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ORIGINAL PAPER

Measuring Sexual Risk-Taking: A Systematic Review of the Sexual Delay Discounting Task

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Abstract

The Sexual Delay Discounting Task (SDDT; Johnson & Bruner, 2012) is a behavioral economic task that assesses sexual risk-taking by measuring likelihood of immediate and delayed condom use. The SDDT is ecologically valid and has been used to test effects of various substances on sexual risk-taking. However, considerable variety in implementation, analysis, and reporting of the SDDT may limit rigor and reproducibility of findings. The current review synthesized studies that used the SDDT to evaluate these possible variabilities systematically. A two-step search (citation-tracking and keyword-based search) was conducted to identify studies that met inclusion criteria (i.e., used the SDDT). Eighteen peer-reviewed articles met inclusion criteria. The SDDT has been implemented primarily in three populations: individuals who use cocaine, men who have sex with men, and college students. Comparable results across diverse populations support the SDDT's validity. A few studies administered substances before the SDDT. Evidence suggests that while cocaine and alcohol increased sexual risk-taking under some conditions, buspirone decreased preference for immediate condomless sex. There was also heterogeneity in the determination of data orderliness (i.e., outliers) and inconsistent reporting of task design and analysis. Considerable differences present in methodologic approaches could influence results. Reducing variation in the administration, analysis, and reporting of the SDDT will enhance rigor and reproducibility and maximize the task's tremendous potential.

Keywords Behavioral economics · Delay discounting · Impulsivity · Condom use · HIV · Sexual risk-taking

Introduction

Condoms, when used properly, are one of the most effective preventive measures against spreading HIV and sexual transmitted infections (STIs; Holmes et al., 2004; Weller & Davis-Beaty 2002). However, condoms are not always used consistently (Paz-Bailey et al., 2016; Smith et al., 2015). Thus, it is important to understand behavioral determinants of sexual risk-taking, particularly around condom use, to reduce the spread of HIV and other STIs, along with their associated burdens. Delay discounting is one potential mechanism underlying sexual risk behaviors like condomless sex.

Delay discounting describes the decrease in subjective value of a consequence with increased time to experiencing that consequence (Ainslie 1975; Mazur et al., 1987). Delay discounting measures in humans have been based predominantly on hypothetical monetary rewards. In delay discounting tasks, participants usually choose between money that is immediately available, but smaller in value versus money that is available later, but is larger in value (Odum 2011). These tasks have been used to identify behavior processes related to issues of public health significance; for instance, people who use drugs consistently show steeper monetary delay discounting (i.e., preferences for immediate, smaller amounts) when compared to matched controls. This is true among people who use nicotine/tobacco, cocaine, methamphetamine,

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opioids, and alcohol (e.g., Baker et al., 2003; Heil et al., 2006; Hoffman et al., 2006; Johnson et al., 2007; Kirby et al., 1999; Madden et al., 1997; Mitchell et al., 2005; Petry 2001).

Recent evidence has demonstrated the domain specificity of delay discounting, where stronger relations are observed between delay discounting and a variety of clinically relevant outcomes when the task measures discounting of outcome-relevant stimuli rather than hypothetical money (e.g., Johnson & Bruner, 2012; Lawyer & Schoepflin, 2013). For example, evidence shows that individuals' percent body fat was more strongly related to delay discounting for hypothetical food (i.e., 10 bites of their favorite food available after various delays versus a smaller number of bites available immediately) than to hypothetical money (i.e., $10 available after various delays or a smaller amount of money available immediately; Rasmussen et al., 2010). Sexual decision-making is another example of domain-specificity observed in delay discounting with clinically relevant behaviors. Johnson and Bruner (2012) showed that delay discounting of sexual outcomes was more strongly related to self-reported sexual risk behavior than hypothetical monetary discounting. Johnson et al. (2017) also showed that cocaine administration dose-dependently decreased likelihood of immediate condom use, but cocaine had no effect on monetary discounting (see also, Johnson et al., 2016 for similar results involving alcohol administration). Taken together, these findings suggest greater sensitivity of delay discounting to clinically meaningful variables, and the importance of assessing discounting of outcomes other than hypothetical money.

Sexual discounting, which examines episodic-level (i.e., event level) sexual risk, has been measured in multiple ways. The wide array of tasks used to measure sexual discounting was discussed in a recent systematic review (Johnson et al., 2021). The Johnson et al. review synthesized findings from studies that measured delay discounting of sex (e.g., Holt et al., 2014), probability of sex (e.g., Jarmolowicz et al., 2015; Lemley et al., 2018), and relations between monetary and sexual delay discounting (Johnson et al., 2021). In contrast, the current review focused exclusively on relevant methodological dimensions (e.g., details about vignettes, delays used, how nonsystematic data are addressed) of the most widely used sexual discounting task: the Sexual Delay Discounting Task (SDDT; Johnson & Bruner, 2012).

The SDDT is a highly promising quantitative measure of an important sexual behavior (i.e., likelihood of condom use), and has received substantial attention in its initial decade of existence. Given its role as a transdiagnostic process underlying many psychiatric disorders (Amlung et al., 2019), research measuring delay discounting will likely continue to proliferate. Further, there is a growing understanding of the value of domain-specific, clinically relevant measures of discounting such as the SDDT. Thus, an important goal of the present review was to highlight the merits of the SDDT, explore the different ways the task is implemented, consider implications of these methodologic variations, and recommend best methodological practices. These methodologic heterogeneities may, in turn, lead to heterogeneity in the findings the task yields. By highlighting these variabilities, the ultimate aim of the current review is to ensure that the science concerning sexual delay discounting going forward is of the highest possible quality. Refining measurement of sexual delay discounting will help to improve the reliability and validity of the task and advance reproducibility efforts.

In Johnson and Bruner's (2012) SDDT, participants were shown pictures of several individuals and asked to select those they would consider having hypothetical casual sex with, based primarily on physical appearance. Participants were further instructed to assume that they are not in a committed relationship, they like the partner's personality, the partner is also interested in casual sex, and they were in the right environment, with no chance of pregnancy. Participants were instructed to select four individuals: persons they (1) most and (2) least want to have sex with (i.e., desirable), as well as persons they perceive (3) most and (4) least likely to have HIV/STIs. Participants were then asked a series of eight questions for each of those four partners, one at a time. The questions are presented as visual analog scales ranging from "0 percent" ("I will definitely have sex with this person now without a condom") to "100 percent" ("I will definitely have sex with this person now with a condom"). The first question measures the participant's overall likelihood of using an immediately available condom (i.e., zero-delay trial). This was followed by seven questions, which keep the "0 percent" statement as is and change the "100 percent" statement to add delays (i.e., "I will definitely wait [delay] to have sex with this person with a condom."). The delays presented in the original study were in an ascending order: 1 h, 3 h, 6 h, 1 day, 1 week, 1 month, and 3 months. These delay questions assess individuals' reported likelihood of waiting for condom-protected sex versus having immediate, condomless sex – positing delayed and protected sex, as well as an HIV/STI-free and a healthy future self, as an implicit, larger later reward.

While Johnson and Bruner (2012) of the original task provided a detailed report of the methods implemented in their investigations, there are notable variations in the studies that have since used the task, including in the delays, vignettes, and analyses used. Given the increasing usage and potential future utility of the SDDT to understand mechanisms underlying sexual risk behavior and decision-making, a methodological review and synthesis is warranted to facilitate comparisons across the literature. Lack of clear standards in implementing this type of task, or variability in administration of the SDDT, data analytic approaches, or lack of complete, transparent reporting of the results may result in replication difficulty or preclude comparisons across studies. Systematic reviews that describe the methodological

approaches used with other hypothetical behavioral tasks like the SDDT have been valuable in advancing the behavioral economics literature regarding risky behaviors (see Kaplan et al., 2018; Reed et al., 2020 for methodological reviews of alcohol and cigarette purchase tasks; respectively). A lack of clear understanding of factors that affect performance on the SDDT could, in the long run, limit future use of the SDDT as a tool for identification of at-risk individuals and intervention targets. Understanding these mechanisms and the relative contribution of delay discounting to sexual risk behavior is critical to developing and identifying efficacious interventions (e.g., Weatherly et al., 2015). The purpose of this systematic review, therefore, was to catalog and describe methods and reported findings from studies that utilized the SDDT and examine implications of the different approaches used.

