Future Thinking Specificity, Delay Discounting and the Mediating Role of Working Memory in Addiction

Thomas G. Langkau
Radboud University

Student number: s1009730
Supervisor: Dr. Julie Krans
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Abstract

Addiction comes with a high risk for relapse. To prevent relapse, future events must be imagined in a specific way, in order to choose appropriate problem-solving strategies. The ability to make specific future projections is called future thinking specificity (FTS). FTS and factors influencing FTS remain understudied in addiction. Working memory capacity, which is negatively affected by addiction, is such a potential factor. Moreover, it remains understudied, whether the tendencies to discount delayed rewards (called delay discounting) is influenced by FTS abilities. The purpose of this study was (1) to compare FTS between participants with and without addiction, (2) to investigate the role of working memory as mediator between addiction and FTS and (3) to investigate the role of FTS as mediator between addiction and delay discounting. Abstinent inpatients with an addiction (n = 20) and a control group (n = 88) completed a FTS test, a working memory test and a delay discounting test. Against our hypothesis, addicts showed significantly higher FTS levels than controls. No mediating role of working memory was found. Furthermore, addiction predicted higher delay discounting. FTS was not a mediator in this relation. However, results of FTS seemed to be influenced by problems during the data-collection. Nevertheless, the underlying ideas of this study remain relevant for future research. Furthermore, we present advice on how to improve the methodological implementation. Finally, our results confirm the existence of a relation between addiction and delay discounting and confirm that treatment should focus on the reduction of delay discounting, in order to prevent relapse.

Keywords: addiction, future thinking, working memory, delay discounting, mediation

Addiction, Future Thinking Specificity, Delay Discounting and the Mediating Role of Working Memory

People with depression tend to remember autobiographical information in an overgeneralized way (Williams & Broadbent, 1986). When emotional cue-words are provided to people with depression and they are asked to recall a specific memory (i.e., a particular event within a timeframe that does not exceed one day), they tend to recall more global and repeated events ('I always enjoyed dinner at a restaurant') instead of specific ones ('Last Sunday I enjoyed dinner with an old friend in a restaurant') (Söderlund et al., 2014). They also generate less specific autobiographical future events (Brown, Root, Romano, Chang, Bryant, & Hirst, 2013). Yet, thinking about your personal future in a specific way could help to anticipate future problems. In this line, it has been found that simulating your personal future in a specific way supports effective coping and problem-solving (Schacter, Addis, & Buckner, 2008), while a less detailed simulation may impair problem-solving abilities (Brown, Dorfman, Marmar, & Bryant, 2012). Other functions that have been found to benefit from specific future projection are emotion regulation, planning and decision-making (Schacter, Benoit, & Szpunar, 2017). The ability to envision the future is called episodic future thinking, prospective thinking, or mental time travel. I will refer to these concepts by using the term *future thinking (FT)*, respectively *future thinking specificity (FTS)*.

Schacter and Addis (2007) proposed with their 'constructive episodic simulation hypothesis' that FT can be seen as the recombination of information from long term memory in order to construct an imaginary future event. Hence, thinking about the past and future relies on the same information. In addition, retrieval of autobiographic memories and FT seem to share the same underlying neural network, including the medial prefrontal cortex, medial temporal lobe, retrosplenial/posterior cingulate cortex, and inferior parietal lobule (Schacter et al., 2008). Functional or structural disfunctions of a memory related structure could therefore also affect someone's FT ability. Damage to medial temporal lobes for example, causes impairment of episodic memory and FT (Race, Keane, & Verfaellie, 2011).

FT has often been linked to executive functioning (see e.g., Williams et al., 2007; D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010). Retrieving and recombining memories in order to imagine the future requires a certain amount of cognitive capacity (Suddendorf & Corballis, 2007). One cognitive ability related to FT is *working memory*, which is crucial to temporarily hold and manipulate information in the mind. In Hill and Emery (2013), regression analysis revealed that working memory capacity predicted FTS. If

working memory is a factor influencing FTS, people suffering from disorders that often go together with working memory impairment should show less specific FT compared to a healthy population.

In this line, substance related addiction would be one of those potential disorders, since drug and alcohol abuse have negative effects on different brain areas. In the following, the term ‘addiction’ will be used to refer to ‘substance use disorder’ (DSM 5; American Psychiatric Association, 2013), which is characterized by the following: (1) consuming larger amounts of a substance or for longer than wanted, (2) not being able to cut down or stop using, (3) spending much time on getting, using or recovering from the use, (4) craving, (5) being unable to carry out major obligations (work, school, home), (6) continued use despite social problems, (7) giving up social, occupational, or recreational activities due to substance use, (8) recurrent use in hazardous situations, (9) continued use, although being aware of physical or psychological problems being caused or getting worse through substance use, (10) increased tolerance and (11) the development of withdrawal symptoms. For a diagnosis at least two criteria must be met.

Addiction has often been related to changes in the prefrontal cortex, which is associated with executive functions, such as working memory (Verdejo-García, Bechara, Recknor, & Perez-Garcia, 2006). Research shows a decreased working memory capacity in abstinent addicts (Verdejo-García, 2006; Fernández-Serrano, Pérez-García, & Verdejo-García, 2011). Working memory impairment is often especially pronounced during intoxication. After chronical use however, impairments can sustain for several weeks or even months, depending on the substance. Substances that show large effect sizes regarding working memory impairment are cocaine, methamphetamine, and heroin (Fernández-Serrano et al., 2011). For MDMA, the effect size is small, but remains rather constant over time. While working memory seems to be impaired shortly after alcohol detoxification, the effect size decreases to 0.37 after a month and 0.19 after several years (Fernández-Serrano et al., 2011). Even though working memory capacity might recover after a certain period of abstinence from alcohol, a negative effect is likely to occur for at least a couple of weeks.

