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Et atferdsøkonomisk perspektiv på rusmiddelavhengighet i lys av nevroøkonomi: Variabler som påvirker, og endrer individuell grad av temporal diskontering. Implikasjoner for behandling - En oversikt

A behavioral economic perspective on substance use dependence in the light of neuroeconomics: Variables that affect, and alters individual rates of delay discounting. Implications for treatment – A review

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HØGSKOLEN I OSLO
OG AKERSHUS

”Almost all alcoholics prefer to be sober (or to drink moderately) than to be alcoholics. But they also strongly prefer to drink today than to abstain today; and since it is always today, they drink.” (Rachlin, 2000, p. 64)

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Sammendrag

Rusmiddelmisbruk og avhengighet relateres til impulsive valg og tap av kontroll, og til utviklingen av atferdsmønstre preget av overdrevent forbruk, hvor avhengighetsatferd overstyrer andre valgalternativer. De langsiktige konsekvensene av slike atferdsmønstre, vil ofte kjennetegnes av at de er ekstremt negative for personen selv hva gjelder helsesituasjon, sosiale relasjoner og familie, økonomi, jobbmuligheter m. m. Atferdsøkonomien har gitt betydelige bidrag til å forstå avhengighet og atferdsmønstre av overdrevent forbruk. Ulike studier har vist at mennesker med rusmiddelavhengighet i større grad enn ikke rusmiddelavhengige, viser større grad av impulsivitet i ulike valgsituasjoner. Et kjennetegn på impulsiv atferd er personens preferanse for umiddelbart tilgjengelige mindre forsterkere til fordel for større forsterkere som er utsatt i tid. Hyperbolsk diskontering har vist seg å være en god modell for å beskrive endringer i preferanse og tap av kontroll, som ofte beskrives å kjennetegne repeterende rusmiddelatferd og tilbakefallsproblematikk. I hvilken grad en person diskonterer fremtidige forsterkere, er et viktig atferdsøkonomisk mål på impulsivitet. Videre har nevroøkonomisk forskning bidratt til økt forståelse for slike diskonteringsprosesser, ved å bl.a. demonstrere hvordan diskontering er relatert til aktivitering i bestemte hjerneområder, under impulsive og selvkontrollerte valg.

Artikkel I gjennomgår teori og forskningslitteratur i et atferdsøkonomisk valgperspektiv på avhengighet, og temporal diskontering som viktig mål på impulsivitet beskrives i lys av nevroøkonomi. Atferdsanalytisk teori trekkes inn i det å forstå motivasjon og preferanse, samt hvordan atferd i nå-tid kan komme under kontroll av fremtidige konsekvenser. Implikasjoner for behandling diskuteres.

Artikkel II er en oversiktsartikkel basert på et systematisk søk over de siste 5 års forskningsstudier på temporal diskontering og rusmiddelavhengighet, samt nevroøkonomiske studier på temporal diskontering. Artikkelens utvalg av studier viser flere funn som

understøtter temporal diskontering som atferdsmessig prosess og et mål på impulsivitet i avhengighet. Flere interessante resultater hva gjelder variabler som påvirker, og også endrer individuell grad av diskontering, beskrives. De nevroøkonomiske studiene bidrar til til økt forståelse av atferdsmessige prosesser i avhengighet. Implikasjoner for behandling diskuteres.

Nøkkelord: Atferdsøkonomi, avhengighet, hyperbolsk diskontering, impulsivitet, nevroøkonomi, rusmiddelavhengighet, selv kontroll, temporal diskontering

Abstract

Substance abuse and addiction are related to impulsivity and loss of control, and the development of behavioral patterns characterized by excessive consumption where the addictive behavior repeatedly is preferred over other choice alternatives. Addictive behaviors can have extremely negative long-term consequences for the individual regarding health, social relations and family, financial income, occupational opportunities and so forth. Behavioral economics has contributed to the understanding of addiction and behavior patterns of excessive consumption.Various studies have demonstrated that people with substance dependency problems prefer smaller sooner reinforcers over larger later reinforcers, to a greater degree than people without dependencies. Further, hyperbolic discounting has been shown to be a good model for describing the preference reversals and loss of control that are associated with repeated drug taking behaviors and relapse. In addition, neuroeconomic research has contributed to the understanding of such discounting processes by the demonstration of how discounting is related to neural activation in specific regions of the brain, while individuals are making impulsive or self-controlled choices.