Method

Search Methods for Identification of Studies

To ensure comprehensive retrieval of studies that have utilized the SDDT, two types of searches were conducted. The first was a citation-tracking search conducted on 5/15/2019, using Google Scholar, Web of Science, Research Gate, and PubMed Central's citation-tracking features to retrieve publications that cited the Johnson and Bruner (2012) article. The second was a more traditional subject-based search of PubMed, CINAHL (EBSCO), PsycINFO (EBSCO), and Psychology and Behavioral Sciences Collection (EBSCO), conducted on 6/17/2019. This search used subject headings and keywords related to three concepts: delay discounting/impulsivity, sexual activity, and risk/sexually transmitted disease. Keywords included variations of sexual delay discounting (e.g., sex delay discounting, SDDT), condom use, and HIV (see Appendix 1 for complete list of keywords). Search results were filtered for English language articles published in and after 2012 and saved into a citation management software (Zotero). Both searches were designed and conducted by author MA, a health sciences librarian, with input from the rest of the project team.

Criteria for Considering Studies for This Review

All published studies that utilized the Johnson and Bruner (2012) SDDT published before the literature searches occurred were included in this review, provided results were published in a peer-reviewed journal, written in English, and included human participants. There were no criteria based on study design or population.

Selection of Studies

The titles and abstracts of each record resulting from the initial search were screened by two authors (a random combination of authors NMG, MK, RFL, and MSB) to determine possible inclusion. Full text of the selected studies were obtained and reviewed following the same procedure. Disagreements were resolved through discussion between reviewers. Information from the final set of eligible studies were extracted by NMG and MK, and reviewed by JCS, RFL, and MSB.

Risk of Bias Assessment

Risk of bias for all studies was assessed using study quality assessment tools available from the National Heart, Lung, and Blood Institute (NHLBI, 2020), which provides tailored assessment for different study designs. The tool consists of 12–14 questions depending on study design. Each study was reviewed by two authors using the appropriate tool independently. Based on ratings given for each question, studies were rated as good, fair, or poor. Ratings for experimental studies included questions on use and description of randomization methods (e.g., blinding) and whether groups were similar on important characteristics at baseline. Questions for case–control studies included whether clinical and control cases were recruited from similar populations and operationalizations of cases. Cross-sectional and pre-post design studies were rated on similar criteria and whether they included justifications for sample size. Generally, studies with low risk of bias, thus suggesting greater confidence that results were valid, were considered good. Studies that were susceptible to some bias but not enough to invalidate study results were considered fair. Disagreements were resolved through discussion.

Results

Results of the Search

The citation-tracking and subject-based searches of the literature retrieved a total of 389 unique records after deduplication. A total of 244 were excluded after title and abstract reviews determined that studies clearly did not use the SDDT, were not published in a peer-reviewed outlet, were not human studies, and/or were not published in English. The remaining 145 articles were reviewed in their entirety to determine whether the SDDT was used. Studies that met all inclusion criteria ($N = 18$) were included in this review (Fig. 1). Bias assessments found 10 studies to be of good quality and eight were of fair quality (Table 1).

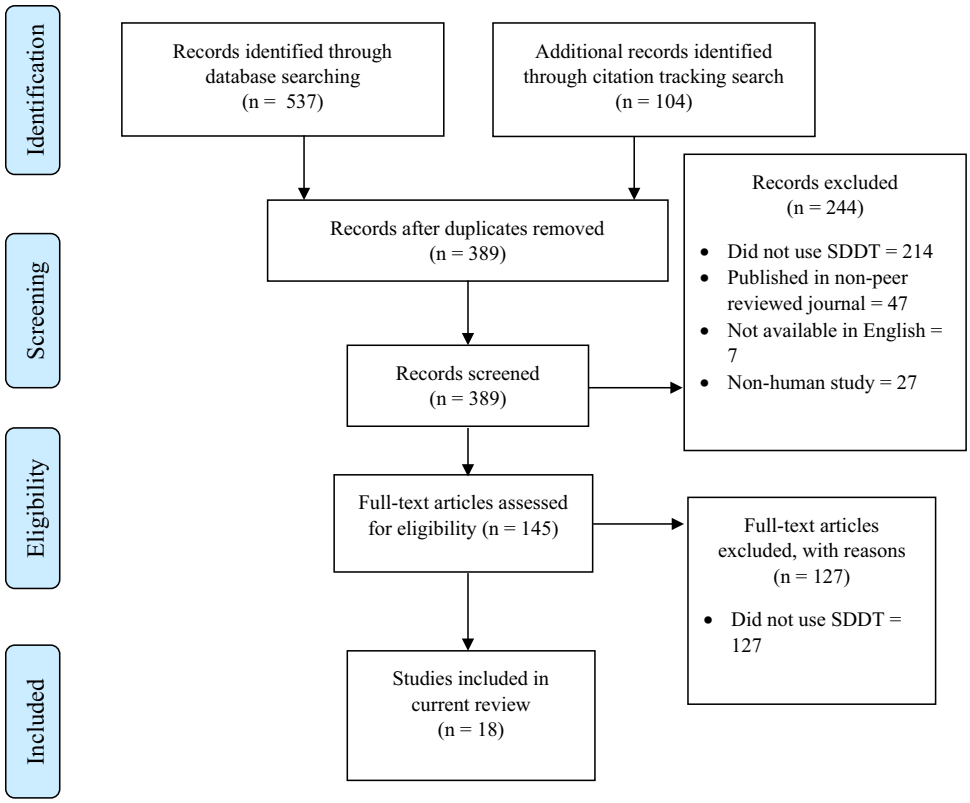

Fig. 1 PRISMA diagram showing identification, screening, eligibility, and inclusion of studies

Sample Characteristics

Eleven of the 18 studies included individuals who used substances recreationally or had substance dependence, including cocaine, opioids, and alcohol. In most of these studies, diagnosis of dependence was based on the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.). Three studies sampled college students and community members. Three other papers implemented the SDDT with men who have sex with men (MSM), two of which (Jones et al., 2018a, b) relied on the same sample using different analyses.

Reported mean age in the studies ranged from 19.4 (Thamotharan et al., 2017) to 48.7 (Johnson & Bruner, 2012). On average, there were about 56% male participants across all studies. Averaged across all studies, approximately 54% of participants were white and 35% were Black/African American participants. Other racial/ethnic groups were not reported upon consistently (Table 1).

Study Designs

Setting

Table 2 displays summary information on study designs. The original Johnson and Bruner (2012) study and two other studies (Johnson & Bruner, 2013; Koffarnus et al., 2016) implemented the SDDT using printed photographs and research assistants to aid in photograph selection. Five studies administered the task online/remotely, and the remaining eight studies reported administering a computerized version in a laboratory setting.

Substance Administration/Use and the Sexual Delay Discounting Task

Four experimental studies measured sexual delay discounting following administration of substances, three of which were among individuals who used cocaine (Tables 1 and 2). Two cross-sectional studies (Johnson & Bruner, 2012, 2013) also assessed the SDDT entirely among individuals who used substances (cocaine). Five case–control studies compared sexual discounting between individuals who use substances and comparison participants who did not use the substance. One study compared sexual delay discounting between individuals who used energy drinks weekly and less than weekly (Meredith et al., 2016). Results of these studies are discussed in greater detail below.