The relation between working memory and FTS leads to the hypothesis that abstinent addicts might show lower FTS compared to non-addicts. Investigating the relation between working memory and FTS in the field of addiction is important, since it might help to understand the high risk of relapse, which can be defined as “a term used to describe the

resumption of drug-taking behavior during periods of self-imposed or forced abstinence in humans" (Epstein, Preston, Stewart, & Shaham, 2006, p. 2). This is argued, because FT gives you the possibility to anticipate consequences prior to acting (D'Argembeau et al., 2010). With the opportunity to consider different potential consequences, long-term goals can be favored over direct needs. For example, the consequence of relapsing into addiction after taking a drug to satisfy a current craving must be evaluated against long term consequences. The tendency to devaluate higher future rewards against smaller immediate rewards is known as *delay discounting*. Thereby, this concept is not limited to alcohol/drugs but describes someone`s tendency to discount different kinds of delayed rewards in general. Studies showed that individuals with an addiction show higher levels of delay discounting compared to controls (MacKillop, Amlung, Few, Ray, Sweet, & Munafò, 2011). Furthermore, it has been found that engaging into future thinking reduces delay discounting (for different studies see Schacter et al., 2017). However, those studies did not look into the specificity of the future thinking. Investigating potential factors that influence delay discounting, such as FTS, is important, since delay discounting plays a role in the development and maintenance of drug use and addiction (Kollins, 2003; Reynolds, 2006). Bickel, Yi, Landes, Hill, and Baxter (2011) showed that working memory training can reduce delay discounting in stimulant addicts. Thereby, they demonstrated the causal role of working memory regarding delay discounting. Going one step further, we suggest that this reduction of delay discounting may have resulted (at least partly) from an increased FTS, facilitated by increased working memory capacity.

While FTS has been studied in depression, less is known about FTS in other psychological disorders like substance related addiction. The current study aims to elucidate the relation between substance related addiction, FTS and delay discounting, while considering the role of working memory. The results could aid in the understanding of mechanisms of relapse, which in turn could result in more efficient treatment interventions. The following research questions have been formulated:

1. Is there a difference in FTS between people with an alcohol/drug addiction who are currently abstinent and people without a substance related addiction?

2. Is the relation between addiction and FTS mediated by working memory capacity?

3. Is the relation between addiction and delay discounting mediated by FTS?

To answer these research questions, abstinent inpatients with a substance related addiction and a non-addiction control group completed a working memory test, a future thinking specificity test, and a delay discounting test. Our first hypothesis was that people with an addiction would show lower FTS compared to the control group. Our second hypothesis was that FTS is mediated by working memory capacity, which is often impaired after chronic alcohol and drug abuse. Addiction should be related to lower working memory capacity, which in turn relates to lower specific FTS. We further expected that delay discounting would be mediated by FTS, whereby addiction is related to lower FTS, which then is related to higher delay discounting. Figure 1 and 2 illustrate the proposed relations between the main variables of this study.

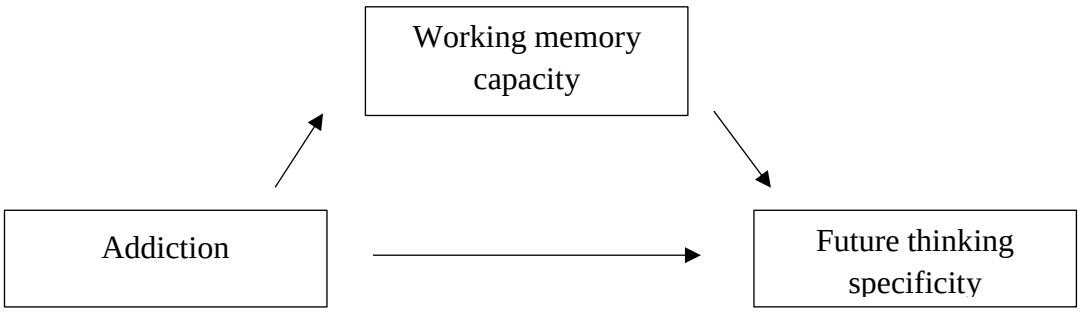

Figure 1. The predicted relation between addiction as independent variable, FTS as dependent variable and working memory capacity as mediator.

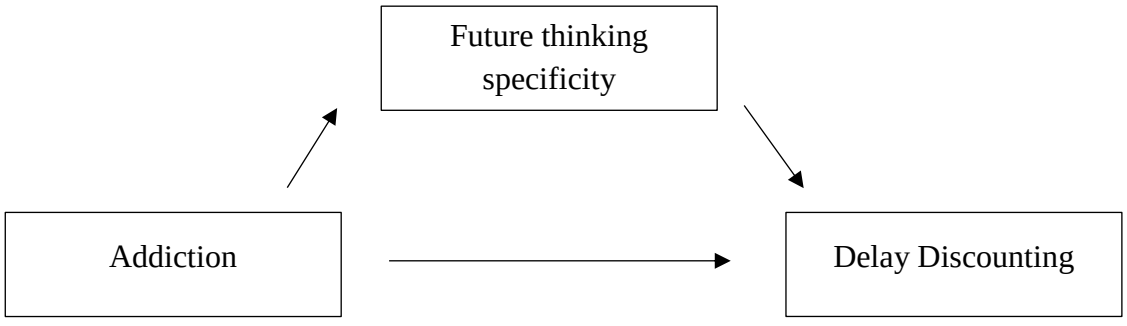

Figure 2. The predicted relation between addiction as independent variable, FTS as dependent variable and working memory capacity as mediator.

Methods

Participants

Data was collected from abstinent alcohol-/drug addicts (referred to as the addiction group) and a non-addicted control group. Potential participants for the addiction group were invited through their primary practitioner at a German inpatient clinic for addiction treatment. Interested patients received an information-flyer about the study, including the researcher`s contact details in order to make an appointment. The control group was recruited via the Radboud SONA research participation system of the Radboud University Nijmegen. Originally there was a total sample size of 135. Data of participants that had consumed drugs/alcohol on the day of participation or one day before were excluded from the analysis (n = 21). All of them were from the control group. This was done to ensure that data was not influenced by current intoxication. Data of control group participants that indicated to be or have been addicted to alcohol/drugs were excluded as well (n = 6). Analysis were conducted with a sample size of n = 108 (addiction group: n = 20, control group: n = 88). Sample characteristics are presented in Table 1.

