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To produce or not to produce? Contrasting the effect of substance abuse in social decision-making situations

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A R T I C L E I N F O

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A B S T R A C T

Substance use disorders (SUD) have been related to high criminal justice costs, expensive healthcare, social impairment, and decision-making deficits. In non-social decision-making tasks, people with SUD tend to take more risks and choose small immediate rewards than controls. However, few studies have explored how people with SUD behave in social decision-making situations where the resources and profits depend directly on participants' real-time interaction, i.e., social foraging situations. To fulfill this gap, we developed a real-time interaction task to (a) compare the proportion of producers (individuals who tend to search for food sources) and scroungers (individuals who tend to steal or join previously discovered food sources) among participants with SUD and controls with respect to the optimal behavior predicted by the Rate Maximization Model, and (b) explore the relationship between social foraging strategies, prosocial behavior, and impulsivity. Here participants with SUD ($n = 20$) and a non-user control group ($n = 20$) were exposed to the Guaymas Foraging task (GFT), the Social Discounting task (SD), and the Delay Discounting task (DD). We found that participants in the control group tended to produce more and obtain higher profits in contrast to substance abuser groups. Additionally, SD and DD rates were higher for scroungers than producers regardless of the group. Our results suggest that producers tend to be more altruistic and less impulsive than scroungers. Knowing more about social strategies and producers' characteristics could help develop substance abuse prevention programs.

1. Introduction

Substance-related disorders (SUD) have been related to high criminal justice costs and social impairment, including failing to fulfill obligations, interpersonal problems, and giving up important social activities [1,2]. In addition, substance-related disorders have been widely associated with social and non-social decision-making deficits. The Northwest region of Mexico is known for its high prevalence of illegal drug use, and one of the crimes related to drug abuse is theft to purchase substances [3]. For example, in juvenile detention centers, 24.3% of crimes were committed under the influence of some substance, and theft was one of the most prevalent offenses [4].

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This study aims to evaluate the relationship between producer-scrounger strategies and prosocial behavior as well as impulsivity by utilizing a new experimental task. For instance, in non-social tasks like delay discounting tasks, previous research has shown that people with SUD tend to prefer small immediate rewards over large later rewards [5], while in decision-making under ambiguity, such as the Iowa Gambling task (IGT), people with SUD tend to choose long-term disadvantageous alternatives [6]. Additionally, in decision-making under risk, such as the Columbia Card Task (CCT) and the Balloon Analog Risk Task (BART), individuals with SUD tend to take more risks even in unfavorable conditions [6–9].

Regarding social-decision making, in social discounting tasks, individuals with SUD tend to show a lower propensity to share resources or exhibit prosocial behavior compared to control participants [10]. In addition, behavioral pharmacology studies have explored the impact of drug consumption on cooperation dilemmas and social processes [11,12]. In the Ultimatum Game, where the first player proposes a division of money and the second player can either accept or reject the offer, the rejection rates of unfair offers were significantly higher for people with alcohol and heroin use disorder than control participants [13]. However, the rejection rates for most unfair offers in ecstasy and cocaine users remain unclear [14–16]. These studies suggest that SUD can affect social decision-making in turn-taking interaction situations, where participants have time to plan and execute a strategy.

The inconclusive findings regarding the relationship between social decision-making and SUD could be attributed to various factors, such as the variety of tasks and social dilemmas used, as well as the experimental conditions in which the participants were studied. Regarding the last one, participants are typically asked to interact with a virtual agent that simulates another participant or imagine their relationship with others [4,17,18]. In this regard, the decision-making behavior of people with SUD has not been studied in social situations where three or more participants compete simultaneously for resources or where profits depend directly on the real-time strategies chosen by other participants. Here we aimed to fulfill this gap by using a novel task inspired by social foraging situations [19,20] that captures the components of a foraging episode (search, identification, selection, consumption, and handling). We consider that one of the advantages of this task is the possibility of studying not only the participants' sensitivity to other participants' choices and profits but also their sensitivity and attention to the behavior and actions of others. This task could provide new information on how people with SUD handle social contexts.