Article I reviews theory and research of addiction in the behavioral economic perspective of choice, and delay discounting as a key measure in impulsivity is described in the light of neuroeconomics. Theory of behavior analysis is described in the understanding of motivation and preference, as well as in describing how future and long-term consequences may come to control behavior in real time. Implications for treatment are being discussed.

Article II is based on a systematic search, reviewing the last five years of research in the field of delay discounting and addiction, in addition to neuroeconomic studies on delay discounting. This papers´ sample of articles report several findings supporting that delay discounting is a relevant measure of impulsivity in addiction. The studies under review report

findings regarding variables affecting and even altering individual discount rates. The neuroeconomic studies may extend the understanding of the behavioral processes of addiction. Implications for treatment are being discussed.

Key words: Addiction, behavioral economics, delay discounting, hyperbolic discounting, impulsivity, neuroeconomics, self control, substance use dependence, temporal discounting.

Et atferdsøkonomisk perspektiv på avhengighet

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Sammendrag

Rusmiddelmisbruk og avhengighet relateres til impulsive valg og tap av kontroll, og til utviklingen av atferdsmønstre preget av overdrevent forbruk, hvor avhengighetsatferd overstyrer andre valgalternativer. De langsiktige konsekvensene av slike atferdsmønstre, vil ofte kjennetegnes av at de er ekstremt negative for personen selv hva gjelder helsesituasjon, sosiale relasjoner og familie, økonomi, jobbmuligheter m. m. Atferdsøkonomien bidrar til å forstå avhengighet og atferdsmønstre av overdrevent forbruk. Ulike studier har vist at mennesker med rusmiddelavhengighet i større grad enn ikke rusmiddelavhengige, viser større grad av impulsivitet i ulike valgsituasjoner. Et kjennetegn på impulsiv atferd er personens preferanse for umiddelbart tilgjengelige mindre forsterkere, på bekostning av større forsterkere som er utsatt i tid. Hyperbolsk diskontering har vist seg å være en god modell for å beskrive endringer i preferanse og tap av kontroll, som ofte beskrives å kjennetegne repeterende rusmiddelatferd og tilbakefallsproblematikk. I hvilken grad en person diskonterer fremtidige forsterkere, er et viktig atferdsøkonomisk mål på impulsivitet. Videre har nevroøkonomisk forskning bidratt til økt forståelse for slike diskonteringsprosesser, ved å bl.a. demonstrere hvordan diskontering er relatert til aktivering i bestemte hjerneområder, under impulsive og selvkontrollerte valg.

Artikkelen gjennomgår teori og forskningslitteratur i et atferdsøkonomisk valgperspektiv på avhengighet, og temporal diskontering som viktig mål på impulsivitet beskrives i lys av nevroøkonomi. Atferdsanalytisk teori trekkes inn i det å forstå motivasjon og preferanse, samt hvordan atferd i nå-tid kan komme under kontroll av fremtidige konsekvenser. Implikasjoner for behandling diskuteres.

Introduksjon

Hvorvidt rusmiddelavhengighet er en frivillig eller ufrivillig tilstand (sykdom) må basere seg på i hvilken grad avhengighetsatferden lar seg påvirke av ulike faktorer som vanligvis påvirker valg og beslutningstakingsprosesser (Branch, 2011; Heyman, 2003). I flg. Heyman (2003), vil avhengighet ikke være ufrivillig dersom svaret på dette er at avhengighetsatferd er under påvirkning av denne type faktorer, og det er vist at faktorer som ny informasjon, insentiver og verdier har bidratt til å redusere rusmiddelkonsum hos mennesker som møter kriteriene for rusmiddelavhengighet (Heyman, 2003).

Det atferdsøkonomiske perspektivet gitt betydelige bidrag til å forstå avhengighet og avhengighetsutvikling i et valgperspektiv (Heyman, 2003). Hvorfor velger mennesker å opprettholde atferdsmønstre av overdrevent forbruk som åpenbart fører til negative konsekvenser for dem selv og deres omgivelser? De negative konsekvenser, i betydningen kumulativt ervervede og ekstreme konsekvenser over en rekke områder, er åpenbare for omgivelsene og for personen selv. Å avstå fra avhengighetsatferden vil kunne gi en formidabel økning i livskvaliteten på sikt.