The addiction group consisted of currently abstinent patients in treatment for substance use disorder (DSM 5; American Psychiatric Association, 2013). Besides addiction, the following DSM 5 disorders were diagnosed within this group: depression (n = 13), post-traumatic stress disorder (n = 2), adjustment disorder (n = 1), generalized anxiety disorder (n = 1), bulimia nervosa (n = 1), borderline personality disorder (n = 1) and attention deficit hyper activity disorder (n = 1). Participants were between 19 and 65 years old (M = 45.65, SD = 11.84). The majority of participants were male. All participants of this group were German except one participant from Turkey. All were German speaking. The majority had an educational diploma lower than high school degree (75%). One participant had no degree. The majority were exclusively addicted to alcohol (70%). The rest was addicted to more than one substance. Other substances that participants were addicted to were cannabis, amphetamine, sedatives/sleeping pills, cocaine, prescription stimulants, prescription opioids and illegal opioids. The individual duration of addiction varied from 3 - 360 months (M = 151.25, SD = 110.65), with 75% being addicted for more than 72 months. To minimize the influences of detoxification on cognitive performance, participants of the addiction group had to be abstinent for at least 30 days prior to participation. Participation was voluntary and without any reward.

The control group (n = 88) consisted of students of the Radboud University Nijmegen, aged between 18 and 28 years old (M = 19.93, SD = 1.87). The majority of participants were

female. Almost all participants were Dutch (n = 46) or German (n = 40), expect one participant from Ireland and one participant form Rumania. All were Dutch or German-speaking. All held a high school diploma or equivalent or a higher degree. 44.3% had consumed alcohol on a monthly basis and 17% cannabis monthly during the last year. 20.5% respectively 8% reported to consume those substances weekly. Other substances were consumed rarely within the control group. For a detailed overview of the consumption pattern of this group see Appendix A.

Table 1
Sample Characteristics

	Addiction (n = 20)		Control (n = 88)	
Variable	*n*	%	*n*	%
Sex				
Male	14	70	22	74
Female	6	30	65	25
Other	-	-	1	1
Level of education				
No degree	1	5	0	-
Less than high school diploma	15	75	0	-
High school/equivalent	3	15	86	97.7
Bachelor`s degree	1	5	2	2.3
Marital status				
Single	12	60	51	58
Relation – not living together	1	5	34	38.6
Relation – living together	2	10	3	3.4
Married	5	25	-	-
Last consumption				
never	-	-	9	10.2
within the last 7 days	-	-	35	39.8
within the last 30 days	-	-	25	28.4
within the last 3 months	15	75	7	8.0
within the last 6 months	1	5	7	8.0
more than 6 month ago	6	20	5	5.7
	M	*SD*	*M*	*SD*
Age	45.65	11.82	19.93	1.87

Notes. n = 108

Chi-square analyses of independence revealed, that there was a significant association between the variable group and the variables sex, nationality, level of education and marital status, with $p < .001$ in all cases. An independent samples t-test further revealed that the difference in age between the groups was significant, $t(19.22) = -9.69$, $p < .001$.

Materials

German versions of all tests were used for the addiction group; for the control group

the Dutch or German version were used depending on the participant`s preference. While participants of the control group used their personal device to complete the study online, a Lenovo G575 Laptop (15.6 inch) was used for testing the addiction group.

Demographic data. Participants were asked for: age, sex, nationality, marital status and level of education. The addiction group was additionally asked for 'type of substance addicted to' and 'date of last consumption'. For the control group those last points were covered in a separate drug screening questionnaire.

Drug Screening Questionnaire. To be able to control for the effects of substance use in the control group, a short drug screening questionnaire (DSQ) was developed for the purpose of this study, based on the NIDA Drug Screen (National Institute on Drug Abuse, 2012). Participants indicated (1) how often they had used certain substances in the past year (never, once or twice, monthly, weekly, daily/almost daily), (2) the date of last consumption (today, yesterday, within last 7 days, within last 30 days, within the last 3 months, within the last 6 months, more than 6 months ago or never) and (3) whether they had ever been addicted to alcohol or drugs (indicating the substance from a list). The full DSQ can be found in Appendix B.

FTS. To measure the FTS in the addiction group, the Autobiographical Memory Test-future version (AMT-f; Kleim, Graham, Fihosy, Stott, & Ehlers, 2014) was used. Ten cue words were presented on cue cards (card 5x10cm) one by one by the researcher (5 positive words: special, love, safe, brave, happy; 5 negative words: stress, tense, hurt, mad, fear)[1]. The words were derived from Dutch words used in Krans, de Bree, and Bryant (2014) and translated into German. Krans et al. (2014) used those words during the original (i.e., past) version of the AMT, not the AMT-f. Yet, they were chosen, since some of the translated words in Kleim et al. (2014) are rarely used in German and could increase the difficulty of the task. For each participant, cue cards were put into an envelope, randomly picked and therefore presented in random order. Participants were asked to describe a specific autobiographical future event related to each cue word. They were instructed to formulate this event as specifically as possible. Instructions included examples of specific and non-specific personal events. Furthermore, participants received two practice items (chocolate and egg)[2]. If responses were non-specific, participants received the following prompt: "Could you be more specific? Can you describe a specific event?". Participants were required to retrieve a

[1] German translation of the positive words: besonders, Liebe, sicher, tapfer, glücklich; German translation of negative words: Stress, angespannt, verletzt, böse, Befürchtung
[2] German translation of the practice words: Schokolade, Eier

specific personal future event within 60 s. As in Kleim et al. (2014), non-response within those 60 s was rated as a non-specific response. Responses were audio-recorded. Afterwards the experimenter transcribed and coded all responses as specific or non-specific. A response was rated as specific if it contained a single event that did not exceed the period of one day (e.g. 'on Sunday I will meet my best friend in the new restaurant around the corner'). Following Raes, Hermans, Williams, and Eelen (2007), who used the original AMT, categoric events (e.g., "going out for dinner'), extended events (e.g., "Studying in Berlin"), semantic associations ("my brother"), omissions and same events (if an event was mentioned twice) were rated as non-specific responses.