Group resource search situations or social foraging situations are particularly interesting for accessing social decision-making because the participants must organize, cooperate, compete, and adjust their behavior to other participants or environment changes, similar to real-life social situations, where the amount of resources or the achievement of goals depends on the behavior of each member of the group [17,18]. There are two approaches for social foraging situations. Firstly, the information sharing model highlights the social advantage of searching and sharing information about food sources simultaneously [21]. Secondly, the Producer-Scrounger Game suggests that group members choose one of two mutually exclusive strategies, which in combination enable the group survival: (a) invest time searching for their resources (Produce), and (b) join a previously discovered patch zone (Scrounge). The Producer-Scrounger Game describes the optimal proportion of producers and scroungers within a group or responses that reaches an Evolutionarily Stable Strategy [21–23]. If all group members tended to scrounge, they wouldn't get the resources needed to survive, showing a non-optimal behavior; if all the group members tended to produce, they would not resist the arrival of a new member with a different strategy, also showing a non-optimal behavior. The Rate Maximization Model (RMM) predicts the proportion of producers that should be in a group based on each strategy intake [19,24]. This model (Equation (1)) assumes that the producer's proportion ($\hat{P}$) in a group will depend on group size (G), the food units in patch zones (F), and the finder share (a).

$$\hat{P} = \frac{a}{F} + \frac{1}{G} \tag{1}$$

Despite model predictions have been tested in several species [12],[16],[19], only a few studies have tested these predictions in human participants in sequential turn-taking tasks or non-real-time interaction tasks [17,18].

Considering that (a) the literature is still inconclusive about the cooperativeness in social decision-making behavior in people with SUD; (b) so far, there is no study investigating decision-making behavior in social real-time interaction in SUD; (c) social foraging situations promote unique scenarios for better understanding social decision-making in group scenarios; (d) there is no study investigating whether the RMM would predict the optimal proportion of producers and scroungers in people with SUD; The objectives of this study are: (I) compare the proportion of producers and scroungers among participants with SUD and controls concerning the optimal behavior predicted by the RMM and (II) explore the relationship between social foraging strategies, prosocial behavior, and impulsivity. We expected to provide information about the relationship between prosocial behaviors and impulsivity in the execution of producer and scrounger strategies in social foraging situations in individuals with SUD. This information will help to design interventions aimed at social readjustment.

2. Method

2.1. Participants

The study included a total of forty participants; Twenty healthy control participants (male: n = 16; female: n = 4; age: $M = 23.08$, $SD = 12.61$), and twenty males with substance use disorders (SUD group) recruited from a residential addiction treatment center in the north of Mexico (male: n = 20 age: $M = 32.07$, $SD = 14.10$). The SUD group participants were in the second or third week of treatment and were referred to by the head psychiatrist of the center. The inclusion criteria included having no withdrawal symptoms, schizophrenia events, or other psychotic disorders reported by the psychiatrist in their file in the 72 previous hours. Individuals who did not meet these criteria were not invited to participate in the study The treatment consisted of 3 months of cognitive-behavioral training and motivational interviewing strategies see for details [25]. The control group was college students and friends or relatives of students. The participants in the control group did not have any psychiatric diagnoses, neurological diagnoses, and substance use disorders. They were invited through a call promoted by the psychology department of the university.

The Sonora Institute of Technology Institutional Review Board (ID 84) approved the research protocol, ensuring that the study design and procedures met the ethical standards outlined in the Declaration of Helsinki. All participants provided written informed consent, which included information about the study objectives, procedures, and potential risks and benefits. Participants were not compensated with money for their participation. Additionally, the informed consent stated that personal information would only be used for research.

2.2. Behavioral tasks

2.2.1. Guaymas Foraging Task (GFT)

To capture the elements of a social foraging episode, the user interface and the design of this task were inspired by the typical experimental preparations used to study social foraging situations in non-human species and Agent-Based Models [19,22]. The objective of this task was to take as many resources (here depicted by carrots) as possible using one of the two strategies, produce or scrounge. In the first frame, four participants were automatically arranged in the center of a virtual habitat (800 x 800 px) with four patch zones (200 x 200 px) in each habitat corner (Fig. 1a). Using a joystick, participants could move an agent (25 x 25 px) in any direction during the task. In subsequent frames, participants could move the agent to a patch zone and hold down the joystick button

