



Comparison of Decision-Making Processes Between Subjects with a Positive and Negative History of Substance Use

Reza Rastgoo Sisakht¹, Rahimeh Negarandeh², Hamid Valizadegan³, Shabnam Mousavi⁴, Maryam Noroozian⁵, Mehdi Tehrani-Doost^{1,6} and Emran Razaghi^{7,8,*}

¹Department of Neuroscience and Addiction Studies, School of Advanced Technologies in Medicine, Tehran University of Medical Sciences, Tehran, Iran

²Médecins Sans Frontières (MSF), Southern Tehran Project, Tehran, Iran

³Behsazan Mellat Co., Tehran, Iran

⁴Max Planck Institute for Human Development, Berlin, Germany

⁵Memory and Behavioral Neurology Division, Department of Psychiatry, Ruzbeh Hospital, Tehran University of Medical Sciences, Tehran, Iran

⁶Department of Psychiatry, Research Center for Cognitive and Behavioral Studies, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran

⁷School of Advanced Technologies, Tehran University of Medical Sciences, Tehran, Iran

⁸School of Medicine, Tehran University of Medical Sciences, Tehran, Iran

*Corresponding author: Associate Professor of Psychiatry, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-9121255458, Fax:+98-2155419113, Email: razaghie@sina.tums.ac.ir

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Abstract

Background: Studies related to decision-making and choice preference in substance use behavior have less commonly focused on decision-making processes per se. Those processes include decision-making time, task-based complexity, and decision-making strategies.

Objectives: The objectives of this study was the production of a culturally modified version of the Mouselab tool for measurement of decision-making processes and to measure differences between decision-making processes in subjects with a positive and negative history of substance use.

Methods: Applying a snowball method for sampling, two groups, of individuals with a positive and negative history of substance use were recruited. The case and control groups consisted of 17 males with the mean age of 35.94 (\pm 12) and 33.8 (\pm 8.83) years, respectively. The measurement tool was a modified version of Mouselab computer game.

Results: Using repeated measurement analysis of variances and *t*-test with non-paired groups for comparing the case and control groups, it was found that the group with a positive history of substance use had a longer time-lapse in the decision-making process ($P = 0.029$). The accuracy of choice, however, was not different between the groups ($P = 0.172$).

Conclusions: Subjects with a positive history of substance use were different in two stages of decision-making process, which are dependent on the ecology and conditions of decision-making process, namely, search for information and decision-making. Two other stages of decision-making process that were dependent on individual cognitive and logical properties, i.e., stop search and choice, were not different in subjects with a positive history of substance use compared to the control group. Although subjects with a positive history of substance use consumed more resources for decision-making, their accuracy of choice was not different from the control group, thereby, ruling out a decision-making-related cognitive deficit.

Keywords: Decision-Making, Choice, Process Tracing, Substance Use, Decision-Making Software

1. Background

By understanding the cognitive processes of decision-making, one would not only be able to determine the applied strategy but also predict the subsequent behavior (1, 2). The ability to strike a balance between immediate and future consequences of choices is defined as decision-making (3, 4). Decision behavior research deals with formulation of theories surrounding cognitive processes by utilizing models that describe human thinking in the pro-

cess of decision-making and judgment (5, 6). Substance use as a choice with short-term rewards and long-term negative consequences (7) is considered a decision-making fault. Although decision-making in substance use has been widely studied, the focus has been on the outcome rather than the process and stages of decision-making (8). In mice studies, for example, have mainly measured memory rather than investigating the process of decision-making (9). By applying Aristotle's concept of Akrasia, some studies have had a philosophical approach to will and respon-

sibility of substance users (10-12). Others, however, believe that disturbed adaptation to a particular situation and the consequent emotions might result in a decision to use (13-15). The stress of poverty and lack of natural resources have also been identified as sources of anxiety, reduced self-control, and subsequent substance use (16-19). Based on all those models an urge for short-term boosters such as overeating, substance use, or procrastination, help the person stay away from excessive emotions or stabilize them (13-16, 19, 20).

