exception. Intertemporal preferences appear to depend on a reference point, and this reference point can be altered through choice framing. Moreover, although this work is still in its infancy, recent history might contribute to the determination of a reference point as well.

Time construal

An obvious contributing factor to how much people value rewards in the future is their perception of the passage of time, and this can also be manipulated through framing. Individuals subjectively perceive time in a nonlinear manner [38]. Whereas the difference between 1 day from now and 10 days from now seems large, the difference between 10 years and 1 day from now and 10 years and 10 days from now seems small. This application of Weber's law to interval timing was formalized in scalar expectancy theory [39,40], and it has long been assumed that interval timing plays an integral role in hyperbolic discounting. Individuals who perceive time as more contracted are more patient [41], and neural activity during temporal judgment tasks predicts temporal discount rates [42]. It has also been shown that drug addicts, who exhibit very high discount rates, also have very short 'time perspectives': when thinking about the future, they tend to project themselves to times about 9 days from now, while healthy people think ahead to an average of 4.7 years from now [43] (for more about psychopathology and temporal discounting, see Box 4).

More pertinent for this review, however, is the idea that shifting one's time perception to make future events seem closer can lead to more patience. This can be achieved by framing future rewards as more concrete, or easier to imagine. This fluency of imagination leads people to believe that the reward is closer at hand, since near-future imagery is more detailed than far-future imagery. This notion is inspired by construal level theory (CLT [44]), an influential hypothesis that relates levels of abstraction in thought to the perception of temporal distance. In CLT, events and outcomes that are more distant are susceptible to "high-level construal," in which more abstract, essential features are emphasized. More

proximal outcomes are construed in “low-level” terms, which are more concrete and detailed. By encouraging low-level construal, then, it may be possible to make future outcomes seem nearer in time.

The perceived closeness of the future can be manipulated by changing the way that delays are described. People tend to use more fine-tuned descriptors of time (i.e., days instead of years) when an event is close. When individuals were prompted to use a fine-tuned metric of time (days) instead of a gross metric (months), they predicted that events would take place in the nearer future, and they estimated that preparation for the events should start sooner [45]. Individuals were also more likely to perceive an event as occurring sooner when the date was ‘like’ the current date (e.g., in the same year, “December 31st”) rather than unlike the current date (e.g., after the same amount of time but in the next year, “January 1st” [46]). Describing the future reward as occurring on a date (“May 1st”) instead of after an interval of time (“180 days”) leads to more patient choice, perhaps by making the delay to the event seem smaller [47–49]. The date/delay effect may not hold for shorter delays, however [48], because people tend to use interval descriptors for shorter delays; using dates when the reward is in the near future might actually make it seem more distant. By using knowledge about how delay descriptions change the perception of time, one can frame intertemporal choices so as to promote patient behavior.

In addition to changing how delays are described, providing a richer context for future rewards can also make them feel more within reach. For example, participants were more patient when they imagined spending a future reward in a particular place (e.g., “$45 in a pub in 30 days” [50]) compared to when they considered the future reward on its own. Making the future reward itself more concrete (e.g., pairing a Paris trip voucher with pictures of Paris) or the present reward more abstract also shifts preferences [51]. Finally, when individuals are shown computer-rendered images of their future selves during choice, they make more far-sighted choices, since this manipulation makes the far future easier to imagine [52].

The perceived amount of time until a future reward is obtained factors into intertemporal decisions. Increasing future reward concreteness or changing the way that delays are described can alter time perception. Although many of the above studies did not include a measurement of time perception, this is the likely mechanism by which these manipulations work.

Incidental carryover effects on intertemporal choice

In the previous section, we described how the framing of the choice itself can change choice, but intertemporal choices can also be influenced by events that occur before the choice and that are peripheral to the choice. We refer to these as ‘carryover’ effects, because they begin before the choice and carry over into the decision. We discuss two major kinds of incidental effects in this section – incidental affect and episodic future thinking.

Incidental affect

A great deal of research on emotion-cognition interactions has shown that experienced emotion can change subsequent choice, and that, conversely, regulating emotion can influence decisions as well ([53]; see Box 3). Thus, one's pre-existing affective state may influence intertemporal choice, even when the state is irrelevant to the choice [53]. These affective states can be induced through a variety of means in the laboratory. Here we will briefly discuss three: exposure to affective stimuli, mood and stress.

Several studies have shown that when individuals view positive affective images before intertemporal choice (e.g., erotic stimuli: [54,55]; attractive faces: [56]; desserts: [57]), they make more impulsive choices. Myopic decision-making might also occur following incidental exposure to negative affective stimuli [58], although the evidence is inconsistent [59], and the effects may depend on individual differences [60]. The mechanism by which affective stimuli alter valuation in this task is still unclear. One dominant theory is known as the appraisal tendency framework (ATF [61]). In this framework, specific affective states give rise to specific cognitive and motivational properties, and will elicit action tendencies that enable individuals to deal with the situation at hand [62]. Findings of mood studies are consistent with this framework. When sad mood is induced prior to intertemporal choice, people become more impulsive [63]. In particular, they become more inclined to choose immediate rewards, possibly in an attempt to seek immediate comfort. Meanwhile, gratitude – a positive emotional state – leads to more patience [64], perhaps because it is associated with a tendency to cooperate, which necessitates a future-oriented outlook.

