Human sign- and goal-trackers detected using a simple Pavlovian device: Differences in self-reported impulsivity and addictive tendencies

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A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Bachelor of Science with Honors in Neuroscience

from the University of Michigan 2015

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I would like to thank my mentor, Dr. Cindy Lustig, for her extensive guidance, support, patience, and sense of humor. Thank you for taking me under your wing and constantly pushing me to exceed my own expectations. I would also like to thank Ziyong Lin for her invaluable help in the form of mid-afternoon meetings and paper critiques – you helped me establish direction and made the writing process so much easier to handle. In addition, I would like to thank Daniel Rizk for introducing me to this project, and all of the other research assistants in the Lustig Lab for always being there to lend a helping hand. Last but not least, I would like to thank my mother, Sharon Schwank. Thank you for teaching me that hard work and persevering through life's challenges with a positive attitude is the best way to accomplish your goals. I cannot thank her enough for her endless support and advice through this entire process.

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Abstract

Substance abuse has been associated with a form of Pavlovian conditioning – autoshaping – where an unconditioned stimulus (UCS) paired with a reliably presented reward elicits a motivated conditioned response, even though that response is not required to produce the reward. In rodent models, animals that exhibit a "sign-tracking" pattern (orientation towards the cue/conditioned stimulus) are considered a model for vulnerability to addiction. However, this connection has not been well established in parallel with human research. Here we provide a more direct test of this hypothesis by using a simple autoshaping task very similar to those used with rodents. Our first question was whether humans would show autoshaping in these testing conditions, and our second question was whether individual differences in autoshaping patterns would be related to individual differences in addictive tendencies. On each trial, a touch-sensitive joystick was presented (CS), and this presentation predicted delivery of a monetary reward (chip worth 25 cents). Participants then completed four behavioral trait questionnaires involving addiction, impulsivity, superstition and appetite influence. Subjects displayed three distinct autoshaping behavioral approach patterns: sign-trackers (orientation towards the joystick), goal-trackers (orientation towards reward delivery), and intermediates. Subjects displaying sign-tracking behavior (but not goal-tracking behavior) had higher scores on self-report measures of impulsive behavior and addictive tendencies towards drugs and gambling. These results suggest the presence of autoshaping in human behavior in response to addictive stimuli and impulsive behaviors, which could play a role in the etiology of substance abuse. Further research is required to investigate the specificity of these findings.

Keywords Autoshaping • Sign-tracking • Goal-tracking • Pavlovian Conditioning • Impulsivity • Addiction • Motivational Incentives • Humans

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Human sign- and goal-trackers detected using a simple Pavlovian device:

Differences in self-reported impulsivity and addictive tendencies

When a stimulus is reliably paired with a reward, it acts as a predictor in the onset of a conditioned response (CR) (Pithers, 1985). In Pavlovian conditioning, an unconditioned stimulus (UCS) – for example, food – is presented to an animal multiple times with a neutral object or event – such as a tone or a light – which serves the role of a conditioned stimulus (CS). The CS initially does not produce any behavioral and/or physiological response, but after constant pairing with the UCS, the animal is trained to elicit a conditioned response (CR) (Rescorla, 1967). This response can indicate future behavioral patterns and complex motivational states, especially in the context of drug-motivated behavior (Robinson, 2009). It has been suggested that the presentation of a drug, or the presentation of a paired stimulus with a drug, generates a motivational and incentivized state to promote substance-seeking behavior within rodents (Robinson, 2009; Stewart, 1984), with the possibility that this behavior is mirrored in humans (Flagel, 2008; Everitt and Robbins, 2005).

A central paradox in the study of substance abuse is that individuals continue to participate in self-destructive activities, despite the knowledge of harmful behavior and increased susceptibility to addiction (Wiers, 2006). For this reason, we are interested in researching a form of Pavlovian conditioning called autoshaping – the approach and contact of a cue/conditioned stimulus – which could allow us to better understand this behavior regarding addictive tendencies in humans.

Research involving multiple animal models has shown that in Pavlovian autoshaping experiments, the CS evokes three different CR behavioral patterns (Burns, 1996; Krank, 2007). Roughly one-third of the experimental group gravitates toward the CS, indicating that the CS has

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gained an incentivized motivational property (Tomie, 2012). These animals are designated as "sign-trackers" (ST) due to their tendency and willingness to approach the CS and engage it visually and physically (Tomie, 2012). Another third of the experimental group seems to learn the predictive nature of the CS (Tomie, 2012). These animals are designated as "goal-trackers" (GT) due to their tendency to approach the location of reward delivery, or the UCS (Tomie, 2012). The remaining third of the experimental group tends to fall somewhere between the sign and goal-tracker approach tendencies, indicating no favoritism towards one form of behavioral patterning over the other (Tomie, 2012).

These animal studies have found that sign- and goal-trackers differ in their vulnerability to substance addiction. When compared to the goal-trackers, animal sign-trackers tend to show a greater vulnerability towards addiction. For example, sign-tracking rodents display a decreased sensitivity to cocaine, in addition to an increase in cocaine self-administration (Flagel, 2007). This decreased sensitivity lead to a higher consumption rate of the drug in order to achieve an equivalent effect, increasing the animal's exposure to the addictive substance and increasing the likelihood of addiction. Rodent sign-trackers have also displayed a decrease in threshold for the sensitization of the neural mechanism underlying incentive motivational stimuli (Robinson and Flagel, 2009).