Descriptive approaches to decision-making vis-à-vis traditional normative models have already been discussed by scholars (5, 21, 22). Choice-based models, as a subset of descriptive approaches, measure the relationship between “attributing” values and “alternative” options of decision-making (23, 24). The structural model describes the final outcome of the decision with no reference to the processes of decision-making. Process tracing, however, is a different descriptive approach that emphasizes on the process of decision-making by focusing on quantity, type, time, and sequence of information acquisition (21, 25). Process tracing models are well-suited for studying human decision-making and understanding of cognitive processes from a psychological perspective (26-28).

Several criteria have been developed to examine the information acquisition behavior in decision-making situations (6). The following aspects of decision-making processes are more commonly measured by researchers (29).

- **Timing of decision-making:** The operational definition for measurement of timing of a decision consists of the time taken to make a decision on each screen or round of a game.

- **Task-based complexity:** Indicates the general aspects of a decision process, including (a) Multiplying of alternatives and attributes (amount of information), (b) Time pressure, (c) Information display style (sequential vs. simultaneous), and (d) Response method (selection vs. scoring).

- **Decision-making strategies:** By definition, a sequence of actions applied to transfer a primary form of knowledge to a pool of the ultimate situation knowledge, where the decision-maker is satisfied that the decision-making issue is resolved, is a decision-making strategy (30). While a decision-making strategy describes the process, based on which, the decision-maker proceeds in a selection among certain alternatives, a multi-attribute evaluative process describes the interaction between information acquisition and the final choice.

2. Objectives

This study aimed to evaluate decision-making processes in everyday life of individuals with a history of substance use according to above-mentioned criteria.

3. Materials and Methods

A culturally modified version of Mouselab software (31, 32) that operated as a game was applied for measurement of decision-making attributes, the details of which are published elsewhere (33). An application of the software is to test patterns of cumulative data acquisition in multivariate and multi-attribute situations (34). Based on the narrative of the game, a young male was determined to select a girl, out of four, to marry (i.e., alternatives). The selection had to be in accordance with preferred criteria based on four characteristics of the girls (i.e., attributes), each available as a binary coding of yes/no (i.e., task-based complexity). The game interface was, therefore, designed as a multi-attribute and multi-variate matrix of 4×4 , with the binary data being hidden under the cells available at a cost (i.e., task-based complexity). The design and sorting of the game were randomized. The game was not a gamble and each round had an actual correct answer.

In our setting, the cost of each information unit - opening a box- was IRR (Iranian Rial) 450 and each time step exhausted IRR 780 (i.e., timing). The starting credit was IRR 900000 for 60 rounds (15000 for each round). By purchase of information (number of opened boxes \times IRR 450 = cost of information acquired), and time spent (number of time steps \times IRR 780) (time pressure). The subject entered the final stage of decision-making process, the choice. If the choice was correct the subject would be provided by a feedback credit bar [IRR 15000 - (cost of information + time pressure)] (i.e., decision-making strategy). However, if the subject would make a wrong choice, he/she would gain no reward from the specific round of the game (i.e., task-based complexity). By moving to the next round, the remaining credit was calculated as the total credit at the beginning of the previous round - amount lost on the current round (i.e., task-based complexity).

The participants in this study included a group of 17 volunteers with a history of at least one year of substance use and no history of chronic medical diseases and a control group of 17 healthy individuals with no history of substance use. The number of subjects in each group was determined according to similar studies. All subjects were male. For sampling, a snowball method with two chains was applied.

4. Results

The mean age of the subjects in the user group was 35.94 (± 12.60) and in the control group was 33.8 (± 8.83) years, where a *t*-test showed no difference between the groups ($P = 0.205$). In terms of education, both groups had a high school diploma or more. The number of individuals with higher education or bachelor's degree was higher in the control group (11 vs. 8).

4.1. Search for Information

An independent-sample *t*-test was conducted to compare the mean values of opened boxes variable between the group with a positive substance use history and control group (Table 1).

4.2. Patterns of Move

Comparison of attribute-based and option-based transitions between the two groups showed no significant difference ($df = 32$, $P = 0.96$ for attribute-based transitions and $df = 32$, $P = 0.30$ for alternative-based transitions) (Table 2).