Table 1 Descriptive characteristics of articles

First author, year	Sample description	Full *N*	Analyzed *N*	% Male	Mean age (*SD*)	Study design	Bias assessment
Studies including substance administration							
Bolin et al. (2016)	Persons who use cocaine	9	9	77.8	39.4 (6.7)	Experimental	Good
Johnson et al. (2017)	Persons who use cocaine	15	12	67	27.25 (6.28)	Experimental	Fair
Johnson (2016)	Persons who are non-dependent users of alcohol	23	23	56.5	25.3 (3.7)	Experimental	Good
Strickland et al. (2017)	Persons who use cocaine	11	11	63.6	44.1 (6.5)	Experimental	Good
Studies comparing persons who use substances with controls							
Herrmann (2014)	Women with opioid use dependency and non-drug using controls	60	60	0	Control: 32.0 (1.2) Opioid: 29.7 (4.6)	Case–control	Fair
Johnson et al. (2015)	Persons with cocaine use disorders and matched non-drug using controls	47	Varied by analysis	Control: 63; Cocaine: 57	Control: 40.0 (15.3) Cocaine: 46.3 (10.9)	Case–control	Good
Koffarnus et al. (2016)	Persons with cocaine dependency, used cocaine recreationally, and non-user controls	195	162	68.4	Control: 36.3 (13.9) Recreational: 24.6 (8.8) Dependent: 43.8 (9.9)	Case–control	Good
Thamotharan (2017)	Persons who used, tried, and abstained from alcohol, marijuana, or cigarettes	155	155	38.1	19.35 (1.39)	Case–control	Fair
Johnson (2012)	Persons with cocaine use dependency	62	62	69.4	48.7 (8.3)	Cross-sectional	Fair
Johnson (2013)	Persons with cocaine use dependency	31	30	58.0	48.5 (8.4)	Test–retest	Fair
Meredith (2016)	National sample of young adults (18–28) who use energy drinks (MTurk workers)	874	767	38.0	23.9 (2.7)	Cross-sectional	Good
Studies with other populations							
Collado (2017)	College students	262	Varied by analysis	44.8	19.72 (1.99)	Cross-sectional	Good
Dariotis (2015)	Never married HIV-negative 18–24-year olds	126	117	44.4	21.34 (1.88)	Cross-sectional	Good
Herrmann (2014)	MSM (Mturk workers)	109	108	100	30.0 (9.1)	Cross-sectional	Good
Jones ((2018a)	Online sample of MSM	1012[a]	Varied by analysis	100	18–24 years old–*N* = 458 (45.3% of sample); 25 years old and older–*N* = 554 (54.7% of sample)	Cross-sectional	Fair
Jones (2018b)	Online sample of MSM	1012	Varied by analysis	100	18–years old–*N* = 458 (45.3% of sample); 25 years old and older–*N* = 554 (54.7% of sample)	Cross-sectional	Good

Table 1 (continued)

First author, year	Sample description	Full *N*	Analyzed *N*	% Male	Mean age (*SD*)	Study design	Bias assessment
Quisenberry (2015)	Mturk workers	408	408	56.0	Median = 30 (IQR—25–37)	Experimental	Fair
Wongsomboon (2017)	College students	75	54	27.8	22.93 (4.53)	Experimental	Fair

[a] Jones et al. (2018a, b) relied on the same sample using different analyses.

Structure of Sexual Delay Discounting Task Administration

Selection of Potential Partner Picture

In line with the original SDDT, most studies showed participants 60 pictures, with 30 photographs of men and 30 of women. The three studies with MSM used 40 (Herrmann et al., 2015) or 41 (Jones et al., 2018a, b) photographs of men only. Thamotharan et al., (2017) reported using 100 photographs and Wongsomboon and Robles (2017) used 40 photographs of the opposite gender for heterosexual participants and 80 photographs for bisexual participants. Across most of these studies, we were unable to assess whether the same pictures as in the original study were used, except for Dariotis and Johnson (2015), which reported replacing 13 photos with younger looking people to increase relevance to young adult participants.

Meredith et al. (2016) provided an explicit "no-partner" option to participants, where participants could choose that they would not have sex with any of the potential partners presented, which would end the task. This additional option made explicit what is implied in other studies included in this review, where participants generally had the option to choose as few potential partners as they preferred, which included selecting no partners. In general, studies asked participants to select potential sexual partners from the presented set of pictures. However, some variations to these methods were used. For example, Wongsomboon and Robles (2017) asked participants to exclude pictures of people with whom they would never want to have sex, and Johnson et al. (2017) assessed the SDDT using only one partner (least likely to have an STI).

Delays to Condom Availability

Fourteen of the eighteen studies used the same delays as the original SDDT (i.e., 0, 1 h, 3 h, 6 h, 1 day, 1 week, 1 month,

Table 2 Characteristics of the Sexual Delay Discounting Task implemented in studies

First author, year	No. of Delays	Delays specified	Manipulation/substance administration
Bolin et al. (2016)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	Buspirone (30 mg/day for 3 days) vs placebo (for 3 days)
Johnson et al. (2017)	8	0, 2 min, 5 min, 15 min, 30 min, 1 h, 3 h, 6 h	0, 125, and 250 mgs/70 kg oral cocaine HCL
Johnson (2016)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	1 g/kg of alcohol vs placebo
Strickland (2017)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	Buspirone (10 and 30 mg) vs Trizolam (.375 mg; positive control) vs Placebo (negative control)
Herrmann (2014)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Johnson (2015)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Koffarnus (2016)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Thamotharan (2017)	5	0, 1 h, 3 h, 6 h, 24 h	NA
Johnson (2012)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Johnson (2013)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Meredith (2016)	7	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 3 mths (1 mth excluded from analysis due to error)	NA
Collado (2017)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Dariotis (2015)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Herrmann (2015)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Jones (2018a)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Jones (2018b)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA
Quisenberry (2015)	8	0, 1 h, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	Health message framing
Wongsomboon (2017)	7	0, 3 h, 6 h, 1 day, 1 wk, 1 mth, 3 mths	NA

Hr(s), Hour(s); Mth(s), Month(s); NA, Not applicable; NR, Not reported; Wk, Week;

3 months). M.W. Johnson et al. (2017) study, which sought to examine the effect of acute cocaine administration on sexual decision making, used shorter delays (i.e., 0, 2 min, 5 min, 15 min, 30 min, 1 h, 3 h, and 6 h).

Vignettes

Vignettes provided to participants were largely in line with the original vignette used in Johnson and Bruner (2012), as described in the introduction. Studies with MSM did not include language about potential pregnancy. Two studies applied slight modifications to the original vignette, to add that the participant and partner met at a social event (Wongsomboon & Robles, 2017) and to add that no one else would be affected (Jones et al., 2018a, b). Johnson et al. (2017) adapted a vignette from a different sexual risk-taking task, but the language was generally consistent with the original vignette.

All but one of the studies used an unspecified STI in the "most/least likely to have an STI" partner condition. Wongsomboon and Robles (2017) used sexually transmitted diseases (STDs) and provided further definitions to participants to indicate that STDs included HIV, syphilis, gonorrhea, and other STDs. Wongsomboon and Robles (2017) were also unique in their use of the word "protection" instead of "condom" in the statements used in the visual analog scales. That is, participants' choices where anchored by the statements "I would definitely have sex with [or without] protection."

Data Analysis

Orderliness of Data

Authors of the original study adapted the SDDT from the monetary discounting literature (Johnson & Bickel 2008), and as such, applied similar criteria to assess orderliness (i.e., systematicity) of the data. Johnson and Bickel put forth two adaptable criteria to determine nonsystematic data: (1) any discounting value (also known as an indifference point in monetary discounting) was 20% greater than the preceding value, and/or (2) the discounting value at the last delay was not less than the value at the first delay by at least a magnitude of 10% of the larger later reward. These criteria were presented with the explicit consideration that what is and what is not considered systematic may differ across context (e.g., task, outcome, modality of collection). As such, modifications may be appropriate when considering the SDDT here. In fact, the authors of the original SDDT study used the first criterion only for sexual delay discounting data, recognizing that people who chose to never discount condom-protected sexual activity were likely engaging in a systematic behavioral process, regardless of the required delay to a condom. A majority of studies either used only one criterion or did not report on application of the criteria. Supplemental Table 1 summarizes the use of these criteria in studies included in this review.