These animal studies have additionally found that sign- and goal-trackers differ in impulsive tendencies. In rodent studies, rats designated as sign-trackers tend to exhibit higher impulsive behavior when compared to goal-tracking rodents (Lovic, 2011). Based on similar findings, it has been hypothesized that sign-tracking CR behavior can be used as a predictor of differences in an individual's impulsivity (Tomie, 2008). Also, as demonstrated by Jentsch and

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Taylor (1999), high indicators of impulsive behavior were linked to an increased vulnerability of drug abuse in humans.

Altogether, these findings suggest that individuals showing sign-tracking behavior could be more vulnerable to substance abuse due to increased impulsivity and addictive tendencies. Given the limited number of human autoshaping experiments when compared to the large amount of animal findings showing differences in addiction susceptibility between autoshaping groups, it is important to assess the possibility of sign- and goal-tracking behavior in humans. In the present study, we used a computerized box-apparatus task to investigate patterns of Pavlovian autoshaping in humans. We predicted that this task would display behavioral patterning similar to those observed in rodent studies. We then investigated individual differences in addictive tendencies through the use of multiple questionnaires, which we then used as predictors of addictive behavior. Our primary hypotheses were to determine whether humans show sign/goal tracking behaviors similar to those seen in animal models and to test whether sign-tracking would be related to individual differences in addictive stimuli and impulsive behaviors.

Method

Participants

Thirty-five participants (16 female) aged between 18 and 27 years (mean 18.3 ± 1.91) participated in the experiment. Subjects were excluded from the data analyses if they failed to follow verbal instructions to collect each chip after it was released and administered into the reward dish. Participants were recruited from the student population at the University of Michigan through the Psychology Department by utilizing the Subject Pool Program administered through introductory psychology courses. Each subject received course credit for

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participating in the experiment. All participants provided informed consent, and the experiment was approved by the University of Michigan Institutional Review Board. Table 1 displays the demographics of the experimental subjects.

Apparatus

The test-box (Figure 1) was a wooden box measuring 17 inches in length, 12 inches in width and 12 inches in height. It was placed on a table 10 inches away from the table's edge, where it remained for the entirety of the study.

A 6-inch joystick with a metal dial on its end was located three inches from the right-hand wall of the apparatus. The metal dial was touch-sensitive and could be touched, clicked, or turned. The joystick was programmed through a MATLAB computer system to exit the test box for 10 seconds once activated, which then retracted for five seconds before then repeating the cycle. Centered on the apparatus, six inches from the test box's base, was a red light that illuminated when the joystick emerged and remained lit for the 10-second duration of the joystick's exposure. Presentation of the joystick served as the conditioned stimulus (CS).

A metal dish measuring 3.75 inches in diameter protruded 0.4 inches out of the test box, and was located three inches from the left-hand side of the wall of the apparatus. The dish was touch-sensitive. A dispenser was programmed through a MATLAB computer system to drop a chip into the dish after each occasion the joystick was exposed. Presentation of the monetary chip reward served as the unconditioned stimulus (UCS).

The joystick sent a signal every 50 milliseconds to indicate whether or not it was touched, while the dish recorded and sent a time-stamp every time it was touched to the computer. Centered on the top of the test box was an HP 3200 HD webcam that also recorded the participants' hand movements, and relayed footage to a nearby laptop.

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Procedure

The experiment was carried out in two phases: a verbal instruction and a performance phase. The task took place in a windowless room with artificial, fluorescent lighting. The participant was seated at a table facing the apparatus and a blank wall. To the subjects' left was a file cabinet, and to the subjects' right was a desk with an unused computer. Behind the participant was a desk with an operating computer utilized by the experimenter to run the MATLAB program that activated the apparatus. A total of 32 chips were dispensed during the task and each was assigned a monetary value of 25 cents to incentivize the subjects to participate. The subject received 25 cents for each chip he or she collected from the reward dish, adding to a total of $8.00.

Phase 1: Verbal Instructions. The box cannot harm you. The joystick on the box can be touched, clicked and turned (demonstrate for participant). Black chips may fall into this dish here (point) during the experiment. Each chip is worth 25 cents. Any chips that you collect are monetized and yours to keep at the end of the experiment. Remember to pick up the chips if and when it drops into the dish. Do you have any questions?

After reading the task instructions aloud to the participant, the experimenter initiated the MATLAB program and left the room for 8-10 minutes. The amount of time the experimenter was absent from the testing room varied to control for the set release of the joystick and the chips, ensuring that the experimenter did not reveal the task's preset nature.

Phase 2: UCS and CS Presentation. Subjects were given 32 CS presentations, all of which were paired with the UCS. Interaction with the joystick during the CS was regarded as an autoshaped (CR) response. Subjects were presented with the CS onset followed 7 seconds later

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by the presentation of the UCS, and then 3 seconds later the offset of the CS. The time between CS presentations was 5 seconds and the task required a total of eight minutes to complete. Chip and joystick presentation occurred whether or not the subject made a CR during the CS. After task completion, subjects participated in filling out five questionnaires.

