External Validity Issues in Delay Discounting Research on Substance Addiction

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Abstract

Abstract The intertemporal decision-making deficits of individuals with substance addiction have been demonstrated by numerous studies using monetary delay discounting tasks. However, recent findings from variants of monetary delay discounting tasks (substance delay discounting tasks, sexual delay discounting tasks, and cross-category delay discounting tasks) have indicated certain limitations of using monetary delay discounting tasks alone in delay discounting research within the field of substance addiction. First, the level of delay discounting for money among individuals with substance addiction may not fully represent their levels of delay discounting for addictive substances, sex, and other natural rewards; second, using only a single delay discounting task may lead to an oversimplification of the intertemporal decision-making process in individuals with substance addiction; finally, monetary delay discounting tasks are less sensitive than their variants to certain clinical characteristics of individuals with substance addiction. Future research should further enrich and expand cross-category delay discounting studies in the field of substance addiction, and conduct in-depth explorations of temporal factors that may influence intertemporal decision-making.

Full Text

Preamble

The External Validity Problem in Delay Discounting Research on Substance Addiction

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Abstract: The intertemporal decision-making deficits of substance addicts have been consistently demonstrated by numerous studies using monetary delay discounting tasks. However, recent findings from variants of the monetary delay discounting task—including substance delay discounting tasks, sexual discounting tasks, and cross-commodity delay discounting tasks—suggest that the exclusive use of monetary delay discounting tasks in substance addiction research has certain limitations. First, substance addicts' delay discounting rates for money may not fully represent their discounting rates for addictive substances, sex, and other natural rewards. Second, relying solely on a single delay discounting task may oversimplify the intertemporal decision-making processes of substance addicts. Finally, monetary delay discounting tasks are less sensitive to some clinical characteristics of substance addicts compared to their variants. Future research should further enrich and expand cross-commodity delay discounting studies in the field of substance addiction and conduct in-depth explorations of temporal factors that may influence intertemporal decision-making.

Keywords: substance addiction; delay discounting; intertemporal decision-making; external validity

Delay discounting is a classic concept in behavioral economics that describes how the subjective value of a delayed reward decays as the delay interval increases when individuals make intertemporal choices between smaller immediate rewards and larger delayed rewards (Bickel, Johnson et al., 2014; Bickel, Koffarnus et al., 2014). The functional relationship between subjective reward value and delay time conforms to hyperbolic or quasi-hyperbolic models (Tong & Han, 2011; Myerson & Green, 1995), with steeper curves indicating higher levels of delay discounting and reflecting greater devaluation of delayed rewards. Since substance addicts typically exhibit a "myopic" tendency—showing preference for immediate rewards (e.g., the instant pleasure from drug use, rapid alleviation of withdrawal symptoms through medication) and insensitivity to delayed rewards (e.g., benefits from a healthy lifestyle, stable employment and income, good interpersonal relationships)—an increasing number of researchers have introduced the delay discounting perspective to study substance addiction, attempting to understand the abnormal intertemporal decision-making behaviors of addicts through this lens (Bickel & Marsch, 2001; Heinz et al., 2012).

Previous research on intertemporal decision-making in substance addicts has predominantly employed monetary delay discounting tasks (MDDT) or their self-report questionnaire version, the Monetary Choice Questionnaire (MCQ) (for detailed content and calculation methods of MDDT and MCQ, see the review by Koffarnus and Kaplan, 2018). A meta-analysis of MDDT and MCQ studies in addiction found that substance addicts showed significantly higher delay discounting rates than healthy controls, with consistent results across different addictive substances (e.g., cigarettes, alcohol, opioids, cocaine) (Amlung et al., 2017). However, recent findings from MDDT variants in the substance addiction field suggest that MDDT and MCQ have certain limitations in this research domain, primarily concerning external validity issues in lab-

oratory studies. First, substance addicts' delay discounting rates for money differ significantly from their discounting rates for non-monetary rewards such as addictive substances (Giordano et al., 2002), sex (Jarmolowicz et al., 2013), health (Friedel et al., 2016), and freedom (Petry, 2003), suggesting that performance on monetary delay discounting tasks may not represent discounting rates for other rewards, especially addictive substances. Second, both MDDT and substance delay discounting tasks, which present identical immediate and delayed options, overlook the complexity of real-life decision-making processes in substance addicts. Incorporating choices between different types of rewards into MDDT (making the immediate and delayed options belong to different categories) can more comprehensively and precisely reflect the characteristics of addicts' intertemporal decision-making (Bickel et al., 2011; Moody et al., 2017). These two limitations of MDDT warrant serious attention from researchers.