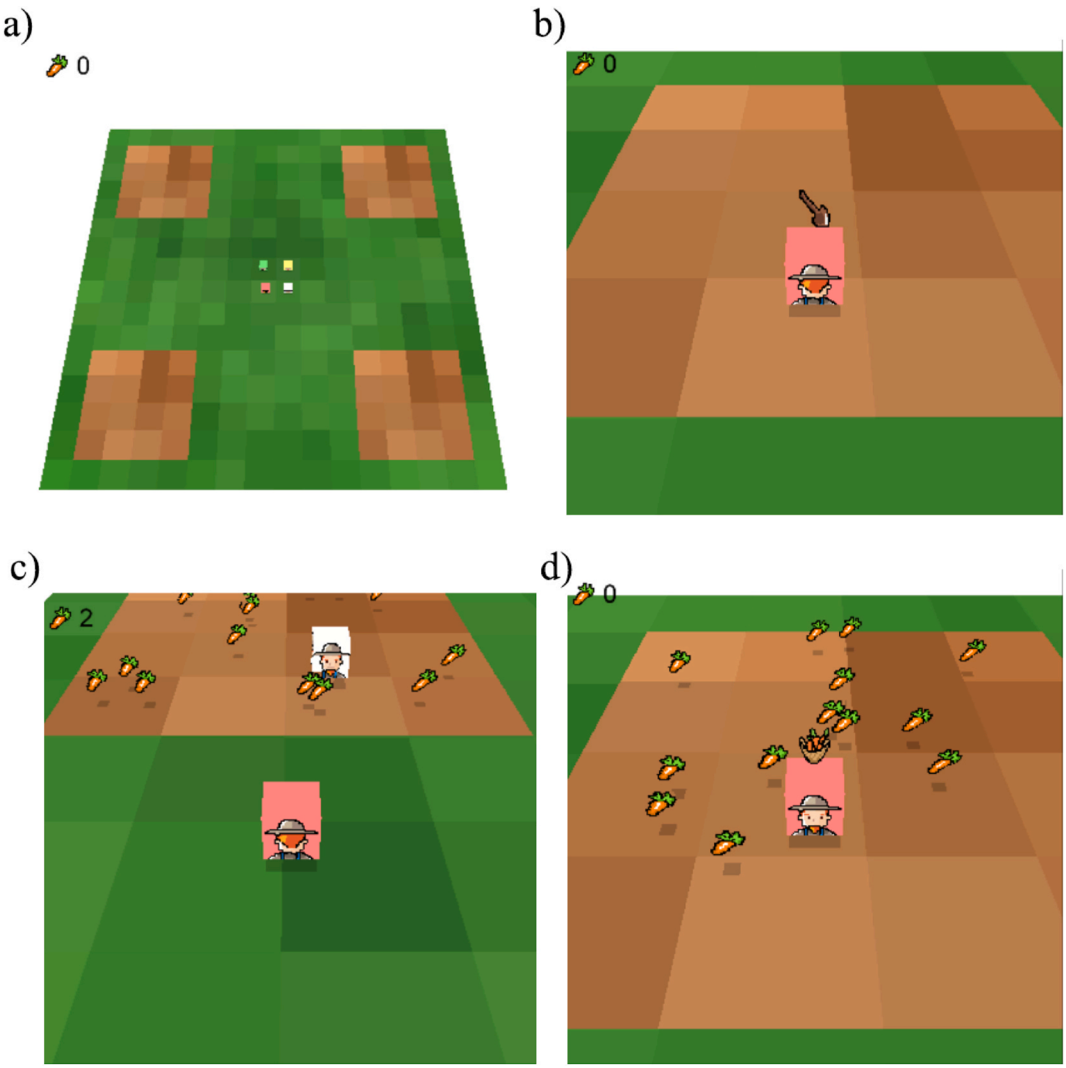

Fig. 1. Screenshot of Guaymas Foraging Task
Note: Each of the panels show a screenshot of the task. a) Transition and patches zones within the virtual habitat, b) Participant producer response within a patch zone, c) Participant joining a patch zone (scrounge), and d) Resource manipulation time.

(2 s) to produce (see Fig. 1b) or join a discovered patch zone to scrounge (Fig. 1c). To consume the carrots, the participants only had to collide with them and wait for the manipulation time (2 s), during which they remained immobile (Fig. 1d). When participants failed to find carrots, a cross was displayed over the agent. The participants were shown the number of carrots consumed in the upper corner of their screen. Before starting the experimental session, participants were exposed to a 60 s training phase in which they had to search individually for five carrots. Subsequently, participants were exposed randomly to four social foraging conditions that differed in the probability of finding resources, high probability (Hp = 0.8) and low probability (Lp = 0.2), and the number of carrots, few units (Fu = 5) and many units (Mu = 15). Each condition lasted for 4 min. For each participant, the producer index was calculated using equation (2) as follows:

$$Producer's\ index = \frac{Producer's\ responses - Scrounger's\ responses}{Producer's\ responses + Scrounger's\ responses} \tag{2}$$

2.2.2. Social discounting task (SD)

Participants were asked to imagine a list of 100 people and order it. Person number 1 should be a precious person for them, while the person in position 100 could be someone they have just met who may not remember their name. At the beginning of each person on the list, participants could choose between giving $200 to the person or taking $100. If they took $100 for themselves, the value of the alternative decreased by 50% (i.e., $50). On the other hand, if they gave the $200 to the person on the list, in the subsequent trial, they could take $150 for themselves (a 50% increase). This procedure was repeated 7 trials for each person on the list. Seven positions of the list (1, 2, 10, 20, 50, and 100) presented in random order were used. To estimate participants' discounting rate, we fit the hyperbolic equation (equation (3)) where V is the subjective value of the delayed outcome, b is the discount rate, and x is the social distance. Higher b values are interpreted as less altruistic [10].

$$V = \frac{A}{1 + bx} \tag{3}$$

The Area Under the Curve (AUC) was calculated from the empirical discounting curve, considering the estimated indifference points. These values provide an atheoretical measure of how' steeply' participants discount a specific outcome. A value equal to 0.0 is the maximum theoretical discounting value, and 1.0 indicates the minimum discounting value. The social discounting task has shown good reliability in the United States population ($r = 0.71$) and Indonesia population ($r = 0.67$) [26].