4.3. Time-Related Variables

As presented in Table 3, time spent on different stages of the game was significantly different between the two groups. There were two categories in this subset of variables. The first category is the amount of time participants held the mouse cursor over the 4×4 matrix on the computer interface in relation to the click time (sum of all the time that cursor was held on each of 16 boxes of the matrix) and the on-click (sum of all the time that cursor was held or moved on the game interface except over the buttons section). These two variables refer to the search and stop search times of a decision cycle. Both variables were significantly different between the two groups ($P = 0.036$ for click time and $P = 0.028$ for on-click time), indicating that participants with a history of substance use spent more time for search and stop search, compared to the control group. The other category refers to the time that participants move the mouse cursor into the buttons area, including mouseover or button time (the sum of all the times the cursor was held or a button was pressed) and mouse-out time (the sum of all the times the cursor was in the buttons area except the mouseover times). These two variables refer to the time that the participant spent on processing information and decision-making. The mouse-out time was also significantly different between the two groups ($P = 0.025$). However, the button time variable did not reveal a significant difference between the two groups.

These results indicate that individuals with a positive history of substance use spent more time on information processing and decision-making stages, compared to the control group. However, the move-on and pressing the buttons was not different between the two groups. Furthermore, a significant difference was observed between the two groups in total time spent on playing the 60 rounds of the game ($P = 0.029$).

4.4. Accuracy of Choice

Our results showed no significant difference in the correct and wrong choice variable between the two groups ($P = 0.172$). However, the credit balance throughout the game was significantly different between the two groups ($P = 0.003$) (Table 4).

5. Discussion

Altogether, decision-making processes were similar between individuals with a positive and negative history of substance use in two processes of stop search and final decision. However, two other stages of decision-making process of searching for information and decision-making were significantly different between the two groups (Table 5).

Lack of significant differences in accuracy of choice, coupled with the lack of a difference in the pathway between the two groups, suggests that these cognitive components might indicate that either the decision to use substances is not related to these two processes of decision-making, or that using substances does not result in considerable change in those processes. By considering sequence and time durations as stages of decision-making and making a choice, it can be concluded that the difference between the groups reveals that individuals with a positive history of substance use consumed more resources, i.e., the time required for each cognitive act corresponds to the energy consumed by brain (25, 35-37). Besides, one may claim that the two processes of searching for information and decision-making do not affect the accuracy of choice.

By measurement of ability to coordinate intent with the actualization of that intent (8, 38) it has been shown that, similar to other individuals, subjects who use substances are capable of determining the best possible strategy to execute and accomplish tasks. However, they might not be able to apply a decided strategy (39-41). It is said that individuals who use substances might suffer from cognitive control defects which restrict their ability to translate their strategies and goals into action (8). According to results of Iowa Gambling Test in subjects who use substances, they are shown to have a lower loss aversion capacity (42), meaning that they are not sensitive to negative

Table 1. Description and Analysis of Data Related to Search for Information (df = 32)

Boxes Opened	A Positive History of Substance Use		Control Group		P Value ^a
	Mean (SD)	Median (Interquartile Range)	Mean (SD)	Median (Interquartile Range)	
Number	475.29 (114.93)	455 (184.50)	407.35 (88.34)	403 (95.50)	0.06
Percent	0.49 (0.11)	0.47 (0.11)	0.42 (0.04)	0.41 (0.10)	0.06
Average	7.92 (1.91)	7.60 (3.07)	6.78 (1.47)	6.71 (1.59)	0.06

^aEqual variances assumed.**Table 2.** Description and Analysis of Path Processing and Tracing Processing of Data (df = 32)

Variables	A Positive History of Substance Use		Control Group		P Value ^a
	Mean (SD)	Median (Interquartile Range)	Mean (SD)	Median (Interquartile Range)	
Attribute-based transition (n)	165.05 (102.87)	135 (111)	163.76 (86.60)	150 (137)	0.96
Option-based transition (n)	211.52 (82.54)	186 (108)	182.47 (80.45)	166 (109.50)	0.30

^aEqual variances assumed.**Table 3.** Description and Analysis of Data Related to Time Spent in the Stages of the Game