Statistical Design

Sign-trackers and goal-trackers were identified by the number of times that they interacted with the joystick versus the chip-delivery dish. Methodology behind this identification involved ranking subject participants based on percent approaches towards the joystick from lowest to highest. Subjects were then divided into three groups, where the top third was assigned the label “Sign-Tracker” (N = 12), the bottom third the label “Goal-Tracker” (N = 12), with the middle third labeled “Intermediate” (N = 11). 91% of participants were between the ages of 18 and 21, 6% were between the ages of 22 and 25, and 3% were greater than or equal to the age of 26. Sign and goal tracking tendencies were then utilized as categorical independent variables in the statistical analysis of individual questionnaire results.

Scores for the AS were broken down into 12 subscales for statistical analyses including: alcohol, cigarettes, caffeine, chocolate, exercise, gambling, music, Internet, shopping, love, and work. Scores for the BIS were broken down into six sub-categories for statistical analyses including: attention, cognitive instability, motor, perseverance, self-control, and cognitive complexity (Patton, 1995). Pearson product-moment correlation coefficient calculations were utilized to assess statistical relationships among variables, while a 0.05 rejection criteria was applied in all following statistical analyses.

Questionnaires

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Addiction Scale (AS; Meyer, 2007). This scale is a measure of an individual's tendency to become addicted to an object or an activity. The AS contains 12 categories, each pertaining to a specific item. Within each category there are eight statements, adding to a total of 96 questions. Each statement is scored on a Likert scale from 1-5, where high values in a category indicate a high likelihood of addictive tendencies toward the listed item.

Barratt Impulsivity Scale (BIS-11; Patton, 1995). This scale measures multiple facets of impulsivity by generating scores of three impulsivity types – attentional, motor and non-planning impulsiveness. Each of these is further divided into two differentiated types of impulsivity within its designated category. The BIS-11 consists of 30 statements scored on a Likert scale from 1-4, where high values indicate a high likelihood of impulsive behavior.

Power of Food Scale (PFS; Lowe, 2009). This scale is a measure of the psychological influence food holds on an individual in a plentiful environment. The PFS consists of 21 statements scored on a Likert scale from 1-5, where high values indicate a high likelihood that food holds a strong psychological influence over an individual.

Paranormal Belief Scale (PBS; Tobacyk, 2004). This scale is a multidimensional measure of beliefs, generating values for seven respective categories: traditional religious belief, psi, witchcraft, superstition, spiritualism, extraordinary life forms and precognition. The PBS completed by participants consisted of 12 statements, which is an abbreviated version of the original PBS that initially contained 25 statements. Our version focused on superstition questions in order to test if a particular group of participants (like sign-trackers) had higher scores for superstitious beliefs, which may relate to how those participants interact with the CS. It is scored on a Likert scale from 1-7, where high values indicate a high likelihood of superstitious belief. Question six is reverse scored to ensure participants were reading instructions properly.

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Exit Questionnaire (EQ; Appendix). This survey inquired about the participants' behavior and thoughts during the apparatus portion of the experiment. The EQ consisted of 8 statements scored on a Likert scale from 1-5, where high values indicate a high likelihood of impulsive and addictive tendencies. Item eight is reverse scored to ensure participants were reading instructions properly. The last two statements were open-ended questions about the apparatus for future experimental and procedural improvements, which were not utilized in the analysis.

Results

An analysis of CS approaches was performed that focused on two sub-groups of subjects: sign-trackers and goal-trackers. For further explanation on subject group assignment, please refer to Statistical Design in Methods. Each participant's interaction with the task's 32 trials was broken down into a binary scale based on the subjects' interaction with, or approach, of the CS. Criteria for interacting with the CS included touching, clicking, or turning the metal-dial or touching the joystick. Approaching the CS was assigned a value of 1, while disengaging the CS was assigned a value of 0. All trial approaches for each group were then averaged. Sign and goal-tracker group means were then plotted (Figure 2). The graph displays a notable difference between sign and goal-tracker groups and their approach tendencies, where goal-trackers' mean CR frequency decreased to a very low level before completely dissipating, whereas sign-trackers' CR frequency remained relatively high throughout all 32 trials. These results indicate that there are three different patterns of behavior being displayed; strong approachers (labeled sign-trackers) who display strong CR tendencies, strong disengagers (labeled goal-trackers) who exhibit weak CR tendencies, and intermediates (not shown on graph) who display neither strong nor weak CR tendencies.

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Multiple independent t-test analyses were then performed to analyze the relationships between these grouping patterns and the subjects' responses to the Barratt Impulsivity Scale and the Addiction Scale questionnaires. Our analyses focused on the sign-tracker and goal-tracker sub-groups previously identified. The results of the independent t-test applied to the Barratt Impulsivity Scale data indicated a significant strong relationship between sign-trackers and the BIS Perseverance sub-category ($t(22) = 2.33$, $p = 0.03$; Figure 3), showing that sign-trackers have a higher frequency of a type of impulsive behavior when compared to goal-trackers. These results indicate that a form impulsive behavior present in humans can play a significant role in an individual's tendency to elicit a CR. Analyses of all other sub-categories did not yield significant results.

The results of the independent t-test applied to the Addiction Scale data indicated that sign-trackers had higher scores than goal-trackers on the AS Drugs subscale ($t(22) = 2.18$, $p = 0.04$; Figure 4) and the Gambling subscale ($t(22) = 2.36$, $p = 0.03$; Figure 4), showing that goal-trackers have a lower frequency of addictive tendencies towards drugs and gambling when compared to sign-trackers. These results suggest that addiction to particular substances can be more likely if an individual exhibits sign-tracker behavioral tendencies towards a CR. Analyses of all other sub-scales did not yield significant results.