Based on the criteria applied in each study, around 90% of data were considered systematic, on average, according to these criteria. The percentage of data that were considered systematic ranged from 77.1 (Jones et al., 2018a, b) to 98% (Strickland et al., 2017). Some studies (e.g., Johnson & Bruner 2013; Wongsomboon & Robles 2017) retained cases of non-orderly data, while others (e.g., Collado et al., 2017) excluded non-orderly data from their analysis.

Statistical Approach

Supplemental Table 1 presents the statistical approaches applied in studies to calculate sexual delay discounting. Most studies calculated sexual delay discounting using an area under the curve (AUC) approach (Myerson et al., 2001) whereas some used the log k alternative. The parameter k serves as an index of degree of discounting and can be used in various analyses, including in extra sums-of-squares F-tests to compare model fit at the individual and group levels. Two papers (Jones et al., 2018a, b) reported on continuous and categorical AUC outcomes after grouping participants in 5 categories based on their AUC scores (i.e., 0–0.25, 0.25–0.50, 0.50–0.75, 0.75–1, and 1), reporting that categorical AUCs were used due to highly skewed discounting data. Further, while most of the studies reported on the mean AUC of each partner condition, four studies reported the median AUCs.

As noted, the likelihood of immediate condom use is assessed using the zero-delay trial. Individuals have different likelihoods of immediate condom use. Thus, to control for effects of these individual differences and isolate the effect of delay on likelihood of condom use, discounting values from delay trials are standardized. Standardization of discounting data (also known as normalization) is achieved by dividing the value reported for each delay by the value in the first (i.e., zero) delay. This results in individuals who report a value of "0%" at the first trial (i.e., those who express preference for condomless sex when a condom is also immediately available) being excluded from analyses, which was reported in several studies (Supplemental Table 1). Standardized data may result in AUCs that exceed 1. This was not reported upon consistently throughout studies included in this review. Whereas some papers constrained AUCs greater than 1 to 1 (e.g., Johnson et al., 2015, 2016), others (e.g., Jones, et al., 2018a, b) excluded AUC values greater than 1. Johnson (2016) also reported analyzing their data with and without constraining AUCs and found no statistical differences in their findings.

Reported Findings

The SDDT results in two main outcomes: (1) likelihood of immediately available condom use (i.e., zero-delay trial) and (2) likelihood of waiting for condom availability (i.e., delay trials). Comparisons can then be made within and/or across partner types (e.g., partners that are most and least desirable, and most and least likely to have an STI) and between different groups for each partner (e.g., individuals who use substances versus controls, or drug versus placebo conditions). Results of interest vary depending on each study's aims and are thus reported differently throughout the 18 studies included here (Table 3). The summary below is presented as follows: (1) summary of findings comparing immediate likelihood of condom use and likelihood of waiting for a condom between most and least desirable partners and (2) summary of findings comparing immediate likelihood of condom use and likelihood of waiting for a condom between most and least likely to have an STI partners.

Summary of Results Based on Partners' Desirability

Overall, results based on partners' desirability suggest greater likelihood of immediate condom use (six supportive findings, three null findings, eight non reported) and greater likelihood of waiting for a condom (ten supportive findings, one null findings, six non reported) for least desirable partners, compared to most desirable partners. Tables 3 and 4 provide full reported results.

Gender Differences Based on Partners' Desirability

For the most desirable partner, two studies (Collado et al., 2017; Dariotis & Johnson, 2015) reported that women had a significantly greater likelihood of immediate condom use, relative to men, whereas Koffarnus et al. (2016) reported no significant differences. Only Collado et al. (2017) reported a parallel finding of greater likelihood of immediate condom use by women, compared to men, for the least desirable partner ($\eta^2 = 0.02$).

Of six studies reporting on gender differences, four reported significantly greater likelihood of waiting for a condom in women compared to men (Collado et al., 2017; Johnson & Bruner, 2013; Quisenberry et al., 2015; Thamotharan et al., 2017) for the partners they most and least wanted to have sex with (i.e., here referred to as most and least desirable).

Dariotis and Johnson (2015) also reported significantly greater likelihood of waiting for a condom in women compared to men in most, but not least, desirable partners when using raw (unstandardized) discounting data ($\eta^2 = 0.03$). However, both Dariotis and Johnson (2015) and Koffarnus et al. (2016) reported no significant differences between men and women in likelihood of waiting for condoms across all partners when using standardized discounting data. Similarly, M. W. Johnson and Bruner (2013) found significantly greater likelihood of waiting for a condom in women compared to men in most and least desirable partners when using AUC at weeks 1 and 2 and k value at Week 2, but not Week 1 for the least desirable partner.

Summary of Results Based on Partners' Sexually Transmitted Infection Status

Overall findings on immediate likelihood of condom use (i.e., zero-delay results) based on partners' STI status suggest there is significantly greater likelihood of condom use with partners perceived to be most likely to have an STI compared to partners perceived to be least likely to have an STI (six supportive findings, two null findings, one non-supportive finding, and eight non-reported). Evidence of greater likelihood of immediate condom use with partners perceived to be most likely to have an STI was reported across various populations, including individuals who use opioids (Herrmann et al., 2014), individuals who use cocaine (Johnson et al., 2015), college students (Collado et al., 2017), and MSM (Herrmann et al., 2015).

Similarly, most of the studies found significantly greater likelihood of waiting for a condom (i.e., delay results) with partners perceived as most likely to have an STI compared to least likely to have an STI (11 supportive findings, six non-reported). As with immediate condom use, results showed greater likelihood of waiting for a condom with the partner perceived to be most likely to have an STI across multiple populations including individuals who used substances, college students and MSM (e.g., Collado et al., 2017; Herrmann et al., 2015; Johnson & Bruner, 2012).

Gender Differences Based on Partners' Gender Differences Based on Partners' Sexually Transmitted Infection Status

Three studies compared likelihood of immediate condom use between men and women. For the partner least likely to have an STI, Dariotis and Johnson (2015) reported that women had a significantly greater likelihood of condom use than men ($\eta^2 = 0.002$), whereas Collado et al. (2017) and Koffarnus et al. (2016) reported no significant differences. All three studies reported no significant differences between men and women in the likelihood of immediate condom use in most likely to have an STI partner conditions.

Limited evidence from six studies indicates men may exhibit greater sexual delay discounting. Collado et al. (2017), M. W. Johnson and Bruner (2013), Quisenberry et al. (2015), and Thamotharan et al. (2017) reported that women had significantly greater likelihood of waiting for a condom compared to men for both most and least likely to have an

Table 3 Reported Sexual Delay Discounting Task results: Likelihood of condom use (zero-delay)

First author, year	Comparison	MSEX	LSEX	MSTI	LSTI
Studies including substance administration					
Bolin (2016)	ML partners after buspirone	Greater likelihood of condom use with LSEX vs MSEX		No diff	
	ML partners after placebo	No diff		Greater likelihood of immediate condom use with LSTI vs MSTI	
	Buspirone vs. placebo	No diff	Greater likelihood of immediate condom use in buspirone vs placebo	Greater likelihood of immediate condom use buspirone vs placebo	No diff
Johnson (2017)	250 mg/70 kg cocaine vs. 125 mg/70 kg cocaine	NA	NA	NA	No diff
	250 mg/70 kg cocaine vs. placebo	NA	NA	NA	No diff
	125 mg/70 kg cocaine vs. placebo	NA	NA	NA	No diff
Johnson (2016)	ML partners	NR		NR	
	Alcohol vs. placebo	No diff	No diff	No diff	No diff
Strickland (2017)	Raw AUC				
	ML partners	No diff		No diff	
	30 mg vs. 10 mg buspirone	No diff	No diff	No diff	No diff
	30 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	30 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	10 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	10 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	Triazolam vs. placebo	No diff	No diff	No diff	No diff
Studies comparing persons who use substances with controls					
Herrmann (2014)	MLpartners	No diff		Greater likelihood of immediate condom use with MSTI vs. LSTI	
	Persons with opioid dep. vs. controls	No diff	No diff	No diff	No diff
Johnson (2015)	ML partners	NR		NR	
	Persons with cocaine use disorder vs. controls	No diff	No diff	No diff	No diff
Koffarnus (2016)	ML partners	Greater likelihood of immediate condom use with LSEX vs MSEX		Greater likelihood of immediate condom use with MSTI vs LSTI	
	Persons with cocaine dep. vs. rec. user	No diff	No diff	No diff	No diff
	Persons with cocaine dep. vs. control	No diff	No diff	No diff	No diff