Artikkelen gjennomgår teori og forskningslitteratur som kan bidra til å kaste lys over rus-, og avhengighetsatferd i et slikt valgperspektiv, og hovedspørsmålene denne oversikten forsøker å svare på knytter seg til hvilke mekanismer som kan bidra til å forklare at til tross for at individet selv er kjent med de langsiktige og negative konsekvensene av sitt rusmiddelmisbruk, så velges avhengighetsatferden gang på gang? Og, kan de samme mekanismene bidra til å forklare den hyppige forekomsten av tilbakefall hos personer som forsøker å bryte mønstre av avhengighet? Videre bør vi spørre hvilke mekanismer som kan identifiseres som virkningsfulle i det å ta kontroll over ulike avhengighetsatferder, og vedlikeholde alternativ atferd?

Litteraturutvalget i artikkelen er subjektivt sammensatt ut fra egen interesse for feltet, og baserer seg på et bredt og ikke avgrenset søk. Målet har vært å belyse det atferdsøkonomiske perspektivet på avhengighet ved hjelp av teoretiske, og empiriske publikasjoner.

Atferdsøkonomi

Atferdsøkonomi søker å forstå hvordan individer gjør sine transaksjoner innenfor de begrensningene som omgivelsene representerer, ved å integrere psykologiske og økonomiske prinsipper (Heather & Vuchinich, 2003; Loewenstein & Elster, 1992). Interaksjonen mellom egenskaper i individets omgivelser og egenskaper hos individet, er av betydning. Betydelig vekt legges på egenskaper ved individets omgivelser i det å forstå hvordan ulike faktorer i miljøet påvirker enkeltmenneskers valg og handlinger i vanlig hverdagsliv, og atferdsøkonomien har bidratt til forståelse av uhensiktsmessig og usunne atferdsmønstre (Bickel et al., 2007). F. eks er det vist at rusmiddelbruk/misbruk påvirkes av faktorer som pris og etterspørsel og nærvær av andre tilgjengelige forsterkere (Chaloupka, Emery, & Liang, 2003; Greenwald & Hursh, 2006; Vuchinich & Heather, 2003). I tillegg vektlegges individuelle egenskaper og forskjeller i forståelsen av individers valg og handlemåter. Individuelle forskjeller som f. eks oppvekst og rushistorikk, historikk hva gjelder valg og beslutningstaking, og i hvilken grad man har utviklet type feilslutninger i valgsituasjoner (*bias*), arv og genetiske disposisjoner m. m, har betydning for utviklingen av misbruk og avhengighet til ulike rusmidler og andre mønstre preget av overdrevent forbruk. (Heather & Vuchinich, 2003). Atferdsøkonomien står for en valg-modell i den betydning at mennesker velger atferdsmønstre, og at valgene knytter seg til konsekvensene av disse mønstrene, altså hvilken funksjon atferdsmønstrene har (MacKillop et al., 2010). Impulsivitet og selvkontroll er sentrale temaer av interesse for atferdsøkonomien, hvor impulsivitet relateres til individets preferanse for umiddelbart tilgjengelige forsterkere, på bekostning av et uforenlig alternativ

som vurderes som mer verdifullt av personen (Ainslie, 2012; Vuchinich & Heather, 2003). Dette kalles preferansereversering, ved at individets preferanse for en forsterker endrer seg som følge av den tidsmessige avstanden til forsterkeren faktisk er tilgjengelig, og preferanse oppstår for andre, mer umiddelbart tilgjengelige forsterkere (Ainslie, 1975, 2012; Green & Myerson, 2004; Rachlin, 2000). Slik preferanse for en mindre, men umiddelbart tilgjengelig forsterker (ofte beskrevet som SS – Smaller Sooner) som går på bekostning av en større, men senere tilgjengelig (utsatt) forsterker (LL – Larger Later), kan således knyttes til begrepene impulsivitet og selvkontroll. Prosessen kalles diskontering, og refererer til reduksjonen i subjektiv verdi av en forsterker som følge av tid til denne faktisk er tilgjengelig (Ainslie, 2012; Green & Myerson, 2004). Preferansereversering knyttes til tap av kontroll ved hurtig diskontering av utsatte forsterkere, og et sentralt kjennetegn i avhengighetsatferd er repeterende kontrolltap hvor avhengighetsatferden velges gang på gang på bekostning av de utsatte og, i utgangspunktet mer verdifulle, forsterkerne som avholdenhet ville gitt i fremtiden (Bickel & Marsch, 2001).