Subjects were excluded from analyses if they did not meet the criteria mentioned in Methods. Table 2 discloses all mean comparison data between sign-tracker and goal-tracker groups of the Barratt Impulsivity Scale and the Addiction Scale. Significant results were not observed when analyses were run on the Power of Food Scale, Paranormal Belief Scale, or exit questionnaire, as seen in Table 3.

Discussion

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In the current study, we investigated if autoshaping patterns are found in humans, while also assessing whether individual differences in these behavioral patterns would be related to individual differences in addictive tendencies. We hypothesized that the apparatus task would show behavioral patterning similar to those found in animal studies. We also hypothesized that individual differences in autoshaping behavioral patterns would play a role in an individual's susceptibility toward addictive tendencies. Although relationships between groups were not as strong as anticipated, their presence still suggests that sign-tracking patterned behavior is positively linked with some addictive and impulsive tendencies. Results were generally supportive of our hypotheses, although further testing will be required.

The finding that showed three distinct behavioral patterns based on joystick (CS) approaches is consistent with the observations made by Krank (2007) seeing that we have observed three possible CR patterns; however, we now see this behavior in humans as opposed to animals. As recognized in animal models, CS approach behavior breaks down very distinctly into three different groups, with the sample size being clearly divided into thirds for each category: sign-tracker, goal-tracker, and those that fall in-between (Tomie, 2012). Accordingly, the three different patterns identified in human behavior were categorized as sign-trackers (ST), goal-trackers (GT), and intermediates (I), with STs displaying strong CR tendencies and GTs exhibiting weak CR tendencies (Figure 2). The displayed behaviors suggest that these patterns established in animal models can be replicated in humans, but further testing is required to obtain a larger sample size if any definitive results are to be made.

Notably, sign- and goal-trackers did not differ either in their general tendencies towards superstitious behavior, as indicated by the Paranormal Belief Scale, or in their specific beliefs about and reactions to the Pavlovian task used here, as measured by the exit questionnaire.

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Instead, a majority of the subjects in both groups (58% of sign-trackers and 92% of goal-trackers) reported in the exit questionnaire that the chip drop (UCS) was not controlled by joystick interaction (Table 3). One possible explanation for this observation is that the approach behavior was unrelated to the UCS, but was rather an effect of the subjects interacting with the joystick out of boredom or curiosity. Another possible explanation is that the experimenter unknowingly implicated the task's preset nature, which could decrease the participant's curiosity towards the CS. However, a more interesting possibility is that there is a dissociation between these conscious beliefs and unconscious motivations and tendencies that may increase vulnerability to addictive behaviors.

Two factors tested from the behavioral questionnaires – addiction to substances and impulsive tendencies – showed significant findings when analyses were run through independent t-tests. While the Barratt Impulsivity Scale (BIS) score as a whole did not reveal any significant results, the analysis of the questionnaire's second order factors indicated a significant relationship of increased impulsive behavior (due to a lack of perseverance when focusing on the UCS) when the subject displayed sign-tracker tendencies. It's been suggested that lack of perseverance may be connected to attentional disorders where an individual finds it difficult to ignore distracting stimuli (Whiteside, 2000), which supports our finding that sign-trackers focus more on the CS. This finding that impulsivity is significantly related to sign-tracking behavior is consistent with previous research performed in animal models by Tomie (2008), and suggests that some forms of impulsivity may play a role in human autoshaping patterns. However, the availability of studies replicating these results in humans is limited. Also, it is unlikely that the poor relationships among the different categories of the BIS were due to poor design, seeing as the questionnaire has been widely accepted and utilized over the past five decades (Ireland,

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2008; Stanford, 2009). Even so, we plan to implement a new impulsivity scale along with the BIS to see if these results are replicable.

A similar pattern was found when analyzing the Addiction Scale (AS). As a whole, the AS score did not indicate any significant results based on our data; nonetheless, when analyses were performed on the individual scales within the AS, two were found to be significantly related to sign- and goal-tracking behaviors. The addictive tendency subscale towards recreational drug use is the first of the two significant findings, whereas gambling is the second. The first result, involving substance addiction, was anticipated. This finding is consistent with previous research indicating that multiple animal models have shown sign-tracking behavior in relation to increased self-administration and decreased sensitivity towards cocaine (Flagel, 2008). This relationship suggests a link between human sign-tracking behavior and substance-related addictive tendencies, which holds many implications for future research and screening methods regarding substance abuse. The second result, involving a non-substance addiction, was not entirely anticipated. While our original thoughts on the experiment were to find connections between substance-related addictive tendencies and autoshaping, non-substance addiction does bear a resemblance to drug dependence (Yau, 2015). The finding that gambling could parallel drug use is consistent with a large body of current research indicating that behavioral and substance addictions share common neurocircuitry systems, specifically within the dopaminergic pathway (Yau, 2015). This not only implicates that there is a possible link for substance-dependent addiction in relation to human sign-tracking, but that there may also be a connection for non-substance dependent addiction as well. The possibility of shared neural circuitry between these two tendencies further implicates a relationship involving human autoshaping and addictive behavior.