The Sentence Completion for Events of the Future Test (SCEFT; Anderson & Dewhurst, 2009) was used to assess FTS in the control group. The SCEPT, that is the version for events of the past, is more sensitive in detecting unspecific responses in non-clinical student samples than the AMT (Raes et al., 2007). The SCEFT is based on the SCEPT and we expected similar advantages for this instrument. Moreover, the SCEFT is suitable for online data collection since the presence of a researcher is not required. It consists of 11 sentence stems (e.g., 'When I look forward to…'). Participants are asked to complete the sentences by generating possible autobiographical future events. The coding was done in the same way as for the AMT-f.

For data-analysis, the percentage of specific responses to the AMT-f and SCEFT were calculated for each participant in order to make the two groups comparable. In the results section, we will refer to this as FTS score.

Working memory. To measure working memory capacity, a computerized n-back task (Ragland et al., 2002) was used. Fifteen letters were presented on a screen one by one for 500 ms per letter with an interstimulus interval of 2500 ms. Twenty different uppercase consonants were used as stimuli. Letters were printed in white on a black background. There were 3 levels: 0-back, 1-back and 2-back. During the 0-back level, the first letter in the sequence is the target letter. Here, participants had to decide whether the current letter was the same as the target letter (K, Z, Q, X, K, M, N, K, K). If this was the case, participants had to press a key ('A'). In the 1-back task participants had to press 'A' whenever the current letter was the same as the letter one position before in the sequence (M, D, D, H, Z, T, T, W). During the 2-back task participants must decide whether the displayed letter is the same as the letter two positions before (X, R, C, R, Q, J, P, Z, P). Again, participants had to press 'A'. Accuracy ((hits – false alarms)/number of blocks) served as a measure of working memory capacity. Both groups were instructed to react as quickly and as accurately as possible. All

participants received one practice trial for each level. Afterwards they had the possibility to repeat the practice trial or to continue to the actual test. During the test, three blocks of each level were completed (3x 0-back; 3x 1-back; 3x 2-back). The nine blocks were presented in random order. Participants could take a short break after each block. Instructions regarding the next block were displayed between the blocks.

Delay discounting. The *Delay Discounting Test* (DDT, Forstmeier & Maercker, 2011) was administered to measure individual delay discounting rates. It contains 27 items, whereby participants had to choose between smaller, immediate rewards (SIR) versus larger, delayed rewards (LDR); e.g. 'Would you prefer EUR 45 today, or 95 EUR in 33 days?'. An individual discounting parameter *k* was calculated based on the response pattern. The *k* value can be derived from the response pattern to the 27 DDT items using SPSS-Scoring-Syntax developed by Forstmeier and Maercker (2011). *K* values run from .00016 to .25. The larger the *k* value, the steeper the discounting. In order to achieve a more normal distribution of the data, the natural log of the *k* parameter was used. Ln*(k)* values range from -8.7 (corresponding k = .00016) to -1.4 (corresponding k = .25). The criterion validity and reliability of the DDT have been confirmed in a sample of 147 older adults (Forstmeier & Maercker, 2011). In our study, Chronbach`s alpha for the DDT was .93. Since the DDT only existed in German, it was translated into Dutch for the control group. Reward and delay sizes remained identical.

Mood. The influence of mood on FTS was demonstrated in several studies (Hallford, Austin, Takano, & Raes, 2018). To be able to control for this influence, the *Beck Depression Inventory-II* (BDI-II; Beck, Steer, & Brown, 1996) was administered to all participants. This self-report test was designed to measure the intensity of depressive symptoms and consists of 21 items (Likert scale 0-3). Scores can fall into four categories: 0-13 (no/minimal depression), 14-19 (mild depression), 20-28 (moderate depression) and 29-63 (severe depression). In our study, Chronbach`s alpha for the BDI-II was .93.

Procedure

The Ethics Committee of the Faculty of Social Sciences of the Radboud University Nijmegen gave their approval before the data collection started (application number: ECSW-2018-019R1). The data collection took place between 01.04.2018 and 23.05.2018. The data of each participant was collected within a single session of around 45 minutes. Except the AMT-f, all tests were administered through the computer-program Inquisit 4 (Millisecond Software, 2015).

Before starting, participants of the addiction group signed an informed consent form.

The data-collection for the addiction group was done individually and took place in a quiet room in the clinic. Tests in the addiction group were administered in the following order: BDI-II, n-back task, AMT-f, DDT, demographic questionnaire. The AMT-f was administered by the experimenter in person, while the other tests were completed at a computer. After finishing the study, participants were thanked. They received an oral debriefing and were invited to ask questions. Moreover, they could leave their mail address in order to receive the final outcomes of the study.

All data of the control group was collected online. Before starting, participants gave their digital informed consent. Tests were administered in the following order: BDI-II, n-back task, SCEFT, DDT, DSQ, demographic questionnaire. After finishing the study, participants were thanked. The contact details of the researcher were presented on the last screen and control group participants were invited to ask questions and to leave their mail address in order to receive the final outcomes of the study. Moreover, control group participants received one SONA credit.

Data-analysis

Data was analyzed with IBM SPSS Statistics 24. The variables mood (BDI-II), working memory capacity (n-back), delay discounting (DDT) and FTS (SCEFT/AMT-f) were tested for outliers, normality and homogeneity of variance. Thereby, outliers were tested by generating boxplots per group and identifying cases lying more than three interquartile ranges away from the upper or lower quartile. Normality was tested by applying the Shapiro-Wilk test per group. To test for homogeneity, Levene`s test for equality of variance was applied. Independent samples t-tests were conducted to compare the two groups on significant differences regarding mood, working memory capacity and delay discounting. Those control analyses were done to support the interpretation of the overall results. To test hypothesis 1, an independent samples t-test was conducted with group (addiction, control) as the independent variable and FTS as dependent variable. To test hypothesis 2, a mediation analysis was conducted with addiction as independent variable, FTS as dependent variable and working memory capacity as the mediator. A mediation analysis was also conducted to test hypothesis 3 with addiction as the independent variable, delay discounting as the dependent variable and FTS as the mediator.