Table 3 (continued)

First author, year	Comparison	MSEX	LSEX	MSTI	LSTI
	Persons who used rec. vs. control	Greater likelihood of immediate condom use in control vs persons who used cocaine recreationally		No diff	No diff
	Male vs female	No diff		No diff	
Thamotharan (2017)	ML partners	NR	NR		
	Persons who used vs. tried vs. abstained from alcohol	NR	NR	NR	NR
	Persons who used vs. tried vs. abstained from cigarette	NR	NR	NR	NR
	Persons who used vs. tried vs. abstained from marijuana	NR	NR	NR	NR
Studies enrolling samples of persons who use substances Only					
Johnson (2012)	ML partners	Greater likelihood of immediate condom use with LSEX vs MSEX		Greater likelihood of immediate condom use with MSTI vs LSTI	
Johnson (2013)	ML partners-Week 1 using AUC	NR		NR	
	ML partners-Week 2 using AUC	NR		NR	
	ML partners-Week 1 using k	NR		NR	
	ML partners-Week 2 using k	NR		NR	
Meredith (2016)	ML Partners	NR	NR		
	Persons who use energy drinks weekly vs. less than weekly	Greater likelihood of immediate condom use in persons who used energy drinks less-than-weekly vs weekly	No diff	No diff	Greater likelihood of immediate condom use in persons who used energy drinks less-than-weekly vs weekly
Studies with other populations					
Collado (2017)	ML partners	Greater likelihood of immediate condom use with LSEX vs MSEX		Greater likelihood of immediate condom use with MSTI vs LSTI	
	Male vs. female	Greater likelihood immediate of condom use in females vsmales	Greater likelihood immediate of condom use in females vs males	No diff	No diff
Dariotis (2015)	ML partners	Greater likelihood of immediate condom use with LSEX vs MSEX		Greater likelihood of immediate condom use with MSTI vs LSTI	
	Male vs. female	Greater likelihood of immediate condom use in females vs males	No diff	No diff	Greater likelihood of immediate condom use in females vs males
Herrmann (2015)	ML partners	Greater likelihood of immediate condom use with LSEX vs MSEX		Greater likelihood of immediate condom use with MSTI vs LSTI	
Jones (2018a)	ML partners	NR		NR	

Table 3 (continued)

First author, year	Comparison	MSEX	LSEX	MSTI	LSTI
Jones (2018b)	ML partners	NR		NR	
Quisenberry (2015)	ML partners	NR		NR	
	Positive vs. negative regret	NR	NR	NR	NR
	Positive vs. negative no regret	NR	NR	NR	NR
	Negative regret vs. negative no regret	NR	NR	NR	NR
Wongsomboon (2017)	Uses different partners than original SDDT	Most Want (MW)	MW/MSTI	MW/LSTI	Least Want (LW)	LW/MSTI	LW/LSTI	MSTI	LSTI
No diff b/n all partner conditions									

AUC, Area under the curve; Dep, Dependency; LSEX, Least want to have sex with partner; LSTI, Least likely to have STI partner; LW, Least want to have sex with partner; ML, Most versus Least partners; MSEX, Most want to have sex with partner; MST, Most likely to have STI partner; MW, Most want to have sex with partner; N, Not applicable; No diff, No statistically significant difference; NR, Not reported; Rec, Recreational; STI, Sexually transmitted infection

STI partners. Johnson and Bruner (2013) also compared men and women using both AUC and *k* discounting values. They found that women had significantly greater likelihood of waiting for a condom compared to men for the least likely to have an STI partner using both AUC and *k*, both at weeks 1 and 2. The difference was only significant in the most likely to have an STI partner when using *k*, both at weeks 1 and 2. On the other hand, Dariotis and Johnson (2015) reported on likelihood of waiting for a condom using raw and standardized discounting data, reporting greater likelihood of condom use in women compared to men in the least likely to have an STI partner condition, but not in the most likely to have an STI partner condition, when using raw discounting data. There were no differences when using standardized discounting data. Koffarnus et al. (2016) reported no significant differences in the likelihood of waiting for condom use between men and women in both most and least likely to have STI partner conditions.

Discussion

The SDDT has been increasingly used in recent years and has great potential to identify individuals who may be more likely to engage in sexual risk-taking (i.e., reduced likelihood of condom use) in real-life. Thus, the aim of this review was to systematically catalog and describe the various methodological approaches in studies using the SDDT, consider implications of applied methods, recommend best methodological practices, and identify areas for future research. Several notable results emerged from the present systematic review. Results from the current review find considerable heterogeneity in methods used to administer the SDDT, including differences in delays used, instructions given to participants (e.g., opt-out option), and type of STIs referred to in the task instructions. Variabilities were also observed in data analyses and limited reporting of findings, which constrain robust comparisons across studies (e.g., meta-analysis). We also found that the SDDT has been used across different groups (e.g., people who use substances, college students), and highlights a need for future research with populations who are at increased vulnerability for HIV/STI acquisition (e.g., young adult MSM, people who inject drugs). To contextualize the implications of the different methods used with the SDDT, we first summarize findings from included studies, followed by methodological considerations and conclude with potential areas of future research and conclusions.

Table 4 Reported Sexual Delay Discounting Task results: Likelihood of waiting for a condom (non-zero-delays)

First author, year	Substance administered/used	MSEX	LSEX	MSTI	LSTI
Studies including substance administration					
Bolin (2016)	ML partners after buspirone	Greater likelihood of waiting for condom with LSEX vs. MSEX		No diff	
	ML partners after placebo	Greater likelihood of waiting for condom with LSEX vs. MSEX		Greater likelihood of waiting for condom with MSTI vs. LSTI	
	Buspirone vs. placebo	No diff	No diff	No diff	No diff
Johnson (2017)	250 mg/70 kg cocaine vs. 125 mg/70 kg cocaine	NA	NA	NA	No diff
	250 mg/70 kg cocaine vs. placebo	NA	NA	NA	Greater likelihood of waiting for condom in placebo vs 250 mg/70 kg
	125 mg/70 kg cocaine vs. placebo	NA	NA	NA	No diff
Johnson (2016)	ML partners	NR		NR	
	Alcohol vs. placebo	Greater likelihood of waiting for condom in placebo vs. alcohol	Greater likelihood of waiting for condom in placebo vs. alcohol	No diff	Greater likelihood of waiting for condom in placebo vs. alcohol
Strickland (2017)	Raw AUC				
	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	Raw AUC				
	30 mg vs. 10 mg buspirone	No diff	No diff	No diff	No diff
	30 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	30 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	10 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	10 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	Triazolam vs. placebo	No diff	No diff	No diff	No diff
	Standardized AUC				
	ML partners	No diff		No diff	
	30 mg vs. 10 mg buspirone	No diff	No diff	No diff	No diff
	30 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	30 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	10 mg buspirone vs. triazolam	No diff	No diff	No diff	No diff
	10 mg buspirone vs. placebo	No diff	No diff	No diff	No diff
	Triazolam vs. placebo	No diff	No diff	No diff	No diff
Studies comparing persons who use substances with controls					
Herrmann (2014)	ML partners	No diff		Greater likelihood of waiting for condom with MSTI vs. LSTI	
	Persons with opioid dep. vs. controls	Greater likelihood of waiting for condom in controls vs persons with opioid dependency across all partners			
Johnson (2015)	ML partners	NR	NR	NR	NR

Table 4 (continued)