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Given past connections found between addictive and impulsive behavioral tendencies, we ran analyses comparing mean AS and BIS scores, expecting a strong positive correlation between the two questionnaires. However, the results did not approach statistical significance, $r = 0.26$, $p = 0.13$. These findings contrast those observed by Jentsch and Taylor (1999), who suggested in an academic review that human impulsivity (in the form of impaired frontal cortical inhibitory control) was linked to an increased vulnerability in drug dependence and abuse. One possible explanation for this is the inclusivity of the AS subscales. It is probable that the broad range of categories within the questionnaire diluted the effects between subject scores, which in turn generated poor mean comparison data.

Overall, our findings indicate that humans fall into three patterns of behavioral approaches when interacting with an unconditioned stimulus. Additionally, our results suggest that sign-tracking behavior in subjects is positively related to impulsive and addictive tendencies. Interestingly, we reported the possibility that only certain forms of impulsivity may play a role in sign-tracking behavior. Furthermore, we found that substance and non-substance dependent addictive behaviors are positively linked with sign-tracking. We did not see evidence of the relationship between addiction vulnerability and impulsivity as suggested by Jentsch and Taylor (1999).

In summary, the present study is one of the first to indicate an autoshaping model present in humans. Furthermore, our data implicates that sign-tracking tendencies in behavior may function as a predictive mechanism for impulsive and addictive tendencies in humans. Establishing this behavioral model could lead to more accurate risk assessments for individuals and earlier intervention for those who suffer from substance abuse.

Limitations and Future Studies

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Unlike any previous human or animal autoshaping experiments, our study did not include an operant conditioning period. This is a common feature in most autoshaping studies that we intentionally chose to eliminate, allowing subjects' personal characteristics and individual differences in addictive tendencies to dictate their behavior in the apparatus task. However, this may have affected how the subject perceived the joystick's function. A majority of subjects reported on the exit questionnaire that the joystick did not have any influence on a chip dropping into the reward dish. This implies that these subjects may not have paired the unconditioned stimulus with the conditioned stimulus, and that their interaction with the joystick was purely out of boredom or curiosity. To account for this possible setback, a future study would include a procedural operant conditioning task where the chip drop is influenced by the subject's interaction with the joystick. The chips would still have an assigned monetary value of 25 cents to reinforce their representation as a reward. After a specified number of trials, the subject would graduate to the UCS and CS presentation task described in the procedure.

Additionally, another limitation to our experiment was our limited sample size and the use of University of Michigan Undergraduate Psychology Subject Pool participants. Power analyses conducted in G*Power 3.17 (Faul, 2009) indicated that N = 12 per group we would need effect sizes of = 1.20 for a power of .80. Post-hoc power for moderate effect sizes (d = .50) was low, estimated at .22. As our participants were undergraduates at a highly-ranked public university, the range of addictive and impulsive behaviors, and thus the ability to detect group differences, was also likely restricted. As described below, we hope to address these issues in future experiments by targeting groups that differ in addictive behaviors and using larger sample sizes.

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A possible setback in our experiment could have been the unanticipated findings of the Barratt Impulsivity Scale (BIS). While the BIS is widely accepted and validated within the psychological research community, total BIS and a majority of subcategory scores proved to be insignificant in relation with sign-tracking behavior, despite opposite findings from both Tomie (2008) and Lovic (2011). However, it has been reported that the BIS may underrepresent certain facets of impulsivity (like urgency), which could also account for our low number of significant findings (Whiteside, 2000). These findings could also be largely due to our limited sample size and relatively healthy population of subject pool students. Based on these findings, we have amended our original IRB proposal to include an additional impulsivity scale, the UPSS-P (Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency Impulsive Behavioral Scale), as a comparative measure for the BIS (Lynam, 2006). The thought behind this is to see if the BIS findings are replicable and generalize to a different impulsivity scale.

Finally, future studies will graduate to targeting groups that are directly affected by substance-motivated behavior. We are currently working on amending our IRB proposal to include parameters for targeting the tobacco smoking population at the University of Michigan. The hope is that findings from this group of individuals will show significantly different and higher scores on the AS, BIS, and UPSS-P, resulting in a positive relationship between these questionnaire scores and sign-tracking. This would support the idea that sign-tracking behaviors are more prevalent in individuals more susceptible to addiction.

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HUMAN SIGN- AND GOAL-TRACKING

Tables

Table 1.

Participant Demographics and Characteristics

Variable	Participants (N = 35)		Sign-Trackers (N = 12)		Goal-Trackers (N = 12)	
	N	%	N	%	N	%
Gender						
Female	16	46	5	42	7	58
Male	19	54	7	58	5	42
Age (yr)						
18-21	32	91	12	100	11	92
22-25	2	6	0	0	0	0
26+	1	3	0	0	1	8
Race						
White	31	89	10	83	12	100
Asian	4	11	2	17	0	0
Medical Conditions						
Attentional Disorder	6	17	4	33	2	17
Emotional Disorder	5	17	3	25	2	17
Physical Injury	3	9	2	17	1	8

HUMAN SIGN- AND GOAL-TRACKING

Table 2.