Variables ^a	A Positive History of Substance Use		Control Group		P Value
	Mean (SD)	Median (Interquartile Range)	Mean (SD)	Median (Interquartile Range)	
Button time	1333.49 (416.40)	1285.90 (505.24)	1182.38 (728.65)	1011 (467.11)	0.46 ^b
Click time	1291750.82 (498172)	1308300 (790349)	976378.82 (313708)	970020 (375837)	0.036 ^c
On-click time	1421200 (538161)	1441200 (853027)	1068600 (320865)	1040100 (391291)	0.028 ^c
Mouse-out time	1505200 (549685)	1507700 (871134)	1133800 (337383)	1093400 (430519)	0.025 ^c
Total time	4218100 (1584780)	4255600 (2514510)	3178700 (968620)	3103500 (1246254)	0.029 ^c

^aAll times in milliseconds.^bEqual variances assumed.^cEqual variances not assumed.**Table 4.** Description and Analysis of Data Related to Accuracy of Choices and Credit Line

Variables	Positive History of Substance Use		Control Group		P Value ^a
	Mean (SD)	Median (Interquartile Range)	Mean (SD)	Median (Interquartile Range)	
Correct choice (n)	41.52(10.74)	44 (11)	46.11 (8.25)	48 (9.50)	0.172
Wrong choice (n)	18.47 (10.74)	16 (11)	11.88 (8.25)	12 (9.50)	0.172
Winning credit (IRR)	28395.52 (6769.74)	28173 (12535.50)	35566.23 (6241.26)	36744 (10270.50)	0.003

^aEqual variances assumed.

feedback. Furthermore, it is argued that in individuals who use substances adaptive decision-making is impaired. In our study, the results were in agreement with such indications.

Some scholars have suggested that by limiting the time of a test, especially when the subject's sense of the passage of time is intensified, the individual's information processing is accelerated at the expense of searching for the infor-

mation (43-46). However, Payne argued that by negatively associating the outcome reward to the passage of time, decision-making further speeds up in addition to already accelerated processing (6, 29). In contrast to conditioning process of incentive salience and craving (9, 47, 48), action-selection systems, that are responsible for declarative and episodic evaluation processes, emerge from simulation of events and future rewards, following a response-result

Table 5. Differences Between Decision-Making Processes in Individuals with a Positive and Negative History of Substance Use

Stages of Decision-Making	Difference
Searching for information	Significantly different
Stop searching	No difference
Decision-making	Significantly different
Final selection	No difference

pathway (49). In our game model, all those booster processes were in action. Therefore, it appears that not only accelerated processing of some stages may compensate for other defective processes (i.e., limited search for information), but also boosting of some processes, for example by negatively associating decision-making time to incentives, may assure the accuracy of choice. It has been demonstrated that individuals who use substances are more likely to tolerate risk and uncertainty in their preferences (8). According to the results of this study, subjects with a positive history of substance use appear to process information and make decisions similar to control subjects, provided they have the minimum required time.

The above argument that some processes of decision-making may have the capacity to compensate other defective stages raises the question of whether using substances is the result of defective decision-making or it is related to factors other than decision-making. By this argument, not only the generalizability of rational addiction theory must be cautioned, but also one should cast doubt on the common belief that rationality-based prevention programs that provide information about negative consequences of using substances would work as expected. Furthermore, the fact that in our study subjects who had used substances spent more time on making the same decisions compared to individuals with a negative history of using substances might be taken as a sign that negative consequences of substance use might have distorted some processes of decision-making without influencing the outcome.

5.1. Conclusions

The aim of this study was to investigate the pathological aspects of cognitive changes in decision-making and choice of substance-using behavior. The results indicated that despite the previously identified cognitive changes in individuals who use substances, those changes may not be general and occur in only specific aspects of decision-making process. The modality of using the time for proper decision-making in individuals with a history of substance use is different and extended from control subjects. However, as the final choice of individuals with a positive or

negative history of substance use were not different, the impression that decision-making processes play as direct components of rational addiction theory (50-52) might need further deliberation. In other words, the behavior of using substances may not be a direct consequence of defective decision-making processes.

5.2. Limitations of the Study

A limitation of this research was the small number of samples. As the study took a long time, participation was dependent on incentives, but as researchers were compensating the incentives they had to limit the study to smaller samples. Wide inclusion criteria that did not differentiate between different types of substances of use (i.e., stimulants, narcotics, sedatives, etc.) may be regarded as another limitation of the study.