Currently, delay discounting tasks have been applied to studies examining the recovery of intertemporal decision-making abilities (Li et al., 2013), interventions (Bickel, Landes et al., 2014), and relapse prediction (McCarthy et al., 2016) in substance addicts. However, existing evidence suggests that MDDT is less sensitive to some clinical characteristics of substance addicts compared to its variants (Johnson & Bruner, 2012; Moody et al., 2017). This raises an important question: Can the exclusive use of MDDT effectively describe and detect substance addicts' intertemporal decision-making abilities (especially those related to substance use) and their dynamic changes?

Considering external validity concerns in addiction-related delay discounting research, this paper compares MDDT with its major variants in the substance addiction field—substance delay discounting tasks, sexual discounting tasks (SDT), and cross-commodity delay discounting (CCD) tasks—to propose two key issues: the domain specificity of delay discounting and the oversimplification of addicts' intertemporal decision-making processes by single delay discounting tasks. We also review evidence indicating that MDDT' s limitations render it insensitive to some clinical characteristics of substance addicts. In our review, we analyze differences in results across various delay discounting tasks from the perspective of the distinct psychological meanings that non-monetary rewards (e.g., substances, sex) and monetary rewards hold for substance addicts. Finally, we discuss future research directions for delay discounting studies in the addiction field.

2 Domain Specificity Issues in Delay Discounting Research on Substance Addiction

A large body of delay discounting research in substance addiction has utilized MDDT (Bickel, Landes et al., 2014; Li et al., 2013) or its questionnaire form MCQ (Karakula et al., 2016), primarily due to their operational convenience. However, as research has progressed, some researchers have introduced substance delay discounting tasks in studies with substance addicts, considering the specific characteristics of the addiction field. These tasks modify the original

MDDT by replacing hypothetical monetary rewards with hypothetical addictive substance rewards such as cigarettes (Bickel et al., 1999), alcohol (Petry, 2001), heroin (Madden et al., 1997), cocaine (Coffey et al., 2003), or marijuana (Johnson et al., 2010). Participants must make intertemporal choices between immediate and delayed substance rewards (e.g., immediate heroin reward vs. delayed heroin reward). Researchers maintain equivalent value between delayed substance rewards in these tasks and monetary rewards in MDDT through either subjective equivalence (where each participant independently assesses the amount of substance equivalent to a certain monetary value) (Giordano et al., 2002) or objective equivalence (where researchers estimate the amount of substance equivalent to a certain monetary value based on market prices) (Madden et al., 1997), enabling direct comparison of potential differences in discounting between substances and money.

Studies across different types of substance addicts consistently find that addicts' delay discounting rates for their corresponding addictive substances are significantly higher than their discounting rates for money (Zhang et al., 2009; Bickel et al., 1999; Coffey et al., 2003; Giordano et al., 2002; Johnson et al., 2010; Johnson et al., 2007; Johnson et al., 2015; Madden et al., 1997; Petry, 2001). This difference may not be a consequence of substance abuse itself. Weatherly et al. (2010) examined delay discounting for money and cigarettes among healthy college students and found that these non-smoking participants also showed significantly higher discounting rates for cigarettes than for money. In Odum and Rainaud' s (2003) study, healthy participants with no substance abuse history exhibited significantly higher discounting rates for alcohol and food than for equivalent monetary value. Interestingly, these participants showed no significant difference in discounting rates between alcohol and food. It is worth noting that although Johnson et al. (2010) found that marijuana-dependent individuals had higher discounting rates for marijuana than for money, this difference disappeared when the researchers controlled for marijuana use frequency in their analysis. These findings suggest that differences between substance delay discounting tasks and MDDT may stem from the "consumable" nature of addictive substances (Johnson et al., 2010; Johnson et al., 2015; Odum & Rainaud, 2003). Money, as a general equivalent for transactions, does not deteriorate or spoil over time. Moreover, in substance addiction behaviors, the addictive substance serves as a primary reinforcer, while money functions as a secondary reinforcer (Zhang et al., 2009; Odum et al., 2020; Odum & Rainaud, 2003). Compared to addictive substances, money has higher tradability (it can be used to purchase various items including addictive substances) and thus better maintains its value over time (Holt et al., 2016). Substance addicts may not directly need monetary rewards but rather expect to exchange them for corresponding amounts of addictive substances. Consequently, monetary and substance rewards hold completely different psychological meanings for substance addicts, making it potentially incomplete to directly use performance on MDDT to describe their intertemporal decision-making characteristics. Although some researchers have proposed, based on meta-analysis, that different types of delay discounting show