Descriptive Statistics for Mean Comparisons of AS and BIS Questionnaires

Variable	Sign-Tracker		Goal-Tracker			
	Mean	SD	Mean	SD	P-value	D-value
Addiction Scale (AS)						
AS total	203.92	36.86	188.25	34.94	0.30	0.44
Alcohol	13.17	4.86	11.92	3.15	0.46	0.31
Cigarettes	8.50	1.00	8.25	0.62	0.47	0.30
Drugs	11.75	5.07	8.50	1.00	0.04	0.89
Caffeine	18.50	8.12	14.42	5.02	0.15	0.61
Chocolate	14.25	4.81	17.08	8.38	0.32	0.41
Exercise	20.58	6.78	19.92	5.62	0.80	0.11
Gambling	9.92	2.19	8.33	0.78	0.03	0.96
Music	22.25	8.30	20.75	7.16	0.64	0.19
Internet	22.25	7.36	21.33	4.42	0.72	0.15
Shopping	15.17	4.09	13.30	7.20	0.45	0.31
Love/Relationships	26.00	4.92	25.50	5.45	0.82	0.10
Work	21.58	5.78	19.00	3.95	0.21	0.52
Barratt Impulsivity Scale (BIS)						
BIS Total	63.83	7.65	59.75	6.37	0.17	0.58
Attention	11.17	3.07	10.58	2.31	0.60	0.21
Cognitive Instability	7.67	2.02	7.08	1.83	0.47	0.30
Motor	14.50	3.03	13.58	3.85	0.52	0.26
Perseverance	7.42	1.44	6.25	0.97	0.03	0.95
Self-Control	12.33	2.90	11.42	2.27	0.40	0.35
Cognitive Complexity	11.00	2.13	10.83	2.37	0.86	0.07

Note. $*p < 0.05$.

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HUMAN SIGN- AND GOAL-TRACKING

Table 3.

Descriptive Statistics for Mean Comparisons of PFS, PBS and EQ Questionnaires

Variable	Sign-Tracker		Goal-Tracker			
	Mean	SD	Mean	SD	P-value	D-value
Power of Food Scale (PFS)						
PFS total	53.58	20.40	56.50	18.88	0.72	0.15
Paranormal Belief Scale (PBS)						
PBS total	5.00	2.52	6.67	5.05	0.32	0.42
Exit Questionnaire (EQ)						
EQ total	22.67	4.66	21.50	3.34	0.49	0.29
CS Controlled Reward	0.42	0.51	0.08	0.29	0.06	0.80

HUMAN SIGN- AND GOAL-TRACKING

Figures

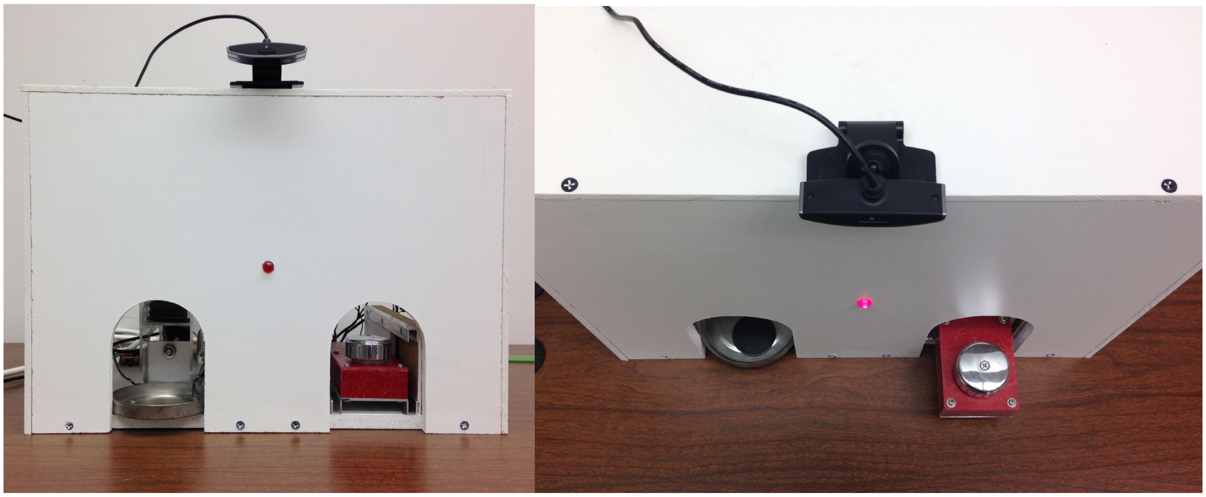

Figure 1. Apparatus. Frontal and birds-eye images of the test-box utilized in the experiment. See text for dimensions and further explanation.

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HUMAN SIGN- AND GOAL-TRACKING