Results

Assumptions: Outliers, normality and homogeneity of variance

Four outliers were identified and excluded from the working memory scores in the control group, since they influenced the group difference regarding working memory capacity

significantly. One outlier was identified for the mood scores in the addiction group. Since this mood outlier did not influence the group difference significantly, it was not excluded. In the control group, all variables (mood, working memory capacity, delay discounting and FTS) were non-normally distributed. For the addiction group only the mood score was non-normally distributed. The assumption of homogeneity of variance was violated for delay discounting and FTS. To minimize the influence of the violated assumptions on the results of subsequent analyses, corrected independent samples t-tests were conducted. Moreover, we used PROCESS macro version 3 to run the mediation analysis, which does not assume normality (Hayes, 2017).

Control analyses

Independent samples t-tests were conducted to compare the groups regarding mood, working memory capacity and delay discounting. Table 2 displays the means and standard deviations of those variables. Overall, mood scores were relatively low and fell in the category 'no/minimal depression'. The groups did not differ significantly regarding mood, $t(106) = 0.395$, $p = .694$. A significant difference was found regarding working memory capacity, with controls showing higher scores, $t(22.66) = 2.41$, $p = .002$, as expected. Furthermore, also as expected, delay discounting was significantly higher in the addiction group, $t(42.95) = -5.35$, $p < .001$.

Table 2
Means and Standard Deviations of Mood, Working Memory Capacity and Delay Discounting Scores per Group

Variable	Addiction			Control			All		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Mood	8.25	10.78	20	9.15	8.79	88	8.98	9.12	108
WM	4.00	0.82	20	4.46	0.51	84	4.37	0.61	104
DD	-3.96	1.00	20	-5.45	1.56	88	-5.17	1.58	108

Note. WM = working memory; DD = delay discounting

Main analyses

Group differences in FTS. An independent samples t-test was conducted to test whether there was a group effect regarding FTS. There was an average FTS score of 15.41% (*SD* = 25.98) within the overall sample. The average FTS score of the addiction group was relatively high (*M* = 65.5, *SD* = 21.14) compared to the very low average FTS score of the control group (*M* = 4.03, *SD* = 4.94). This group difference was significant, $t(19.47) = -12.92$, $p < .001$. Those outcomes were opposite to our hypothesis that people with an addiction would show less specific FT when compared to a control group.

Mediation. A mediation analysis was conducted to test the relation between addiction and FTS mediated by working memory capacity. Figure 3 demonstrates the mediation model based on our results. Path c represents the total effect of addiction on FTS, without working memory capacity being part of the model. Path a represents the effect of addiction on working memory capacity. Path b represents the direct effect of working memory capacity on FTS, while controlling for addiction. Path c' represents the direct effect of addiction on FTS, while controlling for working memory capacity.

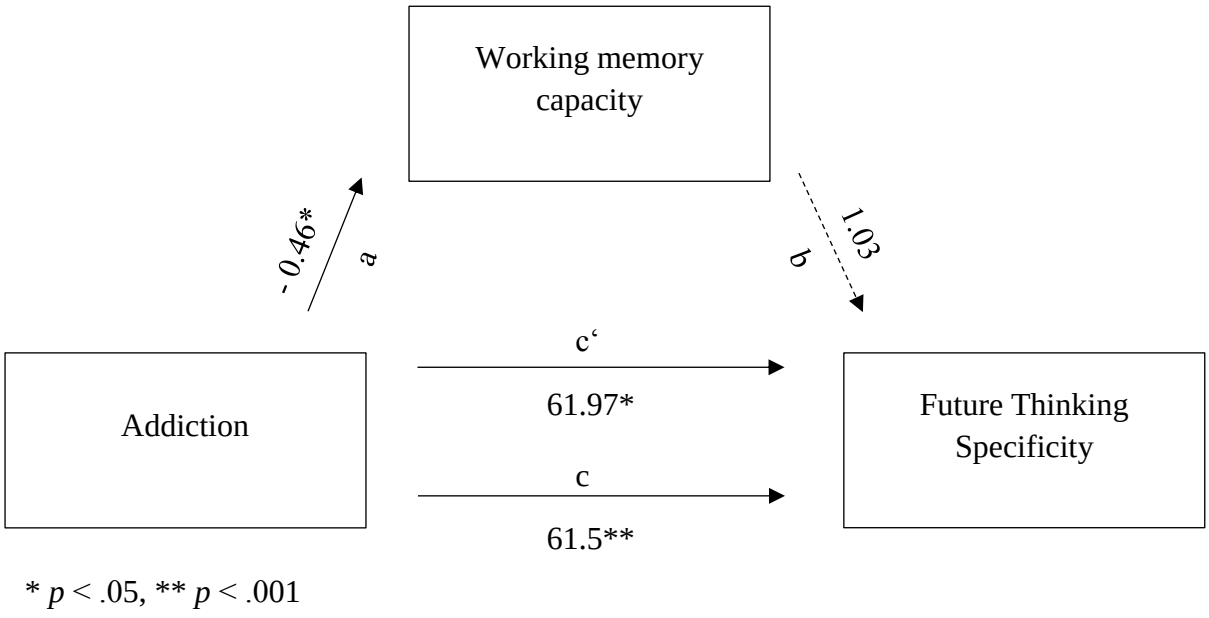

Figure 3. Mediation model based on our results: No indirect effect of addiction on future thinking specificity mediated by working memory capacity.