Another incidental affective state that may influence choice is acute stress. Although stress hormones impact a number of brain regions related to decision-making [65], the effects of stress on intertemporal choice are inconsistent. One study found that individuals became more impulsive under stress [66], whereas another found that there were no effects [67], and yet another found that these effects depended on individual differences in perceived stress [68]. Therefore, the conditions under which stress influences intertemporal choice remains an open question.

In summary, incidental affective states can change intertemporal choice, but the effects are mixed, and likely depend on the specific properties of the affective state.

Episodic future thinking

In line with the idea that affect can flexibly alter choice, future-oriented affect can lead to more patient decision-making. Specifically, if positive episodic future thinking, or prospection, is triggered prior to choice, people make more far-sighted choices, even if the content of the future thought is unrelated to the reward being offered. In a number of studies, it has been shown that people make more patient choices after being reminded of likely positive future events [69–73]. The neural mechanism proposed for this effect involves an interaction between the neural circuits involved in prospection and the network involved in valuation [69,70].

Of course, there was an affective component inherent in the episodic future thought in these studies, since individuals only imagined positive future events. Therefore, it is unclear if this

manipulation works by making the future more concrete (and changing time construal) or by increasing positive affect related to the future. One study [74] found that both neutral and positive episodic future thinking led to decreased temporal discounting, contributing to the 'future concreteness' hypothesis, but another [75] showed that neutral future thinking did not change choice, and negative future thinking led to increased impulsivity, suggesting that affect plays an important role in this process. Yet another possibility is that increasing activity in neural regions involved in episodic thinking is sufficient to lead to more far-sighted choice, and the content of the thought is secondary.

Even though the precise mechanism by which episodic future thinking leads to more patience is unclear, this strategy is worthy of further research. This is especially true since prospection is an intervention that is not subjectively perceived to be effortful (unlike interventions that rely on executive control [76]).

Concluding remarks

Here we have identified two major classes of manipulations of intertemporal choices (see Figure 1, Key Figure). These decisions can be altered both by the way that the choice is framed and by the state of the decision-maker at the time of choice. The framing of the choice itself can lead people to differentially weigh the attributes of the options, by directing their attention toward the delay, the reward magnitudes or the opportunity costs associated with the options. Framing can also change the reference point for the choice, leading to biases in valuation of the smaller/sooner and later/larger rewards. Finally, the delay, which is unique to intertemporal choices, can be perceived as longer or shorter, depending on how the delay and the future reward are described.

These framing effects have implications for domains in which single choices are critical, such as in marketing strategy or investment decisions. For example, a person may be more likely to allocate money to retirement savings if their choice is framed in terms of 'date of retirement' rather than 'time until retirement.' Framing is less likely to influence intertemporal preferences within individuals in a domain-general or enduring manner. Nevertheless, being equipped with the knowledge of how framing effects operate can be powerful. An individual can change the way he/she appraises every choice, potentially culminating in substantial behavioral change.

Events that occur before the choice can also carry over to influence how intertemporal decisions are made. Incidental affective states, such as emotions, moods and stress, can influence choice, perhaps by changing the reference point, or by changing the allocation of attention to choice attributes. Episodic future thinking, on the other hand, might serve to change time construal during choice. The interplay between incidental effects and framing effects on intertemporal choice presents an avenue for future research (Outstanding Questions Box).

Unlike framing effects, the carryover effects described above are less relevant for manipulating one-time choices in domains like marketing. Outside of a controlled experimental setting, it is difficult to know an individual's pre-existing affective or cognitive state. However, if these carryover effects are robust, interventions based on them might be

used to change intertemporal preferences more generally, perhaps in clinical populations. For example, it may be feasible to train people to engage in prospection before intertemporal choice, so that they make more patient choices. This possibility remains to be tested.

Given the various context effects described here, it may seem like a daunting task to develop a unified model of intertemporal choice. However, theory can benefit from the predictability of these phenomena. Just as Kahneman and Tversky accounted for 'mistakes' in risky decision-making by proposing prospect theory, a general model of choice based on cognitive psychology and neuroscience should be able to explain state effects. After all, intertemporal choices are just special cases of the many multi-attribute choices that people face every day. Psychologists, neuroscientists and economists have made a great deal of progress toward describing how attributes are processed and integrated during decision-making. It is becoming clear that to the extent that context influences the processing of reward and time, it will influence intertemporal choice.

The predictability of many of these context effects is also advantageous for policymakers. Advances in the understanding of intertemporal choice can be used to 'nudge' individuals toward making more patient decisions [77]. These contextual influences can also be foundational for new training interventions to help individuals who show pathological choice behavior. Although there may be some stability to intertemporal preferences, they are also profoundly context-dependent. It is time to model them as such.

Acknowledgements

We would like to thank Paul Glimcher, Rebecca Schwarzlose (Editor of *Trends in Cognitive Sciences*), and two anonymous reviewers for helpful comments on earlier versions of this manuscript. This work was supported by funding from the National Institutes of Health (R01AG039283) awarded to E.A.P. and by an NSF Graduate Research Fellowship awarded to K.M.L.