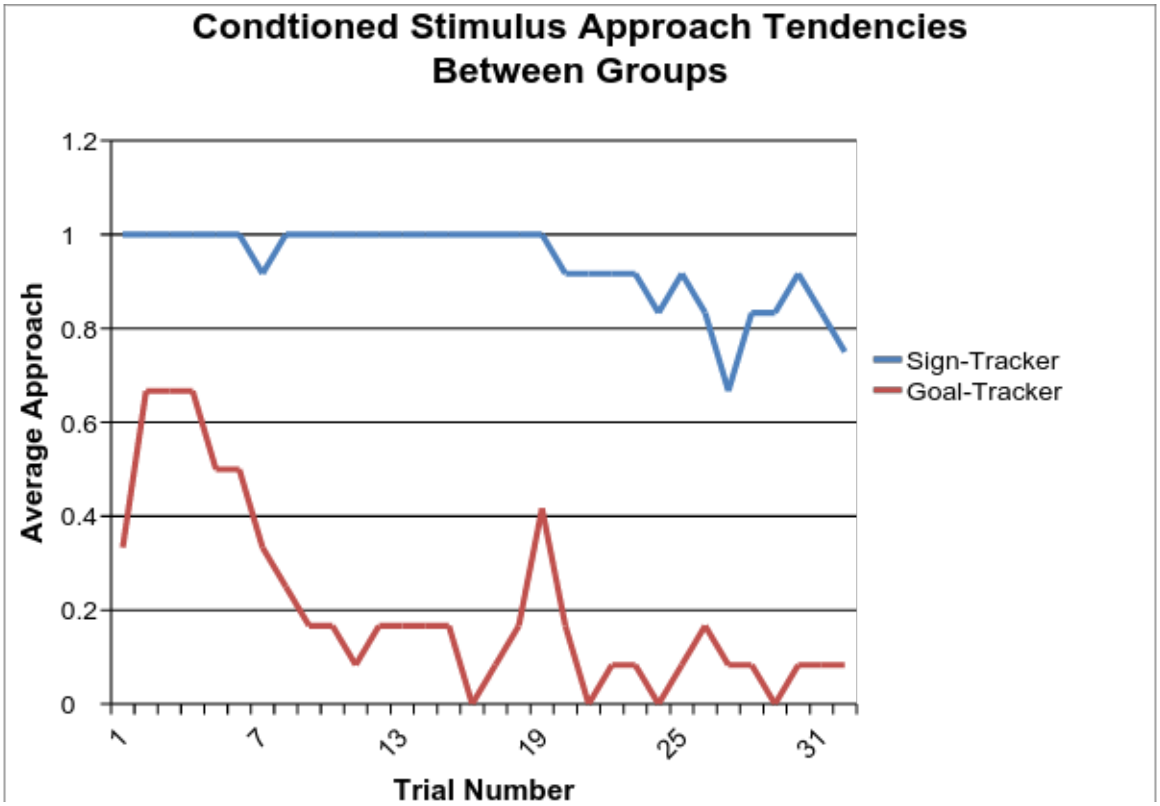

Figure 2. Conditioned Stimulus Approach Tendencies Between Groups. Mean number of joystick approaches per trial was calculated between groups. N = 12 in both the sign-tracker and goal-tracker groups. The intermediate group of subjects is not shown.

HUMAN SIGN- AND GOAL-TRACKING

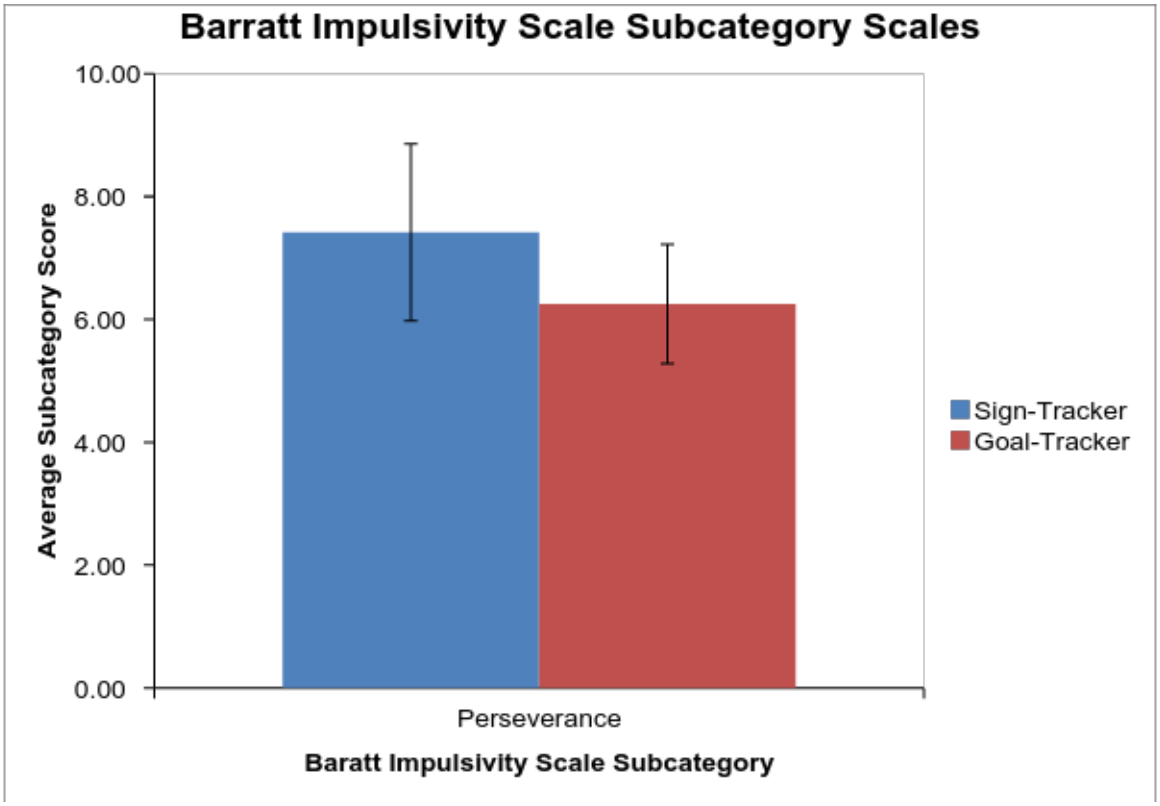

Figure 3. Barratt Impulsivity Scale Motor Category Scores. Higher scores in the Perseverance category of the Barratt Impulsivity Scale were positively correlated with sign-trackers as compared to goal-trackers during the 32 experimental trials. These results were significant at the 0.05 level. N = 12 in both the sign-tracker and goal-tracker groups. The intermediate group of subjects is not shown in this graph. Error bars indicate one standard deviation.