2.2.3. Delay discounting task (DD)

Participants were asked to choose between immediate or delayed monetary hypothetical rewards. At the beginning of each presented delay, participants must choose between the delayed ($200) or the immediate ($100) alternative. If they chose the delayed alternative, the value of the immediate alternative increased by 50% (i.e., $150). On the other hand, if they chose the immediate alternative, it would decrease by 50% (i.e., $50). This procedure was repeated 7 trials for each delay. Five delays (7, 30, 180, 360, and 1080 days) were presented in random order [27]. The AUC, and the b value parameter of the hyperbolic function, allow us to estimate how each participant discounted the monetary consequences. Higher b values are interpreted as more impulsiveness [28]. The delay discounting task has shown good reliability using several outcomes and populations [29,30].

2.3. Procedure

This study used a cross-sectional design for task administration and a factorial design to manipulate the number and probability of resources in the GFT. An anonymous survey website was created for this study. All data was stored on our server in CSV (comma separated values) files using the PHP POST method for future analysis. The files and codes for analysis can be downloaded from https:lcsia.com/PaperData/GFT.zip. The tasks used for this study can be found online at https:lcsia.com/Pruebas.html. Due to COVID-19 restrictions, SUD group assessments were limited to 60 min. Social distancing was also maintained, masks were encouraged, and hand sanitizer was provided. Assessments took place in the psychology offices of the drug rehab facilities for the SUD group, while for the control group assessments took place in the psychology offices of the university. The researcher read the informed consent aloud to the participant and then assigned an ID folio. To perform the GFT, subgroups of four participants were formed. Each participant was given a joystick and sat in an individual seat 1.5 m from a 42-inch monitor. At the end of the GFT task, each participant was given a tablet to complete the DD and SD tasks. Participants were exposed to each task in the following order GFT, DD, and SD.

2.4. Data analysis

For demographic characteristics (age, education, income levels), frequency of tobacco and marijuana cigarettes, frequency of alcohol consumption, and the quantity of methamphetamine used (grams), we calculate the frequencies, means, medians, and standard deviations. To determine whether a parametric or non-parametric statistical test would be used, we perform a normality analysis that includes a Kolmogorov-Smirnov test and a Shapiro-Wilk test, and a homogeneity of variances that includes Levene's test. The results suggested using a nonparametric test for the demographic and substance use characteristics (Mann–Whitney U test), and a parametric test for the outcome variables (i.e., decision-making behavior).

We conducted an ANOVA test for Guaymas Foraging Task dependent variables. For the ANOVA analysis of the producer index, the number of carrots and probability were included, while for the analysis of carrot consumption, the number of carrots, probability, and type of consumption were included. A Pearson Correlation was implemented to test the relationship between the producer index and the RMM predictions. RMM predictions were estimated from food units, group size, and mean group finder share (see additional details and equation (1)). The average producer index of the four conditions was used to classify participants as producers or scroungers. Participants with a mean greater than the 75th percentile of the group were classified as producers, and participants with a mean lower than the 25th percentile were classified as scroungers.

The hyperbola function was used to plot the median indifference points of the SD and DD. An ANOVA (Group*Strategy) was used to compare the AUC of SD and the AUC of DD. All the data and statistical analyses were performed using MATLAB v. R2018b ® and JASP.

3. Results

The SUD group had an average of 84.8 abstinence days (SD = 65.75), and 75% were polysubstance abusers, according to their survey. The group comparisons did not show significant differences among the SUD and controls regarding income level ($p = .356$) and frequency of alcohol consumption ($p = .47$). In contrast, there were statistically significant age differences ($p = .037$, $r = 0.38$), level of education ($p = .005$, $r = -0.51$) frequency of tobacco ($p < .001$, $r = 0.65$), marijuana ($p = .002$, $r = 050$), and quantity of crystal meth consumption in grams ($p < .001$, $r = 0.85$), see Table 1.

The producer index was higher for the control group than the SUD group in all four conditions, regardless of the probability of the number of carrots. In this sense, the SUD group tended to scrounge more than the control group. (Table 2). Additionally, both groups tended to produce more in conditions with fewer carrots and a higher probability of finding them. These results are consistent with the predictions of the RRM and the results obtained in other species [19,31,32].