The analysis revealed that path c was significant, $b = 61.5$, $t(102) = 24.32$, $p < .001$. Addiction predicted a significant proportion of variance in FTS scores, $R^2 = .85$, $F(1, 102) = 591.38$, $p < .001$. Being addicted predicted 61.5 times higher FTS scores, which means that addiction led to more specific FT. Path a was significant as well, $b = -0.46$, $t(102) = -3.18$, $p = .002$. Addiction predicted a significant proportion of variance in working memory capacity scores, $R^2 = .09$, $F(1, 102) = 10.13$, $p = .002$. Being addicted predicted -0.46 times lower working memory capacity scores, which means that addiction led to lower working memory capacity. Path c' was also significant, $b = 61.97$, $t(101) = 23.30$, $p < .001$. However, path b was not significant, $b = 1.03$, $t(101) = 0.60$, $p = .553$. Moreover, the 5000 bootstrapped confidence interval (95%) for the indirect effect of addiction on FTS scores contained 0, [-3.02, 1.49], which means that there was no indirect effect of addiction on FTS scores mediated by working memory.

A second mediation analysis was conducted to investigate the hypothesis that the relation between addiction and delay discounting was mediated by FTS. Figure 4 demonstrates the mediation model based on our results. Thereby, path c represents the total effect of addiction on delay discounting, without FTS being part of the model. Path a represents the effect of addiction on FTS. Path b represents the direct effect of FTS on delay discounting, while controlling for addiction. Path c' represents the direct effect of addiction on delay discounting, while controlling for FTS.

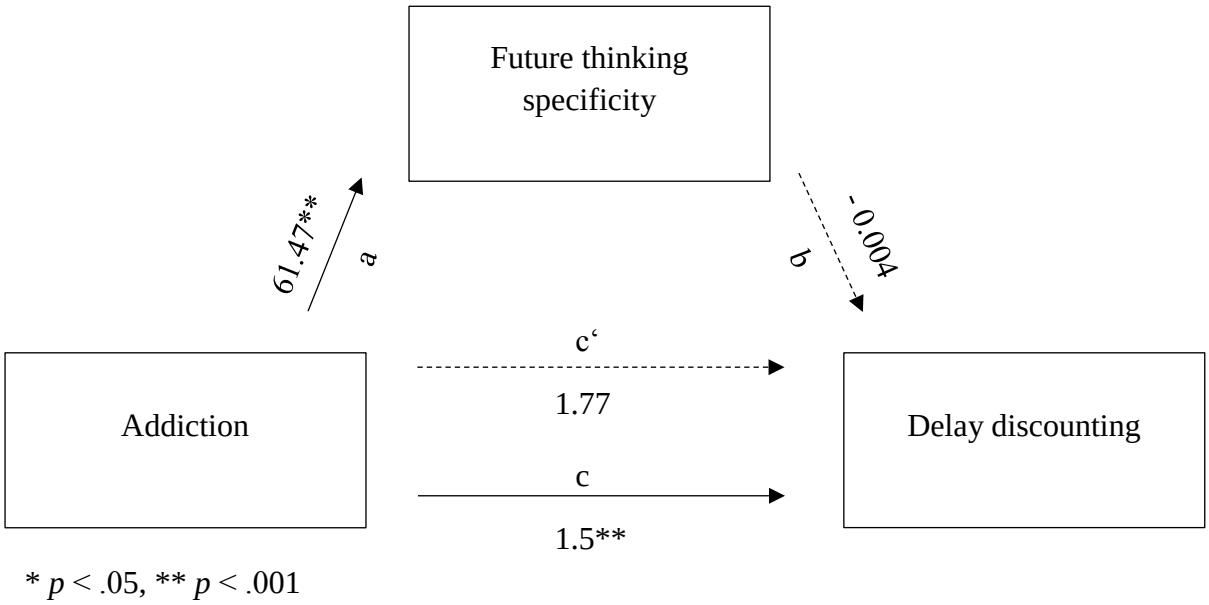

Figure 4. Mediation model based on the results of the second mediation analysis: No indirect effect of addiction on delay discounting mediated by FTS.

The analysis revealed that path c was significant, $b = 1.5$, $t(106) = 4.08$, $p < .001$. Addiction explained a significant proportion of variance in delay discounting, $R^2 = .14$, $F(1, 106) = 16.61$, $p < .001$. Being addicted predicted 1.5 times higher delay discounting rates, which means that an addiction led to stronger discounting of delayed rewards. Path a was significant, $b = 61.47$, $t(106) = 24.79$, $p < .001$. Addiction explained a significant proportion of variance in FTS, $R^2 = .85$, $F(1, 106) = 614.61$, $p < .001$. Being addicted predicted 61.47 times higher FTS scores, which means that an addiction led to more specific FT. Path c' was not significant, $b = 1.77$, $t(105) = 1.84$, $p = .068$. Furthermore, path b was not significant either, $b = -0.004$, $t(105) = -0.31$, $p = .756$. The 5000 bootstrapped confidence interval (95%) for the indirect effect of addiction on delay discounting contained 0, [-1.64, 1.37], which means that there was no indirect effect of addiction on delay discounting mediated by working memory.

Discussion

The aim of this study was to investigate the relation between substance related addiction, FTS, working memory capacity, and delay discounting. In line with our assumption, participants with an addiction showed significantly lower levels of working memory capacity and significantly higher levels of delay discounting. Further, we investigated whether there was a difference in FTS between addicts who are currently abstinent and people without a substance related addiction. Against our hypothesis, the addiction group showed significantly higher levels of FTS. Moreover, we investigated whether the expected relation between addiction and FTS was mediated by working memory capacity. Analysis revealed that working memory capacity was not a significant mediator for the relation between addiction and FTS. However, addiction had a significant effect on working memory capacity and on FTS. Finally, we investigated whether the relation between addiction and delay discounting was mediated by FTS. A significant effect of addiction on delay discounting diminished when controlling for FTS. However, FTS was no significant mediator for the relation between addiction and delay discounting. Addiction had a significant effect on the mediator FTS.

Working memory capacity was significantly lower in the addiction group compared to the control group. This supports findings of other studies that demonstrated the negative effect of addiction on working memory capacity (Verdejo-García et al., 2006; Fernández-Serrano et al., 2011). However, it must be considered that in earlier studies, working memory was also positively correlated with intelligence (Conway, Kane, & Engle, 2003). In our study, we did not include an intelligence test. Therefore, we cannot say whether the two groups differed regarding their level of intelligence. However, we found a significant association between group and educational level, with the control group being higher educated. Research revealed that intelligence and educational achievement are positively correlated (Spinks et al., 2007). Therefore, it is possible that the level of intelligence was higher in the control group compared to the addiction group. If this would be the case, the difference in working memory capacity between our groups could have been influenced by differences in intelligence. Furthermore, research revealed that working memory capacity decreases throughout adulthood (Nettelbeck & Burns, 2010). Since the addiction group was significantly older than the control group, age-related differences could be seen as a second alternative explanation for the differences in working memory capacity.