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HUMAN SIGN- AND GOAL-TRACKING

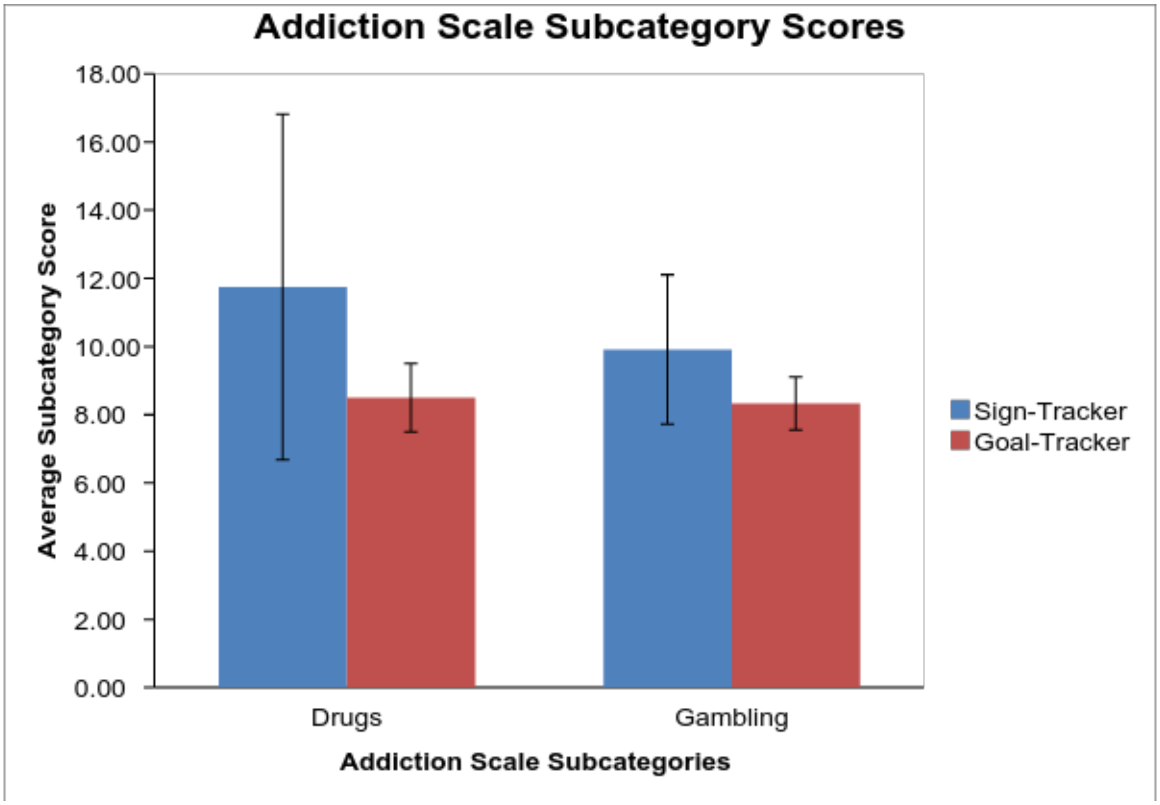

Figure 4. Addiction Scale Subcategory Scores. Higher Scores in the Drugs and Gambling categories of the Addiction Scale were positively correlated with sign-trackers as compared to goal-trackers during the 32 experimental trials. These results were significant at the 0.05 level. N = 12 in both the sign-tracker and goal-tracker groups. The intermediate group of subjects is not shown in this graph. Error bars indicate one standard deviation.

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Appendix
Exit Questionnaire
(Provided to Participant)

Exit Questionnaire

Using the following scale, please answer the questions honestly.
1 = "Strongly **uncharacteristic** of me" or "definitely **not true** for me"
2 = "usually not true for me"
3 = "usually true for me"
4 = "true for me"
5 = "Strongly **characteristic** of me" or "very **true** for me"

---

1. I consider myself to have an 'addictive personality.'
   1 2 3 4 5
2. When I am trying to avoid or cut down on something tempting, I often run into trouble when facing the cues that remind me of that temptation (e.g., a picture, wrapper or advertisement for my favorite food/drink/cigarette; going past the place where I usually partake in this activity.)
   1 2 3 4 5
3. Seeing advertisements for food, restaurants, or cooking shows usually makes me hungry.
   1 2 3 4 5
4. I have to keep tempting items out of my place of living or I can't resist consuming them.
   1 2 3 4 5
5. I struggle to say no when offered my favorite food/drink/cigarette, even if I have just consumed it.
   1 2 3 4 5
6. When I see a cue for my favorite food/drink/cigarette, I feel like I must have it.
   1 2 3 4 5
7. I am easily able to resist consuming my favorite food/drink/cigarette.
   1 2 3 4 5
8. I consider myself to have a strong sense of self-restraint.
   1 2 3 4 5
9. Do you think the joystick was related to the dropping of the chip?
   Yes No
10. Please give us your impressions of the experiment and describe any strategies you may have used or questions you may have about the task.