Footnotes

Authors' Contribution: Reza Rastgoo Sisakht, Maryam Noroozian, and Emran Razaghi developed the original idea. Reza Rastgoo Sisakht, Shabnam Mousavi, and Emran Razaghi developed the study design. Reza Rastgoo and Hamid Valizadegan modified the software. Rahimeh Negarandeh and Reza Rastgoo performed the fieldwork. Reza Rastgoo, Rahimeh Negarandeh, and Emran Razaghi contributed to data acquisition. Reza Rastgoo, Rahimeh Negarandeh, Shabnam Mousavi, Mehdi Tehrani-Doost, and Emran Razaghi contributed to analysis and interpretation of data. Reza Rastgoo Sisakht performed data analysis. Reza Rastgoo Sisakht and Emran Razaghi prepared the manuscript.

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Patient Consent: Participation in this study was voluntarily and required written consent. As the study method included games with monetary credit, the participants received the exact amount they had gained throughout the game just after finishing the exam.

References

1. Payne JW, Braunstein ML. Risky choice: An examination of information acquisition behavior. *Mem Cognit.* 1978;**6**(5):554-61. doi: [10.3758/BF03198244](https://doi.org/10.3758/BF03198244). [PubMed: [24203389](https://pubmed.ncbi.nlm.nih.gov/24203389/)].
2. Payne JW, Braunstein ML, Carroll JS. Exploring predecisional behavior: An alternative approach to decision research. *Organ Behav Hum Perform.* 1978;**22**(1):17-44. doi: [10.1016/0030-5073\(78\)90003-x](https://doi.org/10.1016/0030-5073(78)90003-x).
3. Bechara A. Decision making, impulse control and loss of willpower to resist drugs: A neurocognitive perspective. *Nat Neurosci.* 2005;**8**(11):1458-63. doi: [10.1038/nn1584](https://doi.org/10.1038/nn1584). [PubMed: [16251988](https://pubmed.ncbi.nlm.nih.gov/16251988/)].
4. Bechara A, Damasio AR. The somatic marker hypothesis: A neural theory of economic decision. *Game Econ Behav.* 2005;**52**(2):336-72. doi: [10.1016/j.geb.2004.06.010](https://doi.org/10.1016/j.geb.2004.06.010).
5. Broder A. [Take the best, Dawes rule, and compensatory decision strategies: A method for classifying individual response patterns]. PsyDok Dokumentenserver für die Psychologie; 2001. German.
6. Riedl R, Brandstatter E, Roithmayr F. Identifying decision strategies: A process- and outcome-based classification method. *Behav Res Methods.* 2008;**40**(3):795-807. [PubMed: [18697676](https://pubmed.ncbi.nlm.nih.gov/18697676/)].
7. Redish AD, Jensen S, Johnson A. Addiction as vulnerabilities in the decision process. *Behav Brain Sci.* 2008;**31**(4):461-87. doi: [10.1017/S0140525X08004986](https://doi.org/10.1017/S0140525X08004986).
8. Verdejo-Garcia A, Chong TT, Stout JC, Yucel M, London ED. Stages of dysfunctional decision-making in addiction. *Pharmacol Biochem Behav.* 2018;**164**:99-105. doi: [10.1016/j.pbb.2017.02.003](https://doi.org/10.1016/j.pbb.2017.02.003). [PubMed: [28216068](https://pubmed.ncbi.nlm.nih.gov/28216068/)].
9. Sweis BM, Thomas MJ, Redish AD. Beyond simple tests of value: measuring addiction as a heterogeneous disease of computation-specific valuation processes. *Learn Mem.* 2018;**25**(9):501-12. doi: [10.1101/lm.047795.118](https://doi.org/10.1101/lm.047795.118). [PubMed: [30115772](https://pubmed.ncbi.nlm.nih.gov/30115772/)]. [PubMed Central: [PMC6097760](https://pubmed.ncbi.nlm.nih.gov/PMC6097760/)].
10. Elster J. *Addiction: Entries and exits*. Russell Sage Foundation; 1999.
11. Liccardo Pacula R. *Addiction: Entries and exits*. Edited by Jon Elster. New York: Sage, 1999. *J Ment Health Policy Econ.* 2000;**3**(3):165-6. [PubMed: [11967452](https://pubmed.ncbi.nlm.nih.gov/11967452/)].