Even though it remains unclear in how far the differences in working memory

capacity can be attributed to addiction or the alternative explanations, we investigated its relation to FTS. Hill and Emery (2013) found that higher working memory capacity was an independent predictor for FTS. Although this would suggest higher levels of FTS in our control group, the opposite was the case. FTS was much higher in the addiction group than in the control group. The FTS scores of controls were remarkably low. There are several potential explanations. First, it was discovered that there was a programming error within the SCEFT online data-collection script. This error restricted controls to respond with a maximum of 20 letters per item. Only responses to item 4 could contain more than 250 letters. This restriction forced participants to give short answers, which made it more difficult to report a specific event. However, there was also only one specific response on item 4, which means that there might be an additional explanation. A second explanation would be that the AMT-f and the SCEFT outcomes are not easily comparable. It is possible that the proportion of specific responses to the SCEFT in a non-clinical sample might be lower than the proportion of responses would be to the AMT-f in a clinical sample, even if participants actual FTS levels would be equal. Anderson and Dewhurst (2009), for example, used the SCEFT in a student population. In their study only 24% of the responses were specific (n = 93). In a clinical sample, Kleim et al. (2014) received about 40% specific responses to the AMT-f (n = 50). This potential difference may be caused by the different instructions. In the AMT-f it is explicitly asked to produce specific future events. The meaning of specificity is explained, the procedure is practiced, and prompts are given in case of a non-specific response. The SCEFT instruction only asks for the completion of sentence stems. Following the original instructions (Raes et al., 2007), it was not mentioned that responses should be specific. It is therefore possible, that our results cannot exclusively be attributed to the programming error. The unexpected results could also be caused by the different nature of the tests, which make their outcomes hard to compare.

Based on our results it seems as if addiction predicts more specific FT. However, if the low FTS scores of the controls are caused by shortcomings of the data-collection discussed in the previous paragraph, data of the mediation-analysis could have been affected as well. In this case, conclusions based on the mediation analysis would not be valid. The finding that there was no mediating relation of working memory between addiction and FTS in our model also contradicts findings of earlier studies (Hill & Emery, 2013). Even though it is always possible to find contradicting results, it emphasizes the need to treat our data as potentially invalid. Therefore, the question whether there is a relation between addiction and

FTS and whether this relation is mediated by working memory cannot be answered on basis of this study.

Similarly, on the basis of our results, FTS did not appear to be a mediator in the relation between addiction and delay-discounting. However, the shortcomings of the data-collection could also have affected those results and it is not possible to make a valid conclusion. In contrast, the DDT scores were not affected. The finding that people with an addiction discount delayed rewards stronger is in line with existing literature (Kirby, Petry, & Bickel, 1999; Petry, 2001; Reynolds, 2006; MacKillop et al., 2011). Seeing that most existing studies that investigated the relation between addiction and delay discounting had a cross-sectional design, the causal direction remains unclear (MacKillop, et al., 2011). In our study, the question of causality cannot be answered either. However, our findings still have implications for patients and practitioners in the field of addiction. Regardless of the causal direction, addicts seem to be more attracted by smaller direct rewards compared to higher delayed rewards. When talking about the relation between addiction and delay discounting, we should not only think about the attractiveness of direct rewards in form of alcohol/drugs as a potential risk factor of relapse for addicts. Higher levels of delay discounting might also have a negative impact on other areas of their life and could create additional problems and stress. Delay discounting has for example been associated with harmful behavior and financial mismanagement (Hamilton & Potenza, 2012). At the same time, stress is known as a source of craving (Weiss, 2005) and increases the risk of drug abuse, relapse and even the vulnerability for addiction (Sinha, 2008). In addition to training people with an addiction to withstand a substance, treatment methods should also tackle their discounting behavior in general. This might result in the prevention of stress in different areas and therefore in a decreased risk for relapse.

Although financial problems might be a result of delay discounting, we would like to propose the idea that higher delay discounting scores on the DDT might also be the result of financial problems. During the debriefing of the addiction group, several participants mentioned that they would like to wait for the higher reward but were forced to choose the direct reward due to urgent financial problems. Since the DDT uses monetary rewards, financial circumstances could also be a potential factor influencing delay discounting scores. Whether or not financial circumstances affect someone`s delay discounting scores on delay discounting measures using monetary rewards is an interesting field for future research.

Furthermore, our groups differed significantly regarding age. Moreover, there was a

significant association between group and educational level. Therefore, we must consider those variables for alternative explanations. Research revealed that delay discounting tendencies tent to decrease from childhood to young adulthood and stay quite (Forstmeier & Maercker, 2011) or even decrease further until retirement age (Reimers, Maylor, Stewart, & Charter, 2009). Since we found higher delay discounting rates in the older addiction group, it is unlikely that the differences in delay discounting can be explained by differences in age. In contrast, educational level could offer an alternative explanation for the differences in delay discounting. Research revealed that lower educational level was associated with higher delay discounting rates (Jaroni, Wright, Lerman, & Epstein, 2004; Reimers et al., 2009). Since the level of education in the addiction group was lower compared to the control group, our results would be in line with those studies. Therefore, educational level could (partly) explain the stronger discounting within the addiction group.