certain correlations and thus represent a general trait of individuals (Odum et al., 2020), considering the specific characteristics of the addiction field, substance delay discounting tasks or other MDDT variants may better reflect the intertemporal decision-making processes of substance addicts. Some researchers have noted that participants' monetary delay discounting rates and their range of variation are lower than those for other rewards (e.g., addictive substances), which may prevent the detection of certain factors' effects on delay discounting (e.g., neural stimulation) (Steenbergen et al., 2020). Therefore, we must exercise caution when interpreting results from MDDT in substance addiction populations, and incorporating substance delay discounting tasks can enhance the external validity of delay discounting research on substance addicts.

On the other hand, substance addiction populations face many other life problems beyond their addictive behaviors, with risky sexual behavior and potential HIV infection being typical examples (Lei et al., 2019; Ekhtiari et al., 2017; Thamotharan et al., 2015; Villalobos-Gallegos et al., 2019). The Sexual Discounting Task (SDT) is precisely designed to study risky sexual behavior in addiction populations from an intertemporal decision-making perspective and is highly suitable for laboratory research on addicts' risky sexual behavior (Leeman et al., 2019). In this task, each participant first selects a hypothetical sexual partner from a photo database before the experiment begins. During the task, participants must make intertemporal choices between immediate risky sexual behavior (without condom use) and delayed safe sexual behavior (with condom use) (Koffarnus et al., 2016; Strickland et al., 2017). Studies across different types of substance addicts have found that the correlation between addicts' monetary delay discounting rates and their discounting rates for safe sexual behavior is not significant (Herrmann et al., 2014; Johnson & Bruner, 2012; Johnson & Bruner, 2013; Johnson et al., 2015). These SDT findings further support the hypothesis of domain specificity in delay discounting, suggesting that there may be no general delay discounting rate (Green & Myerson, 2013; Jarmolowicz et al., 2013; Lawyer & Schoepflin, 2013; Mejía-Cruz et al., 2016; Weatherly et al., 2010). Individuals' monetary delay discounting and their discounting for other rewards (e.g., addictive substances, safe sexual behavior) represent independent dimensions (Mahoney & Lawyer, 2018; Stoltman, 2019).

3 Oversimplification of Intertemporal Decision-Making Processes by Single Delay Discounting Tasks

From the perspective of whether immediate and delayed rewards belong to the same category, monetary delay discounting tasks, substance delay discounting tasks, and sexual discounting tasks all constitute Single-Commodity Delay Discounting (SCD) tasks. According to the decision-making scenarios simulated by SCD tasks, participants must choose between immediate and delayed rewards of the same category (e.g., money, drugs, health, or sex) (Giordano et al., 2002; Karakula et al., 2016; Madden et al., 1997). However, substance addicts face not only intertemporal decisions within the same reward category but

more frequently must make choices between different reward categories (e.g., immediate reward from drug use vs. delayed reward of stable employment and income from maintaining abstinence). To better simulate these intertemporal decision-making scenarios, some researchers have proposed delay discounting tasks that include combinations of different reward categories (e.g., immediate substance reward vs. delayed monetary reward, or immediate monetary reward vs. delayed substance reward), known as Cross-Commodity Delay Discounting (CCD) tasks. In these tasks, the quantity of non-monetary rewards (primarily addictive substances) is determined based on each participant' s subjective monetary value assessment (Wesley et al., 2014; Yoon et al., 2018), facilitating comparison across different delay discounting tasks. Comparing laboratory results from CCD tasks with those from SCD tasks has deepened our understanding of the complexity of substance addicts' intertemporal decision-making processes.