A two-way ANOVA analysis revealed a significant interaction between probability and group ($F(1, 38) = 9.274$, $p = .004$, ω2 = 0.038), as well as a main effect of probability ($F(1, 38) = 58.17$, $p < .001$, ω2 = 0.214) and the number of carrots ($F(1, 38) = 13.17$, $p < .001$, ω2 = 0.048). Furthermore, a post hoc Tukey test indicated significant differences in the producer's index between the low-probability and high-probability conditions for the control group ($p < .001$) and SUD group ($p = .013$). The mean group producer index, ordered by the RMM predictions, is presented in Fig. 2. The results suggest that the control group was more sensitive to conditions changes (probability and number of carrots) compared to the SUD group.

The total number of carrots collected by the control group was higher in all conditions (Fig. 3). Concerning the type of consumption (producer or scrounger), the control group tended to collect more carrots using the producer strategy in high-probability conditions than the SUD group, while in low-probability conditions, the control group tended to collect more carrots using the scrounger strategy (see Table 2). These results highlight the sensitivity of the control group to different conditions and their advantage in increasing the amount of resources obtained. A three-way ANOVA revealed a significant interaction among food probability, food units, and groups ($F(1, 38) = 15.78$, $p < .001$, ω2 = 0.066) and a significant interaction among food probability, type of consumption, and groups ($F(1, 38) = 10.42$, $p = .003$, ω2 = 0.157). A main effect was observed for probability ($F(1, 38) = 711.51$, $p < .001$, ω2 = 0.843), number of carrots ($F(1, 38) = 337.61$, $p < .001$, ω2 = 0.518) and type of consumption ($F(1, 38) = 48.6$, $p < .001$, ω2 = 0.520). Additionally, a post hoc Tukey test indicated statistically significant differences in the number of carrots collected among groups in probability conditions ($p < .05$) and the number of carrots conditions ($p < .05$). Moreover, there were statistically significant differences observed between the types of consumption within each group ($p < .05$).

Fig. 4 shows the relationship between the mean producer index and RMM predictions. A Pearson correlation revealed a statistically significant positive coefficient for the SUD group, $r = .44$, $p = .048$ (Fig. 4b), but not for the control group, $r = .089$, $p = .710$ (Fig. 4a). Despite both groups showing consistent behavior with the qualitative predictions of the model [24], only the SUD group behaves according to the quantitative predictions of the model.

Fig. 5 shows the hyperbola model fit and AUC for SD and DD tasks. The SD rate was higher for scrounger (Control: $b = .71$, $R^2 = 0.82$, SUD: $b = 0.09$, $R^2 = 0.95$) than producer participants (Control: $b = 0.04$, $R^2 = 0.85$, SUD: $b = 0.05$, $R^2 = 0.81$) in both groups (Fig. 5a). The area under the curve was higher for producers (Control: $M = 0.51$, $SD = 0.39$, SUD: $M = 0.65$, $SD = 0.12$) than for scrounger participants (Control: $M = 0.18$, $SD = 0.07$, SUD: $M = 0.31$, $SD = 0.25$) in both groups (Fig. 5b). An ANOVA 2x2 revealed a main effect only for the strategy used ($F(1, 1) = 7.77$, $p = .013$, ω2 = 0.26). No significant interaction between the group and strategy was observed ($F(1, 1) = 0.005$, $p = .94$, ω2 = 0.00).

Table 1
Demographic characteristics.

N	Healthy Controls		Substance abusers				*U*	*p*
	20		20					
	Mdn	*M*	*SD*	*Mdn*	*M*	*SD*		
Age	22.5	21.95	2.21	28.5	29.25	10.56	277.5	**0.037**
Level of education (years)	13.5	13.25	3.27	9	10.15	4.42	97.50	**0.005**
Monthly income	5100	$6245.00	$5452.61	1250	$8210.4	$14,504.31	166.0	0.356
Number of tobacco (cigarettes)	0	1.15	3.54	8	11.03	3.54	330.5	**<0.001**
Number of marijuana (cigarettes)	0	0.20	0.41	1.5	2.00	2.22	300.0	**0.002**
Number of alcohol drinks	4.5	4.75	3.64	2	5.35	7.36	173.5	0.47
Quantity of crystal meth (grams)	0	0.20	0.41	1.5	1.90	1.29	370.0	**<0.001**

Note. A Mann–Whitney *U* test was implemented to contrast the variables between the groups.

Table 2
Producer index and number of carrots collected for both groups.