Glossary

Default bias	a preference for the pre-determined default option offered
Endowment effect	the tendency for people to ascribe more value to items that they own
Mood	a diffuse, long-lasting affective state marked primarily by subjective feelings
Opportunity cost	the loss of potential gain from another alternative when one option is chosen
Status quo bias	a preference for the current state of affairs
Stress	an affective state marked by an increase in physiological arousal, glucocorticoid release and ratings of negative affect

References

1. Kahneman D, Tversky A. Prospect Theory: An Analysis of Decision under Risk. Econometrica. 1979; 47:263–292.

2. Simonson I, Tversky A. Choice in context: Tradeoff contrast and extremeness aversion. J. Mark. Res. 1992; 29:281–295.
3. Louie K, et al. Normalization is a general neural mechanism for context-dependent decision making. Proc. Natl. Acad. Sci. U. S. A. 2013; 110:6139–44. [PubMed: 23530203]
4. Louie, K.; De Martino, B. The Neurobiology of Context-Dependent Valuation and Choice. In: Glimcher, PW.; Fehr, E., editors. Neuroeconomics. Elsevier; 2014. p. 455-476.
5. Cox KM, Kable JW. BOLD subjective value signals exhibit robust range adaptation. J. Neurosci. 2014; 34:16533–43. [PubMed: 25471589]
6. Hardisty DJ, Weber EU. Discounting future green: money versus the environment. J. Exp. Psychol. Gen. 2009; 138:329–40. [PubMed: 19653793]
7. MacKillop J, et al. Delayed reward discounting and addictive behavior: A meta-analysis. Psychopharmacology (Berl). 2011; 216:305–321. [PubMed: 21373791]
8. Jarmolowicz DP, et al. Robust relation between temporal discounting rates and body mass. Appetite. 2014; 78:63–7. [PubMed: 24650831]
9. Albein-Urios N, et al. Monetary delay discounting in gambling and cocaine dependence with personality comorbidities. Addict. Behav. 2014; 39:1658–62. [PubMed: 25047890]
10. Kirby KN. One-year temporal stability of delay-discount rates. Psychon. Bull. Rev. 2009; 16:457–62. [PubMed: 19451368]
11. Odum AL. Delay Discounting: I'm a k, You're a k. J. Exp. Anal. Behav. 2011; 96:427–439. [PubMed: 22084499]
12. Odum AL. Delay discounting: trait variable? Behav. Processes. 2011; 87:1–9. [PubMed: 21385637]
13. Anokhin AP, et al. The Genetics of Impulsivity: Evidence for the Heritability of Delay Discounting. Biol. Psychiatry. 2014; 77:887–894. [PubMed: 25555481]
14. Mackillop J. Integrating behavioral economics and behavioral genetics: Delayed reward discounting as an endophenotype for addictive disorders. J. Exp. Anal. Behav. 2013; 99:14–31. [PubMed: 23344986]
15. Bickel WK. Discounting of Delayed Rewards as an Endophenotype. Biol. Psychiatry. 2015; 77:846–847. [PubMed: 25925716]
16. Bickel WK, et al. The behavioral- and neuro-economic process of temporal discounting: A candidate behavioral marker of addiction. Neuropharmacology. 2014; 76:518–27. [PubMed: 23806805]
17. Mischel W. Processes in Delay of Gratification. Adv. Exp. Soc. Psychol. 1974; 7:249–292.
18. Ohmura Y, et al. Discounting delayed and probabilistic monetary gains and losses by smokers of cigarettes. Psychopharmacology (Berl). 2005; 182:508–15. [PubMed: 16167142]
19. Vuchinich RE, Simpson CA. Hyperbolic temporal discounting in social drinkers and problem drinkers. Exp. Clin. Psychopharmacol. 1998; 6:292–305. [PubMed: 9725113]
20. Kirby KN, et al. Impatience and grades: Delay-discount rates correlate negatively with college GPA. Learn. Individ. Differ. 2005; 15:213–222.
21. Hayashi Y, et al. Texting while driving as impulsive choice: A behavioral economic analysis. Accid. Anal. Prev. 2015; 83:182–189. [PubMed: 26280804]
22. Ebert JEJ, Prelec D. The Fragility of Time: Time-Insensitivity and Valuation of the Near and Far Future. Manage. Sci. 2007; 53:1423–1438.
23. Ariely D, Loewenstein G. When does duration matter in judgment and decision making? J. Exp. Psychol. Gen. 2000; 129:508–23. [PubMed: 11142865]
24. Fassbender C, et al. The decimal effect: behavioral and neural bases for a novel influence on intertemporal choice in healthy individuals and in ADHD. J. Cogn. Neurosci. 2014; 26:2455–68. [PubMed: 24738767]
25. Zhao C-X, et al. The hidden opportunity cost of time effect on intertemporal choice. Front. Psychol. 2015; 6:311. [PubMed: 25870570]
26. Radu PT, et al. A Mechanism for Reducing Delay Discounting by Altering Temporal Attention. J. Exp. Anal. Behav. 2011; 96:363–385. [PubMed: 22084496]