Since most of our contradicting results may be affected by methodological problems, the underlying ideas of this research are still valuable for future research and are supported by existing research. For example, Daniel, Stanton, and Epstein (2013) found lower delay discounting rates in people with higher FT imagery abilities. Those findings were in line with an earlier fMRI-study on FT imagery and delay disounting by Peters and Büchel (2009). Although ‘imagery’ is not the same as ‘specificity’, those studies demonstrate the role of FT (and underlying neural networks) regarding delay discounting. Furthermore, in a recent study working memory training seemed to reduce delay discounting by enhancing FT in people with alcohol addiction (Snider, Deshpande, Lisinski, Koffarnus, LaConte, & Bickel, 2018), which would be in line with our hypotheses. Therefore, the chosen variables of our study (addiction, FTS, working memory and delay discounting) are still promising for future research. In this light, we would advise to replicate our study with some adjustments. Most importantly it must be ensured that the used measures for FTS are comparable between the addiction group and the control group. We advise to use the AMT-f for both groups, since it is a frequently used test. Because this test is less sensitive in detecting unspecific responses in a student population we suggest to include non-students in the control group as well. This would also have the advantage of more similar groups regarding educational level, age and marital status. The disadvantage of this design would be that the data of the control group cannot be collected online and the data-collection would become more time consuming. Therefore, it would also be interesting to do more research regarding the SCEFT, which is suitable for online data-collection. For example, it is not known whether this test is also

applicable in a clinical population. If this is the case, research regarding FTS that includes clinical samples could become more economical.

To sum up, our study confirmed the existence of the relation between addiction and delay discounting with addiction predicting higher discounting levels. Those findings imply that treatment for addiction could benefit from incorporating techniques focusing on delay discounting tendencies. Thereby, patients should not only alter their discounting behavior regarding alcohol/drugs, but also reduce their delay discounting in general. The direction of causality between addiction and delay discounting remains unclear and should be the focus of future research. Furthermore, the influence of financial circumstances on delay discounting measures using monetary rewards could be an interesting topic for further research. We also confirmed the existence of the relation between addiction and working memory capacity. No valid answer could be given to the question whether there is a relation between addiction and FTS, whether working memory plays a mediating role in this relation and whether FTS plays a mediating role in the relation between addiction and delay discounting. Nevertheless, the underlying ideas are supported by other studies in this area and therefore remain potentially relevant. Hence, the relation between addiction, FTS, working memory and delay discounting is a promising topic for future research. Moreover, extending FTS research with other clinical populations may be promising. As Hallford et al. (2018) state in their meta-analysis regarding FTS, there is a lot to do since many clinical groups remain understudied.

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Appendix A

Alcohol and Drug Consumption Pattern within the Control Group

	never		once or twice		monthly		weekly		daily or almost daily	
Substance	n	%	n	%	n	%	n	%	n	%
Alcohol[a]	11	12.5	20	22.7	39	44.3	18	20.5	-	-
Cannabis	43	48.9	23	26.1	15	17	7	8	-	-
Cocaine	84	95.5	4	4.5	-	-	-	-	-	-
Prescription stimulants (no prescription)	79	89.8	7	97.7	2	2.3	-	-	-	-
Prescription stimulants (with prescription)	84	95.5	2	2.3	1	1.1	1	1.1	-	-
Amphetamine	84	95.5	4	4.5	-	-	-	-	-	-
Methamphetamine	87	98.9	1	1.1	-	-	-	-	-	-
MDMA/XTC	73	83.0	14	15.9	1	1.1	-	-	-	-
GHB/GBL	87	98.9	1	1.1	-	-	-	-	-	-
Illegal opiate	88	100	-	-	-	-	-	-	-	-
Prescription opiate	87	98.9	1	1.1	-	-	-	-	-	-
Sedatives/sleeping pill	76	86.4	10	11.4	2	2.3	-	-	-	-
Hallucinogens	79	89.8	8	9.1	1	1.1	-	-	-	-
Inhalants (glue, spray)	84	95.5	2	2.3	1	1.1	1	1.1	1	1.1

Notes. $n = 88$

[a] men ≥ 5 drinks/day, women ≥ 4 drinks/day

Appendix B

Drug Screening Questionnaire (DSQ)

In the following, we would like to ask you some questions regarding your alcohol and drug consumption.

1. In the **last year**, how often have you used the following substances?

- Alcohol (Men, 5 or more drinks a day. Women, 4 or more drinks a day)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Cannabis (marijuana, weed, hash, etc.)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Cocaine (coke, crack)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Prescription Stimulants (e.g. Ritalin) **without** prescription
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Prescription Stimulants (e.g. Ritalin) **with** prescription
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Amphetamine (speed)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Methamphetamine (crystal)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- MDMA/XTC
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily

- GHB/GBL (Liquid XTC)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Prescription sedatives or sleeping pills (e.g. Valium, Xanax, Rohypnol)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Opioids (heroin, opium)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Hallucinogens (e.g. magic mushrooms)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Prescription opioids (e.g. oxycodone, methadone, fentanyl)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily
- Inhalants (e.g. glue, paint thinner, hairspray)
  - Never
  - Once or twice
  - Monthly
  - Weekly
  - (Almost) daily

2. When have you used one or more of the mentioned substances **for the last time**?
   Attention: Regarding alcohol, we ask again for a consumption of at least 5 drinks within one day for men and at least 4 drinks within one day for women.

   - Never
   - Today
   - Yesterday
   - Within the last 7 days
   - Within the last 30 days
   - Within the last 90 days
   - Within the last 180 days
   - More than 6 months ago

3. Have you **ever** been addicted to one of the following substances?
   If you have never been addicted to one of substances please choose option one.

   - I have never been addicted to one of those substances
   - Alcohol
   - Cannabis (Marijuana, Weed, Hash, etc.)
   - Cocaine (coke, crack)
   - Prescription Stimulants (e.g. Ritalin)
   - Amphetamine (speed)
   - Methamphetamine (crystal)
   - MDMA/XTC
   - GHB/GBL (liquid XTC)
   - Opioids (heroin, opium)
   - Prescription opioids (e.g. oxycodone, methadone, fentanyl)
   - Prescription sedatives or sleeping pills (e.g. Valium, Xanax, Rohypnol)
   - Hallucinogens (e.g. magic mushrooms)
   - Inhalants (e.g. glue, paint thinner, hairspray)

4. If you have ever been addicted to one of the following substances: For how long have you been addicted (in years)?

   - ……