Although SCD task studies have found that addicts show higher delay discounting rates for substance rewards than for monetary rewards (Giordano et al., 2002; Madden et al., 1997), comparative studies of SCD and CCD tasks in substance addiction populations have further revealed that in CCD tasks where money serves as the immediate reward and the substance as the delayed reward, addicts exhibit higher discounting rates than in SCD tasks where both immediate and delayed rewards are substances. Conversely, in CCD tasks where the substance serves as the immediate reward and money as the delayed reward, addicts show lower discounting rates than in SCD tasks where both options are substances (Bickel et al., 2011; Moody et al., 2017). From the perspective of the substance' s position in the intertemporal choice, substance addicts' discounting rates are always higher when the substance is the delayed reward than when it is the immediate reward, regardless of whether the alternative is money or the substance itself. In other words, when the substance can only be obtained after a delay rather than immediately, substance addicts' preference for the substance decreases (Bickel et al., 2011).

This finding may be related to the consumable nature of addictive substances. According to the decreasing future preference hypothesis proposed by Odum et al. (2020), consumable goods (e.g., drugs, cigarettes) are less attractive to individuals in the future than in the present. When addictive substances are only available after a delay, their value to substance addicts is more likely to depreciate than that of money. This discovery may partially explain the mechanism underlying the effectiveness of contingency management in clinical interventions for addiction. Contingency management stipulates that addicts in treatment receive immediate monetary rewards for providing negative urine test results over a period, with the amount increasing for consecutive negative results. The longer addicts maintain abstinence, the more monetary reward they receive each time, while a single positive urine test resets the reward to the initial level (Landes et al., 2012). The gradually increasing immediate monetary rewards from maintaining abstinence may outcompete delayed drug use (Bickel et al., 2011), thereby motivating addicts to continue abstinence. We may leverage substance

addicts' higher devaluation tendency for delayed substance rewards observed in CCD tasks to help them maintain abstinence.

Although CCD task research is still relatively limited compared to SCD task studies, existing findings suggest that from an external validity perspective, SCD tasks may oversimplify the intertemporal decision-making processes of substance addicts. The intertemporal decision-making processes these individuals face in real life may be more complex than those simulated by SCD tasks. Depending on the specific position of rewards in the intertemporal choice, the relative value of addictive substances and money may change. Continuing to employ CCD tasks to study different types of substance addicts is crucial for describing, explaining, predicting, and intervening in their intertemporal decision-making.

4 Monetary Delay Discounting Task' s Insensitivity to Clinical Features of Substance Addicts

MDDT has been widely used in research on the recovery, intervention, and relapse prediction of intertemporal decision-making abilities in substance addicts. Considering the domain specificity of delay discounting in substance addiction and the oversimplification of addicts' intertemporal decision-making processes by single delay discounting tasks, we have reason to suspect that the exclusive use of MDDT in research may further affect the validity of applied or clinical studies in this field. In other words, whether MDDT is the most ideal task for capturing dynamic changes in substance addicts' intertemporal decision-making abilities during abstinence and intervention remains questionable. Recent studies comparing MDDT with its variants have found that these variants are more sensitive to some clinical characteristics of substance addicts, further supporting our speculation.

Comparisons between MDDT and CCD task results in substance addicts suggest that single-category MDDT may be insensitive to addicts' withdrawal status and addiction severity. Mitchell (2004) examined the same group of cigarette addicts under withdrawal and non-withdrawal conditions using both MDDT and a CCD task where cigarettes served as the immediate reward and money as the delayed reward. The results showed that in the CCD task, although cigarette addicts did not exhibit higher overall delay discounting rates during withdrawal compared to non-withdrawal, they selected immediate cigarette rewards significantly more often during withdrawal. Moreover, the subjective equivalent value corresponding to the indifference point was significantly lower during withdrawal than during non-withdrawal (lower indifference point values indirectly indicate greater devaluation of delayed rewards), reflecting more impulsive decision-making. However, in the single-category MDDT, no significant differences were found between the two states in terms of immediate monetary reward selection frequency or indifference point values. The increased approach toward immediate cigarette rewards rather than immediate monetary rewards after withdrawal in this study indicates that cigarettes and money hold different psychological meanings for addicts. Addiction to a specific substance (e.g.,