12. Levy N. Addiction: The belief oscillation hypothesis. In: Pickard H, Ahmed SH, editors. *The routledge handbook of philosophy and science of addiction*. Oxon (UK); 2019. p. 54-62. eng. doi: [10.4324/9781315689197-6](https://doi.org/10.4324/9781315689197-6).
13. Baumeister RF, Muraven M, Tice DM. Ego depletion: A resource model of volition, self-regulation, and controlled processing. *Soc Cognit.* 2000;**18**(2):130-50. doi: [10.1521/soco.2000.18.2.130](https://doi.org/10.1521/soco.2000.18.2.130).
14. Muraven M, Baumeister RF. Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychol Bull.* 2000;**126**(2):247-59. doi: [10.1037/0033-2909.126.2.247](https://doi.org/10.1037/0033-2909.126.2.247). [PubMed: [10748642](https://pubmed.ncbi.nlm.nih.gov/10748642/)].
15. Tice DM, Bratslavsky E, Baumeister RF. Emotional distress regulation takes precedence over impulse control: If you feel bad, do it!. *J Pers Soc Psychol.* 2001;**80**(1):53-67. [PubMed: [11195891](https://pubmed.ncbi.nlm.nih.gov/11195891/)].
16. Baumeister RF, Heatherton TF. Self-regulation failure: An overview. *Psychol Inq.* 1996;**7**(1):1-15. doi: [10.1207/s15327965pli0701_1](https://doi.org/10.1207/s15327965pli0701_1).
17. Sinha R, Garcia M, Paliwal P, Kreek MJ, Rounsaville BJ. Stress-induced cocaine craving and hypothalamic-pituitary-adrenal responses are predictive of cocaine relapse outcomes. *Arch Gen Psychiatry.* 2006;**63**(3):324-31. doi: [10.1001/archpsyc.63.3.324](https://doi.org/10.1001/archpsyc.63.3.324). [PubMed: [16520439](https://pubmed.ncbi.nlm.nih.gov/16520439/)].
18. Spears D. Economic decision-making in poverty depletes behavioral control. *B E J Econ Anal Pol.* 2011;**11**(1). doi: [10.2202/1935-1682.2973](https://doi.org/10.2202/1935-1682.2973).
19. Bickel WK, Mellis AM, Snider SE, Athamneh LN, Stein JS, Pope DA. 21st century neurobehavioral theories of decision making in addiction: Review and evaluation. *Pharmacol Biochem Behav.* 2018;**164**:4-21. doi: [10.1016/j.pbb.2017.09.009](https://doi.org/10.1016/j.pbb.2017.09.009). [PubMed: [28942119](https://pubmed.ncbi.nlm.nih.gov/28942119/)]. [PubMed Central: [PMC5747999](https://pubmed.ncbi.nlm.nih.gov/PMC5747999/)].
20. Heatherton TF, Baumeister RF. Self-regulation failure: Past, present, and future. *Psychol Inq.* 1996;**7**(1):90-8. doi: [10.1207/s15327965pli0701_20](https://doi.org/10.1207/s15327965pli0701_20).
21. Broder A, Schiffer S. Bayesian strategy assessment in multi-attribute decision making. *J Behav Decis Making.* 2003;**16**(3):193-213. doi: [10.1002/bdm.442](https://doi.org/10.1002/bdm.442).
22. Reisen N, Hoffrage U, Mast FW. Identifying decision strategies in a consumer choice situation. *Judg Decis Making.* 2008;**3**(8):641-58.
23. Rieskamp J, Hoffrage U. *When do people use simple heuristics, and how can we tell? Simple heuristics that make us smart*. New York, NY, US: Oxford University Press; 1999.
24. Harte JM, Koelke P. Modelling and describing human judgement processes: The multiattribute evaluation case. *Think Reas.* 2001;**7**(1):29-49. doi: [10.1080/13546780042000028](https://doi.org/10.1080/13546780042000028).
25. Lohse GL, Johnson EJ. A comparison of two process tracing methods for choice tasks. *Organ Behav Hum Decis Process.* 1996;**68**(1):28-43. doi: [10.1006/obhd.1996.0087](https://doi.org/10.1006/obhd.1996.0087).
26. Koop GJ, Johnson JG. Response dynamics: A new window on the decision process. *Judg Decis Making.* 2011;**6**(8):750-8.