27. Magen E, et al. Behavioral and neural correlates of increased self-control in the absence of increased willpower. Proc. Natl. Acad. Sci. U. S. A. 2014; 111:9786–9791. [PubMed: 24958892]
28. Read D, et al. DRIFT: An Analysis of Outcome Framing in Intertemporal Choice. J. Exp. Psychol. Learn. Mem. Cogn. 2012; 39:573–88. [PubMed: 22866891]
29. Kahneman D, Tversky A. Loss aversion in riskless choice: a reference dependent model. Q. J. Econ. 1991; 106:1039–1061.
30. Kahneman D, et al. Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias. J. Econ. Perspect. 1991; 5:193–206.
31. Loewenstein GF. Frames of Mind in Intertemporal Choice. Manage. Sci. 1988; 34:200–214.
32. Weber EU, et al. Asymmetric discounting in intertemporal choice: A query-theory account. Psychol. Sci. 2007; 18:516–523. [PubMed: 17576265]
33. Johnson EJ, et al. Aspects of endowment: a query theory of value construction. J. Exp. Psychol. Learn. Mem. Cogn. 2007; 33:461–474. [PubMed: 17470000]
34. Dai Z, et al. Reward contrast in delay and probability discounting. Learn. Behav. 2009; 37:281–8. [PubMed: 19542094]
35. Lempert KM, et al. Emotional Arousal and Discount Rate in Intertemporal Choice Are Reference Dependent. J. Exp. Psychol. Gen. 2015; 144:366–373. [PubMed: 25602754]
36. Köszegi B, Rabin M. A Model of Reference-Dependent Preferences. Q. J. Econ. 2006; 121:1133–1165.
37. Koszegi B, Rabin M. Reference-dependent risk attitudes. Am. Econ. Rev. 2007; 97:1047–1073.
38. Zauberman G, et al. Discounting Time and Time Discounting: Subjective Time Perception and Intertemporal Preferences. J. Mark. Res. 2009; 46:543–556.
39. Gibbon J, et al. Scalar expectancy theory and choice between delayed rewards. Psychol. Rev. 1988; 95:102–14. [PubMed: 3353474]
40. Gibbon J. Scalar expectancy theory and Weber's law in animal timing. Psychol. Rev. 1977; 84:279–325.
41. Kim BK, Zauberman G. Perception of anticipatory time in temporal discounting. J. Neurosci. Psychol. Econ. 2009; 2:91–101.
42. Cooper N, et al. Brain activity in valuation regions while thinking about the future predicts individual discount rates. J. Neurosci. 2013; 33:13150–6. [PubMed: 23926268]
43. Petry NM, et al. Shortened time horizons and insensitivity to future consequences in heroin addicts. Addiction. 1998; 93:729–738. [PubMed: 9692271]
44. Trope Y, Liberman N. Construal-level theory of psychological distance. Psychol. Rev. 2010; 117:440–463. [PubMed: 20438233]
45. Lewis NA, Oyserman D. When Does the Future Begin? Time Metrics Matter, Connecting Present and Future Selves. Psychol. Sci. 2015; 26:816–825. [PubMed: 25907059]
46. Tu Y, Soman D. The Categorization of Time and Its Impact on Task Initiation. J. Consum. Res. 2014; 41:810–822.
47. Read D, et al. Four Score and Seven Years from Now: The Date/Delay Effect in Temporal Discounting. Manage. Sci. 2005; 51:1326–1335.
48. LeBoeuf RA. Discount Rates for Time Versus Dates: The Sensitivity of Discounting to Time-Interval Description. J. Mark. Res. 2006; 43:59–72.
49. DeHart WB, Odum AL. The effects of the framing of time on delay discounting. J. Exp. Anal. Behav. 2015; 103:10–21. [PubMed: 25524395]
50. Benoit RG, et al. A neural mechanism mediating the impact of episodic prospection on farsighted decisions. J. Neurosci. 2011; 31:6771–6779. [PubMed: 21543607]
51. Kim H, et al. Similar psychological distance reduces temporal discounting. Pers. Soc. Psychol. Bull. 2013; 39:1005–16. [PubMed: 23653066]
52. Hershfield HE, et al. Increasing saving behavior through age-progressed renderings of the future self. J. Mark. Res. 2011; 48:S23–S37. [PubMed: 24634544]
53. Phelps EA, et al. Emotion and Decision Making: Multiple Modulatory Neural Circuits. Annu. Rev. Neurosci. 2014; 37:263–290. [PubMed: 24905597]