Klassisk økonomisk tenkning forutsetter at det er mulig å maksimere nytte gjennom at mennesker er i stand til å overskue fremtidige konsekvenser av egne valg i nåtid. Atferdsøkonomien tar høyde for at folk ikke oppfører seg rasjonelt. Rasjonaliteten er begrenset i det mennesker bl.a. mangler kunnskap og evner, emosjonelle og ikke-rasjonelle faktorer spiller inn i beslutningstaking, og folk baserer ofte sine valg på ufullstendig informasjon (Simon, 1955). En antakelse i atferdsøkonomien er at ubevisste og systematiske kognitive feilslutninger står i veien for å gjøre rasjonelle valg (Ariely, 2009), og beslutninger i hverdagsliv om kjøp, konsum, sparing, kostholdsvaner, sex og utroskap, sunne vs. usunne vaner osv., er fokus for atferdsøkonomisk undersøkelse.

Atferdsøkonomisk litteratur opererer med ulik bruk av begrepene som omhandler atferdens funksjoner, f. eks *rewards*, *outcomes* og *reinforcers*. I denne artikkelen benyttes hovedsakelig begrepet ”forsterker” om atferds produkter som relateres til funksjon.

Atferdsanalyse

Begrepet forsterker trenger en klargjøring. Den atferdsanalytiske definisjonen av en forsterker knytter seg til at konsekvensene som atferd produserer i sine omgivelser (operant atferd), og som øker frekvensen av denne atferden, er klasser av forsterkende stimuli (Pierce & Cheney, 2008). Forsterkere betegnes som positive forsterkere når atferdens konsekvenser er en stimulusendring der noe tilføres individet, og negative forsterkere når atferden har den effekt at stimuli fjernes fra individet. Knyttet til rusmiddelbruk, vil for eksempel den umiddelbare rusopplevelsen av eufori kunne betegnes som positiv forsterkning. På den annen side vil et rusinntak også kunne ha forsterkende konsekvenser i form av at ubehag og negative følelser, angst og bekymringer m.m. forsvinner, eller at abstinenssymptomer opphører når avhengighetsstoffet inntas, og dette kan betegnes som negativ forsterkning. Begge disse situasjonene vil ha den effekt at den styrker atferden (øker sannsynligheten for fremtidige rusmiddelinntak). Videre vil hendelser som opptrer i umiddelbar nærhet i forkant av atferden som forsterkes, få diskriminative funksjoner. Slike hendelser kalles diskriminative stimuli, og gir anledning for atferden til å forekomme ved å signalisere at forsterkning er tilgjengelig. Grunnen til at diskriminative stimuli får denne funksjonen, er at atferd kan sies å være en funksjon av både hvilke hendelser som forekommer i umiddelbar forkant (diskriminative stimuli), og i etterkant av atferden (forsterkende hendelser). Når individet befinner seg i en situasjon hvor bestemte atferder tidligere er blitt forsterket, øker sannsynligheten for at atferden øker i frekvens når disse foranledningene er til stede. Typer av diskriminative stimuli knyttet til rusmiddelmisbruk vil være varierte og komplekse, men vil kunne ha en samlet effekt på atferden (repeterende rusmiddelinntak). Man kan si at synet av en sprøyte med

heroin kan fungere som en diskriminativ stimulus for atferden rusmiddelinntak, men samtidig vil mange faktorer kunne ha en slik effekt at det gir anledning for rusmiddelinntak over en rekke situasjoner, og det opereres ofte med begrepet stimulus klasse (Pierce & Cheney, 2008) som vil ha en felles effekt på den samme atferden.