cigarettes) may lead to higher discounting rates for that substance (Odum & Baumann, 2007; Odum et al., 2020), and cigarette withdrawal may also make cigarette addicts more inclined to choose immediate cigarettes to alleviate withdrawal symptoms. For addicts in withdrawal, cigarettes serve as direct negative reinforcers to eliminate withdrawal symptoms, whereas money can only do so indirectly (by purchasing cigarettes). This suggests that CCD tasks are more sensitive to cigarette withdrawal status than single-category MDDT. Yoon et al.' s (2009) withdrawal study on cigarette addicts further supports this view. Previous studies' failure to find changes in addicts' delay discounting due to withdrawal duration may be related to the tasks used (Heil et al., 2006; Li et al., 2013), and future research could use CCD tasks to further investigate this issue.

On the other hand, Moody et al. (2017) used both SCD and CCD tasks (four task combinations) to examine delay discounting rates in alcohol addicts with varying addiction severity. They found that addiction severity was significantly correlated with discounting rates in CCD tasks but not with those in SCD tasks. Notably, even when excluding MDDT and comparing SCD tasks where both immediate and delayed rewards were substances with CCD tasks, the correlation between discounting rates in single substance delay discounting tasks and addiction severity remained non-significant. This indicates that CCD tasks' greater sensitivity to addiction severity is not caused by drug craving states induced by exposing abstinent addicts to substance-related stimuli in the experimental tasks. Furthermore, heavy addicts showed smaller variations in discounting rates across the four tasks than light addicts, demonstrating a convergence trend. In this study, the key difference between CCD and SCD tasks was that CCD tasks involved comparisons of relative value between alcohol and money. Considering that addictive substances are consumable and thus more prone to depreciation over time, while money is tradable and relatively stable in value, cross-category reward comparisons involve more complex psychological processes than within-category comparisons at both present and future time points. In summary, CCD tasks more ecologically simulate the intertemporal decision-making scenarios that substance addicts face in real life through more complex task designs, which may explain their greater sensitivity in detecting decision-making patterns across different states and addiction severity levels compared to SCD tasks.

Even without considering CCD task results, studies using only SCD tasks have revealed that MDDT is insensitive to some clinical features related to risky sexual behavior in substance addicts. These findings come from comparisons between MDDT and SDT results. First, in Johnson and Bruner' s (2012) study, cocaine addicts' monetary delay discounting rates were not correlated with their scores on the sexual risk subscale of the HIV Risk-Taking Behavior Scale (HRBS), whereas their discounting rates for safe sexual behavior were significantly positively correlated with their sexual risk scale scores. In other words, cocaine addicts who showed higher discounting rates in SDT indeed engaged in more risky sexual behavior in real life, while their monetary delay

discounting rates were not associated with actual risky sexual behavior. Other studies have found that alcohol addicts' monetary delay discounting rates were significantly correlated with the frequency of risky sexual behavior under alcohol influence but not with overall risky sexual behavior in daily life (Celio et al., 2016; MacKillop et al., 2015). This suggests that results from MDDT cannot effectively predict or explain risky sexual behavior exhibited in real life. Second, MDDT and SDT showed experimental dissociation in acute dosing studies: alcohol consumption increased individuals' discounting rates for safe sexual behavior but did not significantly change their monetary discounting rates (Johnson et al., 2016). Similar results were found in acute dosing studies with cocaine addicts (Johnson et al., 2017). Finally, research has found that young marijuana and cigarette addicts with different addiction severity levels showed significant differences in discounting rates for safe sexual behavior but not for money (Thamotharan et al., 2017), indicating that SDT is more sensitive to addiction severity than MDDT. These results further demonstrate that discounting for safe sexual behavior and discounting for money involve two distinct psychological processes (Johnson et al., 2015). For individuals, sexual behavior and money differ not only as primary (sex related to survival and reproduction) versus secondary (money for commodity exchange) reinforcers. On one hand, the value of sexual behavior is highly time-sensitive, whereas monetary value is relatively stable. More importantly, the value of safe sexual behavior is also influenced by factors such as partner attractiveness, risk of sexually transmitted infections, and pregnancy risk (Stoltman, 2019), whereas monetary value is not affected by these factors (which MDDT cannot simulate). Considering these differences in psychological meaning between sexual behavior and money, SDT' s more authentic simulation of individuals' intertemporal decision-making processes related to sexual behavior may explain its greater sensitivity in detecting clinical features related to risky sexual behavior in substance addicts compared to MDDT.