54. Van den Bergh B, et al. Bikinis Instigate Generalized Impatience in Intertemporal Choice. J. Consum. Res. 2008; 35:85–97.
55. Kim BK, Zauberman G. Can Victoria's Secret Change the Future? A Subjective Time Perception Account of Sexual-Cue Effects on Impatience. J. Exp. Psychol. Gen. 2012; 142:328–335. [PubMed: 22686639]
56. Wilson M, Daly M. Do pretty women inspire men to discount the future? Proc. R. Soc. B Biol. Sci. 2004; 271(Suppl):S177–9.
57. Li X. The Effects of Appetitive Stimuli on Out of Domain Consumption Impatience. J. Consum. Res. 2008; 34:649–656.
58. Guan S, et al. Myopic decisions under negative emotions correlate with altered time perception. Front. Psychol. 2015; 6:468. [PubMed: 25941508]
59. Luo S, et al. The behavioral and neural effect of emotional primes on intertemporal decisions. Soc. Cogn. Affect. Neurosci. 2014; 9:283–91. [PubMed: 23160811]
60. Augustine AA, Larsen RJ. Affect regulation and temporal discounting: Interactions between primed, state, and trait affect. Emotion. 2011; 11:403–412. [PubMed: 21500908]
61. Lerner JS, Keltner D. Beyond valence: Toward a model of emotion-specific influences on judgement and choice. Cogn. Emot. 2000; 14:473–493.
62. Frijda, NH. The Emotions. Cambridge University Press; 1986.
63. Lerner JS, et al. The financial costs of sadness. Psychol. Sci. 2013; 24:72–9. [PubMed: 23150274]
64. DeSteno D, et al. Gratitude: a tool for reducing economic impatience. Psychol. Sci. 2014; 25:1262–7. [PubMed: 24760144]
65. Arnsten AFT. Stress signalling pathways that impair prefrontal cortex structure and function. Nat. Rev. Neurosci. 2009; 10:410–422. [PubMed: 19455173]
66. Kimura K, et al. The biological effects of acute psychosocial stress on delay discounting. Psychoneuroendocrinology. 2013; 38:2300–8. [PubMed: 23768971]
67. Haushofer J, et al. No effects of psychosocial stress on intertemporal choice. PLoS One. 2013; 8:e78597. [PubMed: 24250800]
68. Lempert KM, et al. Individual differences in delay discounting under acute stress: The role of trait perceived stress. Front. Psychol. 2012; 3:251. [PubMed: 22833731]
69. Sasse LK, et al. Effects of prospective thinking on intertemporal choice: The role of familiarity. Hum. Brain Mapp. 2015 DOI: 10.1002/hbm.22912.
70. Peters J, Büchel C. Episodic Future Thinking Reduces Reward Delay Discounting through an Enhancement of Prefrontal-Mediotemporal Interactions. Neuron. 2010; 66:138–148. [PubMed: 20399735]
71. Palombo DJ, et al. The medial temporal lobes are critical for reward-based decision making under conditions that promote episodic future thinking. Hippocampus. 2015; 25:345–53. [PubMed: 25284804]
72. Kwan D, et al. Cueing the personal future to reduce discounting in intertemporal choice: Is episodic prospection necessary? Hippocampus. 2015; 25:432–43. [PubMed: 25676022]
73. Daniel TO, et al. Episodic future thinking reduces delay discounting and energy intake in children. Eat. Behav. 2015; 18:20–24. [PubMed: 25863227]
74. Lin H, Epstein LH. Living in the moment: effects of time perspective and emotional valence of episodic thinking on delay discounting. Behav. Neurosci. 2014; 128:12–9. [PubMed: 24512061]
75. Liu L, et al. The value of emotion: How does episodic prospection modulate delay discounting? PLoS One. 2013; 8:e81717. [PubMed: 24312341]
76. Bickel WK, et al. Remember the future: working memory training decreases delay discounting among stimulant addicts. Biol. Psychiatry. 2011; 69:260–5. [PubMed: 20965498]
77. Thaler RH, Sunstein CR. Libertarian Paternalism. Am. Econ. Rev. 2003; 67:420.
78. Strotz RH. Myopia and Inconsistency in Dynamic Utility Maximization. Rev. Econ. Stud. 1956; 23:165–180.
79. Andersen S, et al. Discounting behavior: A reconsideration. Eur. Econ. Rev. 2014; 71:15–33.
80. Andersen S, et al. Eliciting Risk and Time Preferences. Econometrica. 2008; 76:583–618.