27. Ranyard R, Svenson O. Verbal data and decision process analysis. *A handbook of process tracing methods for decision research.* 2011. p. 115-38. doi: [10.4324/9780203875292](https://doi.org/10.4324/9780203875292).
28. Schulte-Mecklenbeck M, Kuhberger A, Ranyard R. The role of process data in the development and testing of process models of judgment and decision making. *Judg Decis Making.* 2011;**6**(8).
29. Payne JW, Bettman JR, Johnson EJ. *The adaptive decision maker: Effort and accuracy in choice*. Cambridge, UK: Cambridge University Press; 1997.
30. Payne JW, Bettman JR, Johnson EJ. Behavioral decision research: A constructive processing perspective. *Annu Rev Psychol.* 1992;**43**(1):87-131. doi: [10.1146/annurev.ps.43.020192.000511](https://doi.org/10.1146/annurev.ps.43.020192.000511).
31. Willemsen MC, Johnson EJ. *MouselabWEB: Monitoring information acquisition processes on the Web*. 2006.
32. Willemsen MC, Johnson EJ. Visiting the decision factory: Observing cognition with MouselabWEB and other information acquisition methods. *A handbook of process tracing methods for decision research.* 2010. p. 21-42. doi: [10.4324/9780203875292](https://doi.org/10.4324/9780203875292).
33. Rastgoo Sisakht R, Mousavi S, Negarandeh R, Valizadegan H, Noroozian M, Tehrani-Doost M, et al. Choice quality as a function of decision accuracy and search cost. *Iran J Psychiatry.* 2019;**14**(3):203-10. doi: [10.18502/ijps.v14i3.1324](https://doi.org/10.18502/ijps.v14i3.1324).
34. Gabaix X, Laibson D, Moloche G, Weinberg S. Costly information acquisition: Experimental analysis of a boundedly rational model. *Am Econ Rev.* 2006;**96**(4):1043-68. doi: [10.1257/aer.96.4.1043](https://doi.org/10.1257/aer.96.4.1043).
35. Lohse GL. Consumer eye movement patterns on yellow pages advertising. *J Advert.* 1997;**26**(1):61-73. doi: [10.1080/00913367.1997.10673518](https://doi.org/10.1080/00913367.1997.10673518).
36. Newell A, Card SK. The prospects for psychological science in human-computer interaction. *Hum Comput Interact.* 2009;**1**(3):209-42. doi: [10.1207/s15327051hci0103_1](https://doi.org/10.1207/s15327051hci0103_1).
37. Card SK. *The psychology of human-computer interaction*. Crc Press; 2018.
38. Levine B, Robertson IH, Clare L, Carter G, Hong J, Wilson BA, et al. Rehabilitation of executive functioning: An experimental-clinical validation of goal management training. *J Int Neuropsychol Soc.* 2000;**6**(3):299-312. [PubMed: [10824502](https://pubmed.ncbi.nlm.nih.gov/10824502/)].
39. Verdejo-Garcia AJ, Perales JC, Perez-Garcia M. Cognitive impulsivity in cocaine and heroin polysubstance abusers. *Addict Behav.* 2007;**32**(5):950-66. doi: [10.1016/j.addbeh.2006.06.032](https://doi.org/10.1016/j.addbeh.2006.06.032). [PubMed: [16876962](https://pubmed.ncbi.nlm.nih.gov/16876962/)].
40. Valls-Serrano C, Caracuel A, Verdejo-Garcia A. Goal management training and mindfulness meditation improve executive functions and transfer to ecological tasks of daily life in polysubstance users enrolled in therapeutic community treatment. *Drug Alcohol Depend.* 2016;**165**:9-14. doi: [10.1016/j.drugalcdep.2016.04.040](https://doi.org/10.1016/j.drugalcdep.2016.04.040). [PubMed: [27246405](https://pubmed.ncbi.nlm.nih.gov/27246405/)].
41. Valls-Serrano C, Verdejo-Garcia A, Caracuel A. Planning deficits in polysubstance dependent users: Differential associations with severity of drug use and intelligence. *Drug Alcohol Depend.* 2016;**162**:72-8. doi: [10.1016/j.drugalcdep.2016.02.027](https://doi.org/10.1016/j.drugalcdep.2016.02.027). [PubMed: [26971229](https://pubmed.ncbi.nlm.nih.gov/26971229/)].