First author, year	Substance administered/used	MSEX	LSEX	MSTI	LSTI
	Persons with cocaine use disorder vs. controls	Greater likelihood of waiting for condom in controls vs persons with cocaine use disorder	Greater likelihood of waiting for condom in controls vs persons with cocaine use disorder	No diff	No diff
Koffarnus (2016)	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	Persons with cocaine dep. vs. persons who used rec	No diff	No diff	No diff	No diff
	Persons with cocaine dep. vs. control	No diff	No diff	Greater likelihood of waiting for condom in controls vs persons with cocaine dependency	Greater likelihood of waiting for condom in controls vs persons with cocaine dependency
	Persons who used cocaine rec. vs. control	Greater likelihood of waiting for condom in control vs. persons who used cocaine recreationally across all partners			
	Male vs female	No diff		No diff	
Thamotharan (2017)	ML partners	NR		NR	
	Persons who used vs tried vs abstained from alcohol	No diff in likelihood of waiting for condom across levels of alcohol use status across all partners			
	Persons who used vs. tried vs. abstained from cigarette	Greater likelihood of waiting for condom in persons who abstained from cigarettes vs. those who tried or used cigarettes across all partners			
	Persons who used vs. tried vs. abstained from marijuana	Greater likelihood of waiting for condom in persons who abstained from marijuana and persons who tried marijuana vs. persons who used marijuana across all partners			
	Male vs female	Males were less likely to wait for a condom than females across all partners			
Studies enrolling samples of persons who use substances only					
Johnson (2012)	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
Johnson (2013)	ML partners - Week 1 using AUC	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	ML partners -Week 2 using AUC	No diff		Greater likelihood of waiting for condom with MSTI vs LSTI	
	ML partners -Week 1 using *k*	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	ML partners -Week 2 using *k*	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	Male vs female - Week 1 using AUC	Males were less likely to wait for a condom than females in MSEX AND LSEX partners		No diff	Males were less likely to wait for a condom than females
	Male vs female–Week 2 using AUC	Males were less likely to wait for a condom than females in MSEX AND LSEX partners		No diff	Males were less likely to wait for a condom than females
	Male vs female – Week 1 using *k*	Males were less likely to wait for a condom than females		No diff	Males were less likely to wait for a condom than females in MSTI and LSTI partners
	Male vs female – Week 2 using *k*	Males were less likely to wait for a condom than females in MSEX AND LSEX partners		Males were less likely to wait for a condom than females in MSTI and LSTI partners	
Meredith (2016)	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	

Table 4 (continued)

First author, year	Substance administered/used	MSEX	LSEX	MSTI	LSTI
	Persons who use energy drinks weekly vs. less than weekly	No diff	Greater likelihood of waiting for condom in persons who use energy drinks less than weekly vs those who use weekly[a]	No diff	No diff
Studies with other populations					
Collado (2017)	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	Male vs. female	Males were less likely to wait for a condom than females in all four conditions			
Dariotis (2015)	ML partners (Raw AUC)	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	ML partners (Standardized AUC)	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
	Male vs female (Raw AUC)	Males were less likely to wait for a condom than females	No diff	No diff	Males were less likely to wait for a condom than females
	Male vs female (Standardized AUC)	No significant differences in likelihood of waiting for condom between males and females across all partners			
Herrmann (2015)	ML partners	Greater likelihood of waiting for condom with LSEX vs MSEX		Greater likelihood of waiting for condom with MSTI vs LSTI	
Jones (2018a)	ML partners	NR		NR	
Jones (2018b)	ML partners	NR		NR	
Quisenberry (2015)	ML Partners	NR		NR	
	Positive vs. negative with regret	Greater likelihood of waiting for condom in negative with regret vs positive	Greater likelihood of waiting for condom in negative with regret vs positive	Greater likelihood of waiting for condom in negative with regret vs positive	Greater likelihood of waiting for condom in negative with regret vs positive
	Positive vs. negative with no regret	No diff	Greater likelihood of waiting for condom in negative with no regret vs positive	Greater likelihood of waiting for condom in negative with no regret vs positive	No diff
	Negative with regret vs. negative with noregret	Greater likelihood of waiting for condom in negative with regret vs negative no regret	No diff	No diff	No diff
	Male vs. female	Males were less likely to wait for a condom than females across all partners			

Table 4 (continued)

First author, year	Substance administered/used		MSEX		LSEX	MSTI		LSTI	
Wongsomboon (2017) (Uses different partners than original SDDT)		MW	MW/MSTI	MW/LSTI	LW	LW/MSTI	LW/LSTI	MSTI	LSTI
	MW	–	–	–	–	–	–	–	–
	MW/MSTI	No diff	–	–	–	–	–	–	–
	MW/LSTI	No diff	Greater likelihood of waiting in MW/MSTI vs MW/LSTI	–	–	–	–	–	–
	LW	Greater likelihood of waiting in LW vs MW	Greater likelihood of waiting in LW vs MW/MSTI	Greater likelihood of waiting in LW vs MW/LSTI	–	–	–	–	–
	LW/MSTI	Greater likelihood of waiting in LW/MSTI vs MW	Greater likelihood of waiting in LW/MSTI vs MW/MSTI	Greater likelihood of waiting in LW/MSTI vs MW/LSTI	No diff	–	–	–	–
	LW/LSTI	Greater likelihood of waiting in LW/LSTI vs MW	Greater likelihood of waiting in LW/LSTI vs MW/MSTI	Greater likelihood of waiting in LW/LSTI vs MW/LSTI	No diff	No diff	–	–	–
	MSTI	Greater likelihood of waiting in MSTI vs MW	Greater likelihood of waiting in MSTI vs MW/MSTI	Greater likelihood of waiting in MSTI vs MW/LSTI	No diff	No diff	No diff	–	–
	LSTI	No diff	No diff	Greater likelihood of waiting in LSTI vs MW/LSTI	Greater likelihood of waiting in LW vs LSTI	Greater likelihood of waiting in LW/MSTI vs LSTI	No diff	Greater likelihood of waiting in MSTI vs LSTI	–

AUC, Area under the curve; Dep, Dependency; LSEX, Least want to have sex with partner; LSTI, Least likely to have STI partner; LW, Least want to have sex with partner; ML, Most versus Least partners; MSEX, Most want to have sex with partner; MSTI, Most likely to have STI partner; MW, Most want to have sex with partner; NA, Not applicable; No diff, No statistically significant difference, NR, Not reported; Rec, Recreational; STI; Sexually transmitted infection

[a]Meredith et al (2016) reported persons who use energy drinks weekly had a significantly lower likelihood of waiting for a condom in the least want to have sex with partner compared to those who use energy drinks less than weekly, however, this difference was no longer statistically significant when adjusted for covariates.

Synthesis and Implications of Reported Findings

Consistency of Discounting Condom Protected Sex as a Function of Delay

Findings from all 18 studies indicated that condom-protected sex was discounted as a function of delay to condom availability, highlighting the robust and consistent effect delay to condom availability exerts on condom use. Overall findings support sexual delay discounting is a malleable construct that is responsive to partner characteristics, perceived STI/HIV risk and other variables (e.g., pharmacological and behavioral manipulations). Sexual delay discounting, as a mechanism underlying sexual decision-making, can thus be an intervention target.

Behavioral tasks, such as the SDDT, present an important step forward for research and prevention efforts for HIV and other STIs (Haberer et al., 2015), for several reasons. First, a large number of studies of condom use have focused on between-subject variables including gender, age, and health beliefs or attitudes and risk perception. Tasks such as the SDDT show that environmental variables (e.g., partner characteristics, substances) can cause changes in condom-use behavior, often within the same individual. Such tasks, however, can also offer a target for intervention, and may have potential for facilitating accurate identification of at-risk individuals. Second, research has largely relied on participants to share sensitive information accurately and honestly. Retrospective self-report is limited by recall and desirability biases, with researchers calling for objective measures of sexual behavior research (Traeger et al., 2018). The SDDT could be used to identify individuals who may be less likely to use readily available condoms. Such individuals may benefit particularly from educational or behavioral interventions to increase overall condom use (Whiting et al., 2019). The SDDT could also help to identify people whose likelihood of condom use decreases when they are not readily available. Evidence indicates that likelihood of condom use decreases even when short delays are introduced (e.g., 5 min; Johnson et al., 2017). One study among men who have sex with men (MSM) found that 24% reported that they recently engaged in unprotected anal intercourse because a condom was not readily available (Herrmann et al., 2015). Their study also found that engaging in this behavior was significantly associated with greater sexual delay discounting in the "most likely to have an STI" partner (Herrmann et al., 2015). People who would use a condom when it is available but may not use it if there is a delay to condom availability might benefit from tailored interventions that facilitate condom carrying (Johnson et al., 2021) (e.g., reminders). Future research could also examine whether reducing sexual delay discounting can potentially bring about changes in real-life sexual risk behaviors. Future interventions and experimental manipulations focused on sexual decision-making may use the SDDT to assess sexual risk-taking.