81. Thaler R. Some empirical evidence on dynamic inconsistency. Econ. Lett. 1981; 8:201–207.
82. Laibson D. Golden eggs and hyperbolic discounting. Q. J. Econ. 1997; 112:443–478.
83. Rubinstein A. “Economics and psychology”? The case of hyperbolic discounting. Int. Econ. Rev. (Philadelphia). 2003; 44:1207–1216.
84. Marzilli Ericson KM, et al. Money Earlier or Later? Simple Heuristics Explain Intertemporal Choices Better Than Delay Discounting Does. Psychol. Sci. 2015; 26:826–33. [PubMed: 25911124]
85. Tversky A. Choice by elimination. J. Math. Psychol. 1972; 9:341–367.
86. Van den Bos W, McClure SM. Towards a general model of temporal discounting. J. Exp. Anal. Behav. 2013; 99:58–73. [PubMed: 23344988]
87. Pine A, et al. Encoding of marginal utility across time in the human brain. J. Neurosci. 2009; 29:9575–81. [PubMed: 19641120]
88. Green L, et al. Rate of temporal discounting decreases with amount of reward. Mem. Cognit. 1997; 25:715–723.
89. Estle SJ, et al. Discounting of monetary and directly consumable rewards. Psychol. Sci. 2007; 18:58–63. [PubMed: 17362379]
90. Odum AL, Rainaud CP. Discounting of delayed hypothetical money, alcohol, and food. Behav. Processes. 2003; 64:305–313. [PubMed: 14580700]
91. Paglieri F, et al. Is it patience or motivation? On motivational confounds in intertemporal choice tasks. J. Exp. Anal. Behav. 2015; 103:196–217. [PubMed: 25545635]
92. McClure SM, et al. Separate neural systems value immediate and delayed monetary rewards. Science (80-.). 2004; 306:503–7.
93. Metcalfe J, Mischel W. A hot/cool-system analysis of delay of gratification: dynamics of willpower. Psychol. Rev. 1999; 106:3–19. [PubMed: 10197361]
94. Bradley MM, et al. The pupil as a measure of emotional arousal and autonomic activation. Psychophysiology. 2008; 45:602–7. [PubMed: 18282202]
95. Sokol-Hessner P, et al. Thinking like a trader selectively reduces individuals’ loss aversion. Proc. Natl. Acad. Sci. U. S. A. 2009; 106:5035–5040. [PubMed: 19289824]
96. Sokol-Hessner P, et al. Emotion regulation reduces loss aversion and decreases amygdala responses to losses. Soc. Cogn. Affect. Neurosci. 2013; 8:341–350. [PubMed: 22275168]
97. Sokol-Hessner P, et al. Determinants of Propranolol’s Selective Effect on Loss Aversion. Psychol. Sci. 2015; 26:1123–30. [PubMed: 26063441]
98. Sharot T, et al. Neural mechanisms mediating optimism bias. Nature. 2007; 450:102–5. [PubMed: 17960136]
99. Scheres A, et al. Temporal reward discounting and ADHD: Task and symptom specific effects. J. Neural Transm. 2008; 115:221–226. [PubMed: 17876680]
100. Heerey EA, et al. Delay discounting in schizophrenia. Cogn. Neuropsychiatry. 2007; 12:213–221. [PubMed: 17453902]
101. Steinglass JE, et al. Increased Capacity to Delay Reward in Anorexia Nervosa. J. Int. Neuropsychol. Soc. 2012; 18:773–780. [PubMed: 22591835]
102. Pinto A, et al. Capacity to delay reward differentiates obsessive-compulsive disorder and obsessive-compulsive personality disorder. Biol. Psychiatry. 2014; 75:653–659. [PubMed: 24199665]
103. Ritschel F, et al. Temporal delay discounting in acutely ill and weight-recovered patients with anorexia nervosa. Psychol. Med. 2015; 45:1229–39. [PubMed: 25579471]
104. Dixon MR, et al. Contextual control of delay discounting by pathological gamblers. J. Appl. Behav. Anal. 2006; 39:413–22. [PubMed: 17236338]
105. Giordano LA, et al. Mild opioid deprivation increases the degree that opioid-dependent outpatients discount delayed heroin and money. Psychopharmacology (Berl). 2002; 163:174–82. [PubMed: 12202964]
106. Yi R, Landes RD. Temporal and probability discounting by cigarette smokers following acute smoking abstinence. Nicotine Tob. Res. 2012; 14:547–58. [PubMed: 22311959]

107. Roewer I, et al. Nicotine deprivation, temporal discounting and choice consistency in heavy smokers. J. Exp. Anal. Behav. 2015; 103:62–76. [PubMed: 25641080]

108. Decker JH, et al. On Weight and Waiting: Delay Discounting in Anorexia Nervosa Pretreatment and Posttreatment. Biol. Psychiatry. 2014 DOI: 10.1016/j.biopsych.2014.12.016.

109. Landes RD, et al. Delay discounting decreases in those completing treatment for opioid dependence. Exp. Clin. Psychopharmacol. 2012; 20:302–9. [PubMed: 22369670]

110. Morrison KL, et al. Altering impulsive decision making with an acceptance-based procedure. Behav. Ther. 2014; 45:630–9. [PubMed: 25022774]

111. Dennhardt AA, et al. Change in delay discounting and substance reward value following a brief alcohol and drug use intervention. J. Exp. Anal. Behav. 2015; 103:125–40. [PubMed: 25533393]

Box 1

Modeling intertemporal choice

Discounted utility functions, in which the value of rewards decreases with the delay to receiving them, have existed in economics for centuries. However, in the last quarter of the twentieth century, numerous experiments showed that people do not discount future rewards at a constant rate. That is, rather than being exponential, discounting functions are hyperbolic ([78] although this is debated in economics: see [79,80]). People treat the near and far future differently – they are more impulsive for goods that will arrive soon and more patient when both outcomes will arrive later [81]. This sort of 'preference reversal' is the main justification behind the widespread adoption by psychologists of the hyperbolic model, in which there is one discount rate parameter (often referred to as k). Although this model is commonly used in psychology, other functional forms have also been developed, the most prominent of which in economics is the quasi-hyperbolic model [82]. In this model, the difference in intertemporal preferences between the near and far future is accounted for by two parameters (i.e., β and δ).