	High prob - Few units				High prob - Many units				Low prob - Few units				Low prob - Many units			
Group	Control		SUD		Control		SUD		Control		SUD		Control		SUD	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Producer Index	0.90	0.18	0.24	0.71	0.47	0.59	0.17	0.67	0.06	0.57	0.02	0.48	−.14	.54	−.20	.65
Total Carrots collected	64.0	7.09	51.2	14.5	75.4	10.0	71.1	11.7	17.3	6.8	14.6	6.9	39.3	10.6	27.0	9.1
Producer carrots collected	62.3	9.74	37.4	23.6	63.5	22.4	49.6	29.4	11.2	7.65	9.15	16.8	23.1	16.6	15.3	12.3
Scrounger carrots collected	1.65	3.34	13.8	16.2	11.9	16.8	21.5	20.4	6.10	5.45	5.45	3.72	16.2	12.2	11.6	9.7

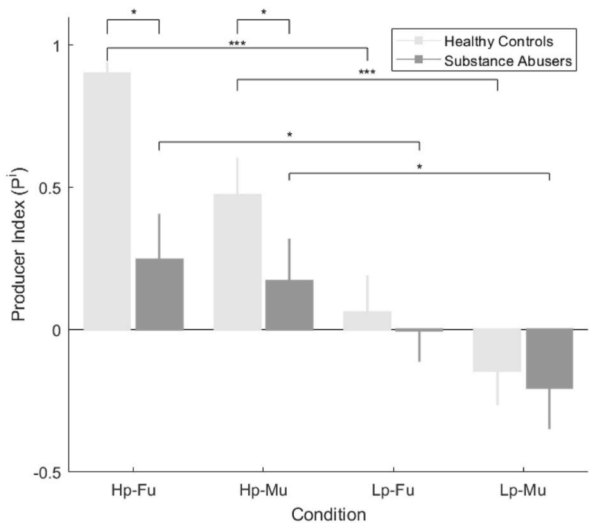

Fig. 2. Mean group producer index.

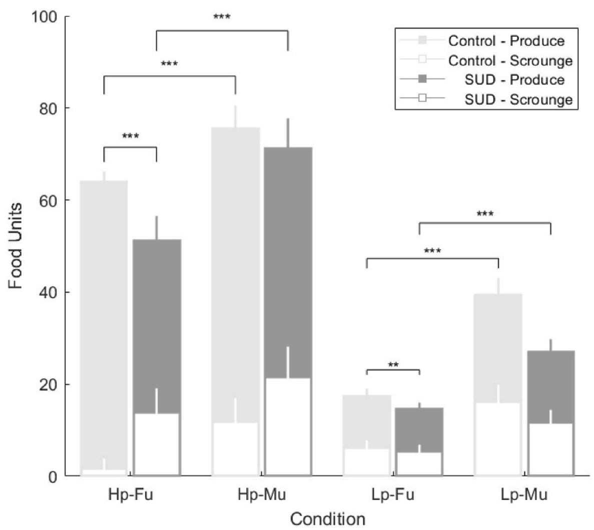

Fig. 3. Mean group number of carrots collected.

In the DD task, the discount rate was higher for scroungers ($b = 0.07$, $R^2 = 0.63$) than producers ($b = 0.002$, $R^2 = 0.39$) for the control group, and higher for producers ($b = 0.02$, $R^2 < 0.01$) than scroungers ($b = 0.001$, $R^2 = 0.88$) for SUD group (Fig. 5c). It is important to note that the hyperbola model fit was poor. The AUC was higher for producers (Control: $M = .56$, $SD = 0.26$, SUD: $M = 0.47$, $SD = 0.35$) than scrounger participants (Control: $M = 0.15$, $SD = 0.26$, SUD: $M = 0.19$, $SD = 0.17$) in both groups (Fig. 5d). An ANOVA 2x2 revealed a main effect only for the strategy used ($F(1, 1) = 8.91$, $p = .009$, $\omega 2 = 0.30$). No significant interaction between the group and strategy was observed ($F(1, 1) = 0.27$, $p = .61$, $\omega 2 = 0.00$).

4. Discussion

4.1. Guaymas Foraging Task (GFT) validation

To validate the GFT task as a suitable task for assessing social decision-making behavior, we compared the producer index among SUD and control groups with the optimal behavior predicted by the RMM. It is important to note that, unlike other turn-taking interaction tasks, this task involves four participants interacting simultaneously analogously to social foraging situations. The results show that the producer index was higher for both groups in high-probability conditions and in conditions where the number of carrots was lower. This result is consistent with the predictions of the RMM and those reported in other species, indicating that the proportion of producer responses increases with the finder's share when the probability of finding resources is high; conversely, when