Partner Desirability and Partner Desirability and Sexually Transmitted Infection Status Findings Status Findings

Despite the methodological differences noted, overall findings tended to indicate reduced likelihood of immediate condom use and reduced likelihood of waiting for delayed condom-protected sex with the "most desirable" (relative to least desirable) and the "least likely to have an STI" (relative to most likely to have an STI) partners. These results synthesize evidence regarding the consistency and sensitivity of the task to experimental factors based on desirability and STI perceptions of potential partners, and align with previous research showing partner attractiveness can influence perceptions and sexual behavior intentions (e.g., Kruse & Fromme, 2005). Desirability of a partner may be a particularly relevant factor influencing sexual decision-making processes related to risk and delay (Berry et al., 2019). Further, little knowledge of a partner's sexual history and STI likelihood may be common in casual sex scenarios, and it is impossible to gauge STI status from appearance. Sexual education efforts may highlight the risk of contracting an STI is associated with all partners, regardless of physical appearance.

Substance-Related Findings

In studies comparing individuals who used substances with controls, results from delay trials and results based on partner desirability were more consistent compared to results from zero-delay trials and results based on partners' STI status, respectively. Overall, results indicated that individuals who used substances tended to have steeper discounting (i.e., reduced likelihood of condom protected sex with delay to condom availability) compared to matched controls based on partners' desirability, but results were mixed based on partners' STI status. Similar patterns of findings were reported in substance administration studies. Active substance administration resulted in steeper discounting compared to placebo administration based on partner desirability (with the exception of Bolin et al. (2016), buspirone maintenance study as predicted, given its potential therapeutic effects). Acute substance intoxication may decrease perceptions of risk, and increase arousal leading to increased propensity for risky sexual decision-making (see Berry & Johnson 2018 for discussion). This review highlights the interactive effects of substances with partner desirability and delay to condom availability in that substance use may exacerbate already high-risk scenarios involving high partner desirability and delay to condom availability.

Synthesis and Implications of Sexual Delay Discounting Task Administration and Analyses

Sexual Delay Discounting Task Administration

It is important to consider the impact of the SDDT's design (e.g., vignettes, order of delay presentations) on resulting data. Evidence from other behavioral economic tasks (e.g., alcohol purchase task review, Kaplan et al., 2018; monetary delay discounting, Robles et al., 2009; Robles & Vargas, 2007, 2008) suggests that task designs may influence participant responses, and thus, affect study findings and conclusions. For instance, evidence from the monetary delay discounting literature indicates that the order of presentation of rewards and delays affect participant responses and resulting discounting data (Robles & Vargas, 2007, 2008; Robles et al., 2009). Given the heterogeneities reported in this review, it is challenging to assess the specific impact of methodologic details in SDDT administration (i.e., effect of the different vignettes, "no-partner" options, number and length of delays, as well as the number and type of photographs) on studies' results. Thus, to enhance the rigor and reproducibility of detected effects, this review highlights that, to the extent possible, it will be important to (1) maintain uniformity in SDDT administration (to reduce variability), and (2) report methodologies implemented in studies in full (either in manuscript text, appendix, or supplemental attachments). Different research questions might lead to differences in how the SDDT is implemented. Thus, researchers are encouraged to make use of open science practices (e.g., OSF preregistration) to publish all study materials (e.g., full vignettes used). Such efforts will help to enhance study reproducibility and aid in comparisons among studies. As studies continue to implement the SDDT, future meta-analyses can compare effect sizes and identify patterns of findings based on differences in implementation of the SDDT.

Sexual Delay Discounting Task Analyses and Reporting

Inconsistencies in reporting of findings were also observed, with most studies, justifiably, focusing their reporting on their main research questions. As noted, the SDDT allows for a multitude of possible comparisons. To some extent, it is to be expected that not all studies report all possible comparisons, due to parsimony and practical considerations (e.g., journal word count limits), however should be balanced with necessity. Specifically, a central finding in this review was the disparate reporting of likelihood of immediate condom use (i.e., zero-delay results) versus likelihood of waiting for a condom (i.e., delay results). Several studies did not report on zero-delay results. Distinguishing sexual risk at zero delay from condom use after a delay is critical for understanding the contribution of delay discounting mechanisms to likelihood of condom use and has applied implications for developing efficacious and targeted interventions (i.e., the absence of zero delay reporting limits the ability to isolate the effects of delay). For example, for individuals who have a high likelihood of condom use if immediately available, but drastic reductions in likelihood of use if required to wait, clinical interventions might aim to enhance processes that facilitate optimal weighing of risk with delay (e.g., future episodic thought, visualizations of condom carrying, "condom implementation intentions"). Such targeted interventions may result in consistent condom-carrying for unplanned sexual encounters. Thus, researchers are encouraged to report findings from zero and delay comparisons in full.

Regarding analyses of SDDT data, there was a lack of consistency in the application of criteria used to determine data orderliness and approaches used to address non-systematic data (i.e., outliers). The two criteria adapted from Johnson and Bickel (2008) were used and reported in three of the 18 papers, while other studies reported one or no application of either criterion (Supplemental Table 1). As noted in Johnson and Bickel (2008), non-systematic data may indicate serious violations of discounting assumptions, with critical implications for study results and their interpretation (e.g., responding randomly, lack of understanding of the task. or lack of an impact of delay on decision making). Although investigators may apply both, either, or neither criterion depending on their research questions, to aid in scientific rigor, reproducibility, and to allow for comparisons across studies, specific and comprehensive reporting of data analytic methods used in studies is encouraged.

In addition, there exist differences in the calculation of sexual delay discounting across studies (Supplemental Table 1). Several studies reported calculating area under the curve (AUC; e.g., Johnson et al., 2017) whereas others modeled discounting curves and compared discounting parameters (i.e., used log k; e.g., Bolin et al., 2016). Studies also varied in use of raw (e.g., Dariotis & Johnson, 2015), mean (i.e., parametric; e.g., Collado et al., 2017), median (i.e., nonparametric; e.g., Quisenberry et al., 2015), or categorized (e.g., Jones et al., 2018a, b) AUC scores. As in other delay discounting research (e.g., monetary discounting), it is important to note that in some instances, AUC versus k values or raw versus standardized AUC values can lead to differing results and/or conclusions (e.g., Dariotis & Johnson 2015; M. W. Johnson & Bruner 2013; Strickland et al., 2017). Further, there were inconsistencies in the reporting of and approaches used for data standardization and outliers.

Similarly, effect sizes for study findings were not reported in all studies. In one study, the effect size for likelihood of immediate condom use (i.e., zero-delay results) was larger for differences based on partner STI status ($\eta^2 = 0.12$), compared to differences based on partner desirability ($\eta^2 = 0.02$; Collado et al., 2017). Effect sizes for differences in likelihood of

waiting for condom use (i.e., delay trials) and gender differences ranged from small to medium ($\eta^2 = 02–0.08$). Effect sizes were larger for differences between substance use/administration versus control groups (e.g., Cohen's $d = 0.52$, Thamotharan et al., 2017; Cohen's $d = 0.72$, Johnson et al., 2017). Thus, clearly communicated rationales, as well as a priori decisions might facilitate comparison of effect sizes and reduce publication bias in future research.