Although the hyperbolic model has been very useful for characterizing behavior in intertemporal choice tasks, it has limited predictive power in various contexts [83]. Therefore, the general trend is toward using more heuristic-based models (such as similarity-based models [83], ITCH [84] and DRIFT [28]). In similarity-based models, when two options are similar in one attribute (e.g., time), the other attribute will be weighed more heavily in the decision [83]. ITCH, the Intertemporal Choice Heuristic model, builds on this principle, and proposes that people decide by computing a weighted sum of four variables: the absolute and relative differences in magnitude between options, and the absolute and relative differences in time between options. The DRIFT, or Difference-Ratio-Interest-Finance-Time, model does not include relative comparisons, but it accounts for more patient choice when a decision is framed as an investment. These heuristic models are powerful because they rely on well-documented psychological principles, such as reference-dependence [1] and attribute-level comparison [85]. They also include weighting parameters for different variables, so they can potentially explain context effects due to attentional shifts.

Finally, models based on neuroscience are on the horizon [86]. The neural processing of any choice begins with option representation, followed by valuation, followed by action selection. Learning how intertemporal decisions are influenced at each of these stages can result in a deeper understanding of this decision process.

Box 2

Disentangling value and discount functions

In most experiments discussed in this review, it is assumed that the subjective value of a reward increases linearly as a function of its amount (e.g., $20 is subjectively worth twice as much as $10). This is an oversimplification, however, since it has been demonstrated that subjective value is a nonlinear (concave) function of objective amount. Without modeling value and discounting functions separately (e.g., as in [87]), it is difficult to know if contextual factors change the value of rewards, the rate at which future rewards are discounted, or both.

Discount rates have been shown to shift, for example, when both options offered increase or decrease in value. In a phenomenon known as the 'magnitude effect,' when the amounts of the rewards offered are larger, people tend to be more patient [88]. For instance, many people would take $10 today instead of $20 tomorrow, but their choice would reverse if the immediate amount were $1,000 and the delayed amount $2,000. The magnitude effect can be explained without reference to discounting, but simply by considering that value functions for delayed rewards may be steeper than those for immediate rewards. That is, the difference between $10 today and $10,000 today is perceived as smaller than the difference between $10 in a year and $10,000 in a year. Along these lines, the cost of waiting when the amounts are smaller (i.e., wait one day for $10 more) is larger than the cost of waiting when the amounts are larger (i.e., wait one day for $1000 more), so reward magnitude also influences the value of the waiting period.

This same reasoning can also account for differences in discount rate among good types. In general, discount rates for consumable goods, such as food and drugs, tend to be higher than discount rates for money [89,90]. This might be because money is exchangeable for many different kinds of goods, and the motivation to maximize it is higher [91]. Moreover, an individual's physical state (e.g., hunger) contributes to the valuation of consumable goods, and this state fluctuates over time. In contrast, appreciating future monetary rewards is less likely to depend on predicting future physical states [89]. In sum, the subjective value of the rewards being considered is an important factor for assessing and interpreting differences in discount rate.

Box 3

The role of emotion in intertemporal choice

It is often assumed that emotion leads us to choose smaller, sooner rewards at our long-term expense. One influential model proposes that intertemporal choices are the output of a competition between two systems: an impulsive, emotional, 'hot' system and a patient, deliberative, 'cool' system, that each have their own neural substrate [92,93]. Although this claim has some intuitive appeal, it has not been substantiated, since few studies have measured or manipulated emotional variables during intertemporal choice.

In the same study in which we showed that intertemporal choices are reference-dependent [35], we measured pupil dilation. Pupil dilation, like skin conductance, is a nonspecific measure of arousal, including arousal in response to emotional stimuli [94]. We found that arousal did not reliably correlate with the subjective value of either immediate or delayed rewards, but rather, this relationship varied depending on the structure of the choice set. Arousal increased when the more variable reward in the paradigm was better than expected, whether the more variable reward was immediate or delayed [35]. Importantly, this response was positively valenced, consistent with the interpretation that it was an emotional response, and not simply a reaction to novelty or surprise. This finding suggests that arousal, one important component of emotion, has a nuanced role in this decision process. It is possible that arousal may be directly linked to reference-dependent choice. Indeed, there are studies from the domain of risky choice that suggest that this might be the case [95–97].

Further support for the idea that both immediate and delayed rewards elicit emotional responses that influence choice comes from studies investigating how increasing the emotional salience of delayed rewards increases patience. Manipulating the mental representation of a future reward to make it more concrete can change its emotional intensity and the choice. When participants were asked to imagine specific ways that they could spend future rewards, they rated those rewards as more emotionally intense and they were more likely to choose delayed rewards [50]. Furthermore, this manipulation engaged neural regions known to be involved in the future projection of personal events and their modulation by emotion [98].

Emotion is multidimensional, and it has become clear that a two-system framework, in which the role of emotion is to lead us to choose immediate rewards, is too simplistic. The emerging science suggests instead that emotion can contribute to valuation of both immediate and delayed rewards, depending on contextual factors.