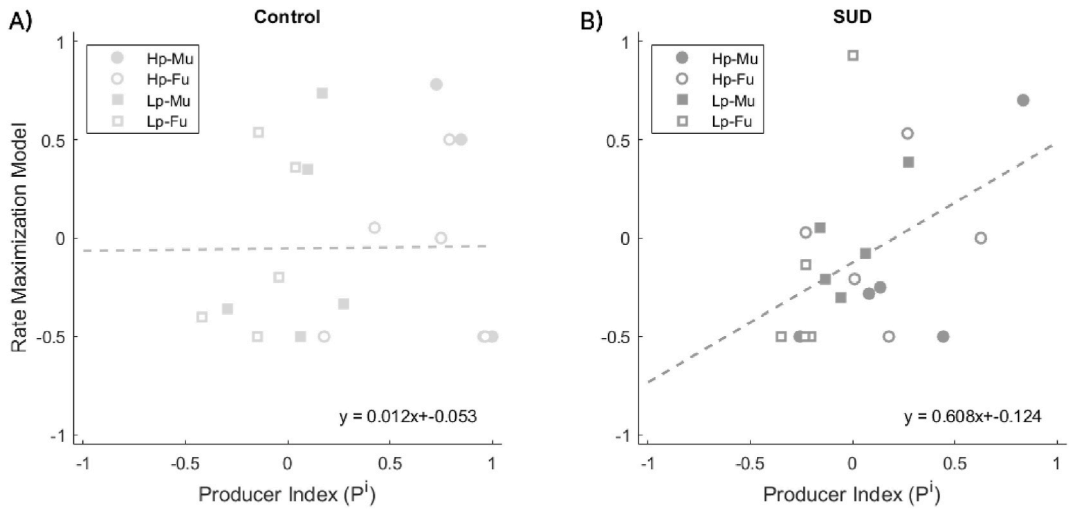

Fig. 4. Relation between producer index and model's predictions.

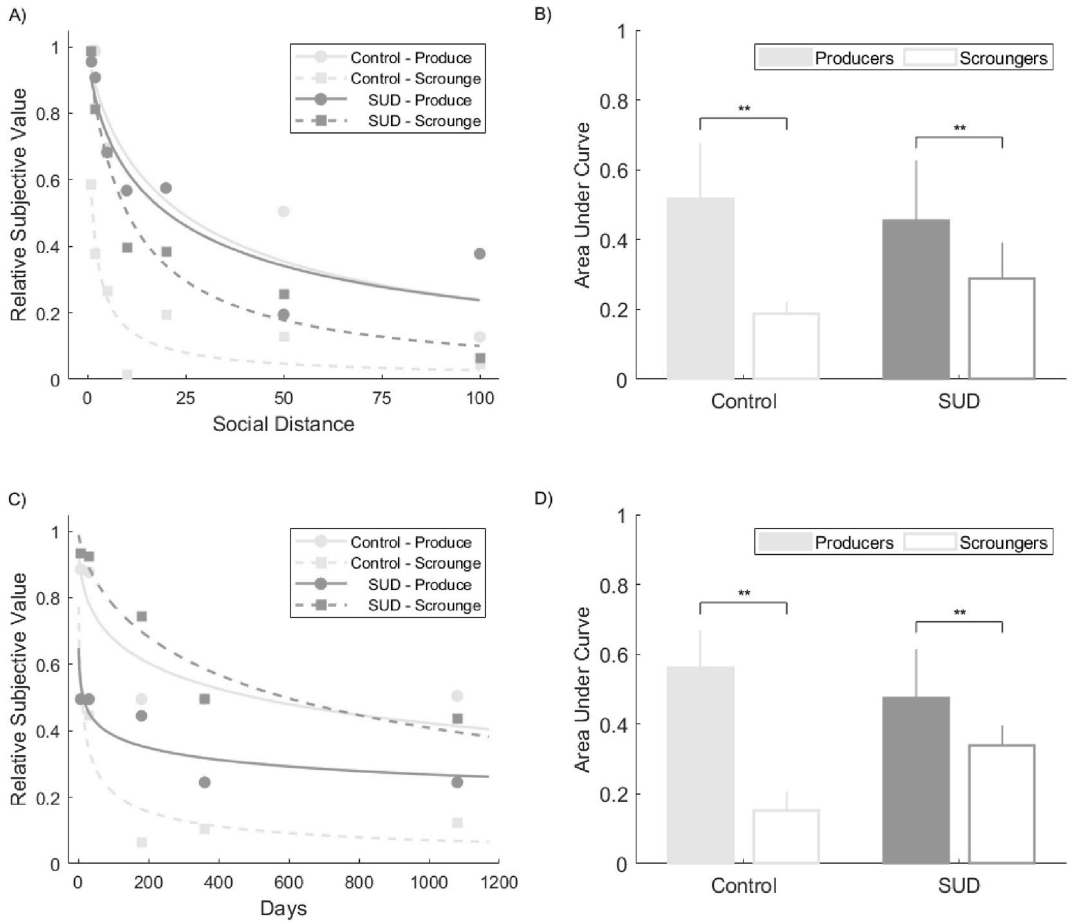

Fig. 5. Subjective value for group and strategy in social and delay discounting tasks.

there are many resources, the opportunities for scrounging increase, leading to a decrease in the proportion of producer responses [19], [20],[31],[32].