Considerations and Recommendations

Based on findings from this systematic review, considerations and recommendations on how to implement and report on the SDDT are provided. The number of pictures presented likely has little to no effect on results, however, to ensure replicability, when studying similar populations as past studies, studies may benefit from using pictures from previously published studies. On the other hand, when working with new or specific populations, studies may benefit from tailoring the content of the pictures (i.e., the photographs of the different potential casual sexual partners) to their target study sample and reporting on these modifications. For example, if participants are young, photos could be of young partners, and vice versa, as was done by Dariotis and Johnson (2015). To ensure that participants have enough variety to choose from, future researchers are encouraged to use pictures from a diverse population, in race/ethnicity, age, amount of clothing, etc.

Most studies included in this review allowed participants to select the same potential partner in different dimensions of the SDDT (i.e., desirability and likelihood of STI), although most studies did not report partner selection across dimensions. While most studies asked participants to choose partners they would have sex with, one study (Wongsomboon & Robles 2017) initially asked participants to exclude pictures of individuals they would never want to have sex with (see also Meredith et al., 2016 for a "no partner" condition). Without a systematic examination, it is impossible to say the extent to which these differences have an effect, if any. Evidence from papers included in this review and elsewhere (Johnson et al., 2021) indicates that the steepest discounting is observed for partners considered (1) most desirable, and (2) least likely to have an STI. Given practical considerations (e.g., participant burden), future researchers may elect to use either or both of those partner conditions, when using all four partner types becomes challenging (e.g., acute substance administration studies, time constraints), as was done by Johnson et al. (2017).

Zero delay results should be reported to isolate the influence of delay discounting in sexual decision-making, as well as the influence of various experimental and pharmacologic manipulations on likelihood of immediate versus delayed condom availability. Delays to condom availability used in most studies were in hours, weeks, and months. Only one study applied considerably shorter delays (Johnson et al., 2017; 0, 2 min, 5 min, 15 min, 30 min, 1 h, 3 h, and 6 h). Both versions have resulted in similar findings. However, it is important to consider what these delays imply to participants, and how they might affect responses. When asked how long they would consider waiting if a condom were to be available in 2 min versus 1 h (which have both been used in studies as the shortest nonzero delay period), a participant may be interpreting the 2 min delay as a short delay because they, for instance, may be going to another room, to their car, etc. to get a condom in those 2 min. In contrast, a delay of 1 h may be interpreted as having to go to the store. Both circumstances introduce other confounding factors. Convenience, cost, and access may be considerations that a participant is thinking through when deciding how long to wait for a condom. That is, a participant may report that they prefer to engage in condomless sex now if the alternative is waiting 1 h, if that 1 h delay is interpreted as having to go to the store vs. going to another room in their house to get the condom. Further, shorter delays may be better suited following acute substance administration, to limit the task to the active drug time course. More systematic research is needed in this area. In terms of transparent analyses and reporting, a priori assumptions should be stated clearly for data analysis, and open access and supplemental materials should be utilized for results presentation.

Future Directions

This review also highlights critical areas for future research. There is a dearth of experimental studies examining the role of substances in sexual risk-taking as measured by the SDDT, with only one alcohol administration study. Given the well-established role of substances, and, in particular, the role of alcohol, in facilitating the spread of HIV/STIs (Berry & Johnson, 2018; Centers for Disease Control & Prevention, 2019; Santos et al., 2013; Swartzendruber et al., 2019; Wilson et al., 2008), future research is needed. Similarly, future studies can also measure SDDT under "hot" states that parallel real-life sexual decision making (e.g., after inducing sexual arousal). Further, gender comparisons were not always reported. However, findings indicated that women have a higher likelihood of condom use and higher likelihood of waiting for a condom across partner conditions. Given differences in STI/HIV risk between men and women (Sychareun et al., 2013), further research comparing differences in sexual delay discounting between genders is needed. In addition, although there were three studies focused on assessing sexual delay discounting among MSM, two of these papers (Jones, et al., 2018a, b) relied on the same sample. Future laboratory studies examining the effects of substance administration on the SDDT in populations with increased vulnerabilities to HIV and STIs, such as young adult MSM who use substances, may

be increasingly helpful in identifying and targeting mechanisms that may reduce sexual risk while under the influence of substances.

Regarding SDDT administration, there was a lack of specificity in the STIs presented to participants across studies. This could potentially be because the original task did not specify a particular STI. However, research indicates that risk perception for HIV and other STIs (e.g., chlamydia, herpes) varies considerably (Mevissen et al., 2009). Thus, results from these studies should be interpreted within the context of the STI presented to participants as they may not necessarily generalize to other STIs. Importantly, only one study explicitly noted HIV when presenting likelihood of STIs (Wongsomboom & Robles, 2017). Given differing risk perceptions between HIV and other STIs, it will be important for future research to assess risk associated with HIV, by either assessing HIV risk separately and/or explicitly including HIV as one of the STIs presented to participants. Further, risk perceptions, which have been shown to influence sexual risk behaviors (Remien et al., 2005), may vary for non-HIV STIs. That is, individuals may express greater likelihood of condom use with partners perceived as most likely to have an incurable STI (e.g., herpes) compared to a curable STI (e.g., chlamydia). Berry et al. (2019) found that likelihood of condom use was related to the type of STI in the Sexual Probability Discounting Task, for example, where participants reported less likelihood of condom use when presented with a probability of contracting chlamydia, compared to HIV. This difference in discounting based on STI curability, however, has not yet been examined in the sexual delay discounting literature. On the other hand, the lack of specificity in the type of STIs presented in SDDT studies may increase the ecological validity of the measure, as an individual may be more likely to make the decision to have sex with a casual sex partner without assessing the partner's status for various STIs separately. Future research can help disentangle the influence of varying STIs on sexual risk-taking by assessing likelihood of condom use by presenting both specified and unspecified STIs.

Importantly, this review highlights a lack of research aimed at reducing sexual delay discounting. Only three studies included in this review have sought to reduce sexual risk-taking by administering buspirone (Bolin et al., 2016; Strickland et al., 2017) or presenting different health outcome messages (Quisenberry et al., 2015). Future research on preventive (including just-in-time) interventions to reduce sexual risk-taking, especially when individuals are under the influence of substances, is critically needed. Further, growing evidence suggests targeted behavioral interventions, such as episodic future thinking have shown some success in reducing monetary delay discounting in laboratory settings (Rung & Madden 2018; Stein et al., 2016). Future research could examine the efficacy of these interventions in reducing sexual delay discounting.

Limitations

This review has some limitations. Primarily, this review exclusively focused on the M. W. Johnson and Bruner (2012) SDDT. As noted, there are other measures of sexual delay discounting which are utilized less frequently. Future investigations could examine the relations between the different sexual delay discounting measures. Further, although we used a risk of bias tool that accounted for different study designs, bias assessments reported here should be understood in context of the designs of the included studies. For instance, it is likely that power analyses were not reported for several early studies given the novelty of the task, thus downgrading the bias rating of several papers. To our knowledge, three papers that included the SDDT were published during manuscript preparation, after the search for this review was conducted, and thus, were not included here. The authors reviewed these studies. Results from these studies do not change conclusions drawn in the current review or considerations outlined for future directions. Lastly, the exclusion of non-English papers and studies published in non-peer-reviewed outlets may introduce a publication bias.

Conclusion

This review highlights the reliability and validity of the SDDT as a measure of sexual risk-taking despite the heterogeneity of methodologies. The SDDT can also be implemented across different modalities facilitating data collection remotely and from hard-to-reach populations. Although the need for parsimony and journal guidelines on word count are important practical considerations, researchers are encouraged to report on all aspects of studies and findings to contribute to the rigor of the literature and reproducibility of studies. This review also highlights areas in which further research is needed, including more prospective studies to determine if changes in sexual delay discounting are related to changes in real-life sexual behaviors. There is also a need for more experimental substance administration studies, to determine chronic, acute, and dose dependent effects of substance use on sexual risk behaviors.

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Declarations

Conflict of interest The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. NMG, MSB, MA, and RFL contributed to the design of this project. MA designed and conducted the literature searches. NMG, MSB, MK, RFL conducted the initial and full article reviews. JCS reviewed extracted information. All authors contributed to manuscript preparation, revised the manuscript, and approved for publication. All authors report no conflicts of interest.

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