Box 4

Interventions to change temporal discounting in psychopathology

Several psychiatric disorders are associated with aberrant temporal discounting. For example, people suffering from drug addiction [7], attention deficit/hyperactivity disorder [99], schizophrenia [100] and pathological gambling [9] demonstrate consistently high discount rates. On the other hand, individuals with anorexia and obsessive-compulsive personality disorder have been shown to have low discount rates compared to healthy controls ([101,102] but see [103]). Context influences discount rate within these disorders as well. Gamblers discount future rewards more in a gambling context [104]. Opioid-dependent individuals deprived of opiates discount at a greater rate [105], as do nicotine-deprived individuals ([106] but see [107]). Encouragingly, treatment may shift discount rates as well – for example, inpatient treatment for anorexia increases impulsivity [108], inpatient treatment for opiate users increases patience [109], and working memory training increases patience in cigarette smokers [76]. Mindfulness-based [110] and motivational-based interventions [111] may also work to decrease discounting. However, there is scant evidence demonstrating that changes in temporal discounting mediate the effects of treatment on recovery. Still, translating some of the manipulations described here into longer-lasting training interventions may hold some promise for psychiatry.

Outstanding Questions Box

- How well do the context effects described here translate to real-world decisions?
- How can we leverage these manipulations to help individuals with psychiatric disorders?
- Are some manipulations more effective in changing discount rate than others?
- What are the limits of context effects in intertemporal choice? Do people have a 'true' discount rate that is only subtly modulated by situational factors, or can one go from impulsive to patient simply by changing the context?
- Can we use susceptibility to context effects as an individual difference variable to learn more about how people recruit different mechanisms to make decisions?
- How long lasting are incidental effects on intertemporal choice? That is, how long after an incidental state is induced will choices be influenced by it?
- How do framing effects and incidental effects interact? What are the mechanisms by which incidental states influence choice (through changing attention, reference points, and/or time construal)? How can we harness behavioral and neuroscience techniques to investigate these questions?
- Are the context effects described here unique to intertemporal choices, or common to all decisions? To what extent do these manipulations shift the discount rate specifically, and to what extent are they shifting other choice variables, such as the way that monetary rewards are valued?
- Given that there is asymmetry in the maturation of different neural systems involved in decision-making, how do context effects change throughout development? Relatedly, will these malleability manipulations be as effective, or more effective, in children, adolescents and older adults?
- Through what mechanisms do social factors influence intertemporal choice? Social influences on intertemporal choice have been relatively underexplored, but there is a burgeoning literature suggesting that input from social others can influence decision-making.

Trends

- Intertemporal choices are decisions between outcomes realized at different points in time. They are prevalent and often consequential.
- While intertemporal preferences are generally thought to be stable, contextual manipulations can shift people's choices toward being more patient or impulsive.
- These manipulations fall into two broad categories: framing effects, in which the way a choice is described influences choice, and incidental effects, in which a pre-existing state modifies subsequent decisions.
- The mechanisms by which context effects operate are based on psychological principles and concepts, such as attention, reference-dependence, time construal, affect, and prospection. Knowledge of these context effects might be used to design interventions and to improve models of intertemporal choice.

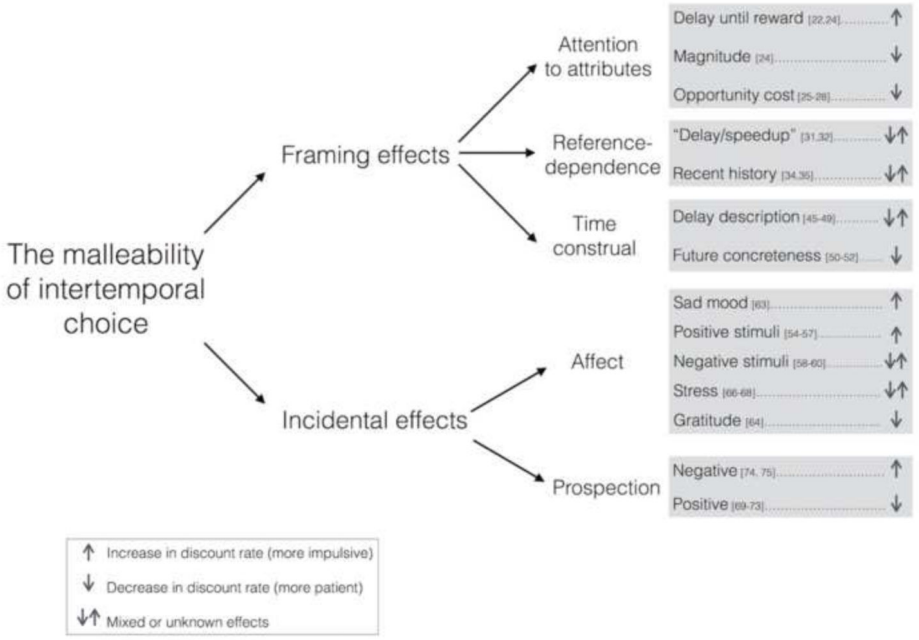

Figure 1.

Two primary means by which context influences intertemporal choice. Individuals can be more impulsive or patient depending on the way that choices are framed (framing effects) or on the decision-maker's current state (incidental effects). Major manipulations summarized in this review are presented with respect to whether they increase discount rate, decrease discount rate, or have mixed or inconsistent effects.