42. Ahn WY, Vasilev G, Lee SH, Busemeyer JR, Kruschke JK, Bechara A, et al. Decision-making in stimulant and opiate addicts in protracted abstinence: Evidence from computational modeling with pure users. *Front Psychol.* 2014;**5**:849. doi: [10.3389/fpsyg.2014.00849](https://doi.org/10.3389/fpsyg.2014.00849). [PubMed: [25161631](https://pubmed.ncbi.nlm.nih.gov/25161631/)]. [PubMed Central: [PMC4129374](https://pubmed.ncbi.nlm.nih.gov/PMC4129374/)].
43. Verplanken B. Need for cognition and external information search: Responses to time pressure during decision-making. *J Res Pers.* 1993;**27**(3):238–52. doi: [10.1006/jrpe.1993.1017](https://doi.org/10.1006/jrpe.1993.1017).
44. Verplanken B, Weenig MWH. Graphical energy labels and consumers' decisions about home appliances: A process tracing approach. *J Econ Psychol.* 1993;**14**(4):739–52. doi: [10.1016/0167-4870\(93\)90019-h](https://doi.org/10.1016/0167-4870(93)90019-h).
45. Dhar R, Nowlis SM. The effect of time pressure on consumer choice deferral. *J Consum Res.* 1999;**25**(4):369–84. doi: [10.1086/209545](https://doi.org/10.1086/209545).
46. Dhar R, Nowlis SM, Sherman SJ. Comparison effects on preference construction. *J Consum Res.* 1999;**26**(3):293–306. doi: [10.1086/209564](https://doi.org/10.1086/209564).
47. Bernheim BD, Rangel A. *Addiction and cue-conditioned cognitive processes*. National Bureau of Economic Research; 2002.
48. Berridge KC, Robinson TE. Liking, wanting, and the incentive-sensitization theory of addiction. *Am Psychol.* 2016;**71**(8):670–9. doi: [10.1037/amp0000059](https://doi.org/10.1037/amp0000059). [PubMed: [27977239](https://pubmed.ncbi.nlm.nih.gov/27977239/)]. [PubMed Central: [PMC5171207](https://pubmed.ncbi.nlm.nih.gov/PMC5171207/)].
49. Redish AD, Mizumori SJ. Memory and decision making. *Neurobiol Learn Mem.* 2015;**117**:1–3. doi: [10.1016/j.nlm.2014.08.014](https://doi.org/10.1016/j.nlm.2014.08.014). [PubMed: [25192867](https://pubmed.ncbi.nlm.nih.gov/25192867/)]. [PubMed Central: [PMC4428655](https://pubmed.ncbi.nlm.nih.gov/PMC4428655/)].
50. Becker GS, Murphy KM. A theory of rational addiction. *J Polit Econ.* 1988;**96**(4):675–700. doi: [10.1086/261558](https://doi.org/10.1086/261558).
51. Becker GS, Grossman M, Murphy KM. Rational addiction and the effect of price on consumption. *Am Econ Rev.* 1991;**81**(2):237–41.
52. Monterosso J, Ainslie G. The behavioral economics of will in recovery from addiction. *Drug Alcohol Depend.* 2007;**90** Suppl 1:S100–11. doi: [10.1016/j.drugalcdep.2006.09.004](https://doi.org/10.1016/j.drugalcdep.2006.09.004). [PubMed: [17034958](https://pubmed.ncbi.nlm.nih.gov/17034958/)]. [PubMed Central: [PMC2756459](https://pubmed.ncbi.nlm.nih.gov/PMC2756459/)].