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Literature Review

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Delay Discounting

Delay discounting, also known as time discounting or temporal discounting, is a procedure which involves asking participants whether they would prefer an immediate reward now, or a larger reward at a later time. When participants choose the smaller but sooner reward over the larger but later reward, this indicates that participants discount the value of the rewards because of time. The difference in how participants value reward over time then makes for interesting comparisons about peoples' behavior. Because delay discounting, can be used as an indicator as how rapidly a reward loses value over temporal distance and as an index of ability to delay gratification, delay discount rates can roughly be seen as an estimate of how impulsive or patient a participant is, and as such, has been linked with various impulsive behaviors such as smoking, or binge drinking (MacKillop et al., 2011). The link behavior and delay discounting will be discussed in depth in a subsequent section.

Delay discounting in humans is mostly done with a series of hypothetical[1] binary monetary choices or via a matching method. The binary choices method may have participants answering an assortment of questions about whether they would $10 now or $30 in one month. The matching method would ask a question such as "how many dollars could in one month would make you indifferent to $10 today?" Each of these methods are then converted to a discount rate using a number of different methods described in more detail in the subsequent

[1] Previous literature regarding delay discounting found no difference between hypothetical rewards and actual rewards, although most of this work has been confined to small amounts (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003)

section. Previous research on the matching method and the binary choice method has tested both methods in a within-subjects designs and found that the matching method yielded lower discount rates than binary choices possibly because binary choices creates demand characteristics that make subjects feel like they *need* to discount (Read & Roelofsma, 2003). Because of how flexible the framework for using delay discounting is, delay discounting has been used in a wide variety of situations including animal subjects (pigeons deciding how long to wait for larger but later amounts of food; rats waiting for more water (Green et al., 2007)), and hedonistic items (e.g. 1 cigarette now or 2 cigarettes in an hour).

In this paper we will use the binary choice method as it has been shown to be easier for participants to understand and to be better at predicting behavior (Hardisty et al., 2011). We will hold the delayed the constant reward constant (known as a fixed delayed reward) and ask about a series of ascending[2] immediate rewards (or in some cases payments) (e.g. $10 now or $30 in one month; $12 now or $30 in one month; etc.). The point at which subjects switch from sooner rewards to later rewards (or vice versa), is the point at which the subject sees the rewards of being roughly equal in value (so if someone prefers $30 in a month to $10 now, but $12 now to $30 later, we can think of their switch point as approximately $11). This is known as *the indifference point*. Subjects who answer the questions in an inconsistent fashion (i.e. without clear indifference points), are most commonly excluded from analysis, although in this paper we will also include these subjects in a measure of how often subjects choose the later but larger choices.

Calculating Discount Rates

[2] Some previous research has indicated that ascending choice order has been shown to affect discount rates in a way that makes subjects appear less patient, but for the most part, that is beyond the scope of this paper (Hardisty et al., 2011).

Delay discount rates are then most commonly assessed in two ways. The first way, is as a hyperbolic discounting measure given by the equation $V = A / (1 + kd)$, where V is the indifference point or subjective value, A is the delayed reward, k is the free parameter that estimates discount rate (i.e increases in k indicate more impulsivity, and a k value of 0 indicates that the subject values the future and present exactly the same), and d is the delay. The alternative approach of quantifying delay discounting is the area under the curve (AUC) method which is atheoretical (Myerson, Green, & Warusawitharana, 2001). To calculate AUC all the delays and indifference points are normalized by expressing them as a proportion of the maximum value. Each delay and indifference point pair are compared in the equation, $x_2 - x_1 [(y_1 + y_2)/2]$, where x_1 and x_2 are successive delays and y_1 and y_2 are the indifference points associated with those delays. Because I am using a fixed delayed reward, and a single time delay, a full-fledged AUC measure is not viable. Instead I will use a nonparametric adapted version where I simply normalize the indifference points, creating a measure ranging between 0 and 1 where 0 indicates no patience at all and 1 indicates absolute patience (Bartels & Urminsky, 2011).

There is a third way to assess discounting although it is less common than the previous two methods. The third method is called the quasi-hyperbolic method (Laibson, 1997). This method distinguishes consistency of discounting from level of discounting by assuming a higher discount factor (β) in the first period, but a constant discount factor for subsequent periods (δ) (Urminsky & Zauberman, 2014). In other words, β can be thought of as a measure of present bias, while σ can be thought of as the long run discount factor (Urminsky & Zauberman, 2014). In this paper delta will be calculated as $\delta = (V_2/A)^{\wedge(1/6)}$ where V_2 is the later indifference point, and A is the larger but later amount, and $\beta = (V_1/A)*(1/\delta^{\wedge 5})$ where V_1 is the sooner indifference point.

Delay Discounting, Behavior & Demographics

Delay discounting has been linked to a wide range of behaviors although some of these relationships have been linked more strongly than others. For example, previous research demographic variables such as gender (c.f. Jarmolowicz et al., 2014; Weller, Cook, Avsar, & Cox, 2008) and age (Buono, Whiting, & Sprong, 2015; Stoeckel, Murdaugh, Cox, Cook, & Weller, 2013) have generally returned mixed or inconclusive results. However, in domains like cognition, delay discounting seems to be well associated. A large scale meta-analysis has linked delay discounting to intelligence and being cognizant during decision making in trick math questions (Shamosh & Gray, 2008; Frederick, 2005).

Furthermore, there have also been a lot of studies relating delay discounting with health-related behaviors. Other large scale meta-analysis have found significant relations between delay discounting and BMI (Amlung, Petker, Jackson, Balodis, & MacKillop, 2016; Emery & Levine, 2017) exercise (Sweeney & Culcea, 2017), and addictive behaviors such as smoking, drinking, and drug use (Amlung, Vedelago, Acker, Balodis, & MacKillop, 2017; MacKillop et al., 2011). There is a link between delay discounting and credit card borrowing and FICO scores as well (Meier & Sprenger, 2010; Meier & Sprenger, 2012).

Lastly, there have been a large amount of "one-off" type studies which have found a significant effect in delay discounting and a behavior in a domain less commonly looked at. These include voting (Fowler & Kam, 2006), finishing your prescription (Chabris et al., 2008), dental status (Kang & Ikeda, 2015). These are effects worth further looking into in future research.

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