5 Summary and Outlook

This paper reviewed delay discounting studies in the addiction field using MDDT and its major variants from an external validity perspective. Accumulating evidence suggests that delay discounting may be domain-specific (Lawyer & Schoepflin, 2013; Mejía-Cruz et al., 2016), with different types of delay discounting holding different psychological meanings for substance addicts (Odum & Rainaud, 2003). Meanwhile, single delay discounting tasks may oversimplify the intertemporal decision-making processes of substance addicts. Additionally, MDDT is less sensitive to some clinical characteristics of substance addicts than its variants, and introducing appropriate tasks based on specific research questions can compensate for this limitation. Examining substance addicts' delay discounting rates in cross-commodity tasks can effectively expand our understanding of their real-life intertemporal decision-making (Moody et al., 2017). Studying intertemporal decision-making in substance addicts not only helps explain their addictive behaviors and implement effective interventions from a behavioral economics perspective but also provides guidance and inspiration for

clinicians and social workers to address other problems in this population' s lives (e.g., high HIV infection rates) (Johnson & Bruner, 2012). Based on this review, we propose the following future research directions for delay discounting studies in the addiction field:

First, from an external validity perspective, cross-commodity delay discounting tasks involve not only intertemporal decision-making but also choices between different reward types, making them more similar to real-life intertemporal decision-making scenarios faced by substance addicts. However, existing CCD task studies with substance addicts have used overly limited cross-category combinations, mostly confined to addictive substances and money. In real life, addicts face far more diverse intertemporal decision-making combinations, such as immediate substance use versus delayed health, good interpersonal relationships, stable employment, etc. Future research should further enrich and expand cross-commodity delay discounting tasks to better approximate the real lives of substance addicts, thereby increasing external validity and deepening our understanding of their intertemporal decision-making processes.

Second, as delay discounting research in substance addiction continues to develop, beyond focusing on reward types in delay discounting tasks (money, addictive substances, safe sexual behavior, health, freedom, etc.), the authenticity of delay intervals has also attracted researchers' attention. Studies have found that delay discounting rates derived from imagining delay intervals versus actually experiencing them are not correlated (Johnson, 2012), and whether other activities are restricted during the delay interval constitutes an opportunity cost, leading substance addicts to show different discounting rates and intertemporal decision-making patterns for the same reward (Johnson et al., 2015). Additionally, researchers have noted that individuals' subjective time perception may be an important factor influencing their intertemporal decision-making (Paasche et al., 2019; Wittmann & Paulus, 2008; Zauberman et al., 2009). Future research should further investigate the mechanisms through which delay intervals influence substance addicts' intertemporal decision-making and identify temporal factors that may affect their choices. Research on the mechanisms of delay intervals can both enrich our understanding of intertemporal decision-making in substance addiction populations and potentially improve the external validity of intertemporal decision-making research.

Third, some addiction-related delay discounting tasks use non-monetary rewards (e.g., addictive substances, health, sexual behavior) as delayed rewards and employ subjective estimation methods to determine the quantity of delayed rewards (Jarmolowicz et al., 2014; Johnson et al., 2007). While this approach enhances external validity, it undoubtedly increases researchers' workload, as they must "tailor" experimental procedures for each participant. Moreover, whether abstract concepts like health and sex can be meaningfully measured in monetary terms remains questionable. Future research should consider these issues to ensure that delay discounting studies maintain good external validity while remaining operationally feasible.

Fourth, considering the specific characteristics of substance addiction populations, money in real life may serve as a tool to obtain drugs. The process of exchanging money for drugs may be subject to uncertainties such as inflation, constituting a "hidden cost" that causes fluctuations in the attractiveness of money to substance addicts. Future delay discounting studies could incorporate questionnaires or interviews to explore the real motivations behind substance addicts' pursuit of monetary rewards after experiments conclude. This approach could further clarify and address potential limitations of monetary delay discounting tasks while providing insights for research exploring the influence of motivation on delay discounting in substance addicts.

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Note: Figure translations are in progress. See original paper for figures.