However, only a statistically significant correlation between the producer index and the RMM model was observed for the SUD group. This was expected since very few studies report close results to quantitative predictions [31] One of the reasons is that the RMM model does not consider the possibility of finding multiple patch zones [23]. In our task, as in natural conditions, the participants can simultaneously produce multiple patch zones. Moreover, as the control group tended to produce more, it was expected that this would impact the relationship between the producer index and the model prediction. Nevertheless, these findings suggested that our task worked as expected and that it is a valid instrument to access social decision-making in foraging situations and understand how participants organize and adjust their behavior to other participants or environment changes. We believe that this task could be used in the future to understand more or detect some of the patterns associated with resource theft in human participants.

4.2. Comparison between SUD and control groups

Differences in producer index were found between the SUD and control groups. The control group had a higher producer index in all four conditions than the SUD group, especially in the high-probability conditions where the optimal strategy was to produce. Our findings suggest that the SUD group adapted less to environmental changes and lower behavioral flexibility. The SUD group could not identify the more favorable conditions for producer responses. The control group obtained more units than the substance abuser participants. This finding is consistent with the literature, which has already demonstrated that exposure to substance abuse can impair various features of executive functions and that chronic substance users are unable to adjust their behavior based on the risks, gains, and losses of non-social decision-making scenarios [6],[8],[33],[34].

The capacity to adjust the decision-making behavior according to environmental contingencies is crucial, not only to obtain greater benefits as shown in other tasks (such as the IGT or BART) but to improve in real-life situations [8,35].

The findings indicate that the proportion of producers within a group can be influenced by not only ecological factors, such as group size or habitat richness, but also by psychological factors. Interventions that focus participants' attention on the context and its changes and on understanding the benefits of being a producer when the proportion of scroungers is high or the finder's share is greater, could help reduce resource theft behaviors.

4.3. Social foraging strategies, prosocial behavior, and impulsivity

Concerning the relationship between social foraging strategies, prosocial behavior, and impulsivity, we found that in the SD, the social discount rate was higher for scroungers than producers, and the AUC was lower for scroungers than producers. Despite other studies that suggest that substance abusers tend to show less prosocial behavior [10], our result suggests that the producers are more altruistic or show more prosocial behavior than the scroungers, regardless of the group. In the producer-scrounger game when the producers find a patch zone, they share the resources with the scroungers, in this sense, it is reasonable to assume that the producers are more willing to share the resources in the SD. In the DD task the AUC was lower for scroungers than producers in the control and the SUD group, suggesting that scroungers tended to be more impulsive than producers. In our task, producers must spend time and effort searching for resources, while scroungers must only wait to discover a patch zone. When there are many producers, scroungers do not have to wait as long to get food units. In this sense, being a scrounger would be equivalent to a small immediate reward and being a producer to a large later reward. The results of this study suggest that promoting altruism and self-control management could help reduce the execution of scrounger responses in SUD people. Mindfulness strategies have been found to reduce impulsive decision-making [36,37]. Interventions with these strategies can support the regulation of high impulsivity.

4.4. Limitations

Some limitations and biases in the study include the small sample size and demographic differences between the groups, such as age, gender, and educational level. Future studies will aim to increase the sample size and account for differences in mono-drug abuse and poly-drug abuse. Some studies that applied DD tasks found no significant differences between mono-drug and poly-drug abuse [34],[38]. However, it is important to note that a task such as the Guaymas foraging task could potentially be affected by the type of drug and the presence of poly-drug abuse. We recommend homogenizing participants' demographic characteristics, such as age, gender, and educational level, using Propensity Score Matching to match healthy controls and substance abusers to test their effects on the tasks used for this study. Education level is a variable that can influence cognitive performance, and in turn, substance abuse can influence academic achievement [39]. Therefore, we recommend considering education as a covariate.

Nevertheless, this is the first study comparing healthy control and substance abuse users in real-time social decision-making during foraging situations. Our results showed evidence that producers tend to be more altruistic and less impulsive. Knowing more about social strategies and producers' characteristics could help develop substance abuse prevention programs.

Author contribution statement

1 - Conceived and designed the experiments.
2 - Performed the experiments.
3 - Analyzed and interpreted the data.
4 - Contributed reagents, materials, analysis tools or data.
5 - Wrote the paper.

Data availability statement

Data associated with this study has been deposited at https://doi.org/10.6084/m9.figshare.21365310.v1.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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