Betydningen av kontekst er sentral i atferdsanalytisk tenkning. Atferden er alltid betinget, i betydningen avhengig av andre omstendigheter, og det skilles på diskriminative (se over) og motivasjonelle hendelser. Motivasjonelle operasjoner (MO) er slike miljøhendelser som endrer verdien av en forsterker (eller straff), og på den måten endrer effekten av denne på atferden. Samtidig er MO også miljøhendelser som har den effekten at de endrer forekomsten av relevant atferd (atferd som produserer de forsterkende konsekvensene (Laraway, Snycerski, Michael, & Poling, 2003). Motivasjonelle operasjoner kan ha både forsterkeretablerende effekt, og evokativ effekt på atferd, og på den annen side kan de ha forsterkerreduserende effekt og en svekkende (abativ) effekt på atferden. Relatert til rusmiddelbruk, vil dette være relevant i det å få en bredere forståelse av kontekstuelle forhold og miljøhendelser som øker verdien på forsterkere (rusmiddelet). Abstinenssymptomer vil for eksempel kunne ses på som deprivasjon for rusmiddelet, som fører til at subjektiv verdi av rusmiddelet øker, og samtidig øker sannsynligheten for personens avhengighetsatferd (i.e. skaffe rusmidler, innta rusmidler). Emosjonelle responser på små og store livshendelser kan ha forsterkeretablerende effekt på rusmidler, og øke sannsynligheten for rusmiddelinntak. Når Lisa som har vært rusfri i 7 uker, får vite at kjæresten hennes har gått fra henne, vil denne hendelsen kunne generere emosjonelle reaksjoner (blir lei seg, sint, føler seg sveket osv.), som kan øke Siljes sug etter å ruse seg (forsterkeretablerende effekter), og øke sannsynligheten for at hun velger å ruse seg (evokative effekter) (Laraway et al., 2003).

I et atferdsanalytisk perspektiv vil atferdens naturlige kontingenser (miljøhendelser i forkant og forsterkende hendelser som resultat av atferden), forklare etableringen og

opprettholdelsen av atferd og klasser av atferd. Naturlige kontingenser har imidlertid ofte effekter som ikke er egnet til å forsterke eller straffe atferden i nåtid. Disse ikke-direkte virkende effektene av atferden er ofte utsatte i tid, de kan være usannsynlige, og de kan være av liten betydning for atferden her og nå, men som over tid vil ha kumulativ betydning. Malott (2002) illustrerer dette med et eksempel på hvordan et mønster av tanntrådbruk hver dag, opprettholdes. Bruk av tanntråd i seg selv har sannsynligvis for små umiddelbare konsekvenser til at dette forsterker atferden. Men over tid vil daglig tanntrådbruk ha store kumulative gevinster i form av null hull og en hyggelig tannlegeregning. Konsekvenser som er utsatte, eller usikre med tanke på om de faktisk blir en realitet, og de kan være av liten betydning i seg selv, kjennetegner slike ikke-direkte virkende konsekvenser (fungerer ikke som forsterkere for atferden/atferds klassen). Allikevel kan slike konsekvenser komme til å påvirke atferd i nåtid. Relatert til rusmiddelmisbruk vil for eksempel effektene av å ikke ruse seg, være preget av at konsekvensene ikke er nære i tid (proksimale), men av kumulativ betydning i form av positive effekter for personen i et lengre tidsperspektiv. Regelstyring av atferd er bindeleddet mellom atferd i nå-tid, og konsekvenser som er utsatt i tid, og i atferdsanalytisk litteratur skilles det på såkalte proksimale, kortsiktig forsterkningsrelasjoner, og på ultimate, langsiktige forsterkningsrelasjoner (Baum, 2005). Teorien er at atferd kommer under stimuluskontroll av regler, og at regler på denne måten fungerer som verbale diskriminative stimuli. Reglene viser både til implisitte og eksplisitte sammenhenger, og regler peker mot noe langsiktig av betydning. Proksimale forsterkningsrelasjoner knytter seg til kontingenser for å følge regelen, mens de ultimate relasjonene relateres til bredere kategorier av forsterkere, herunder helsefremmende konsekvenser, tilgang til ressurser, relasjoner og reproduksjon, såkalte HRRR (se Baum, 2005). De proksimale kontingensene for å følge regler er relevante i det å forstå hvordan atferd kan komme under diskriminativ kontroll av eksplisitte og implisitte regler. I følge Malott (2002), vil regler også fungere som

motivasjonelle operasjoner, idet reglene kan øke effekten av de proksimale effektene av det å følge/ikke følge regelen. Når atferd kommer under kontroll av regelstyring, vil både sosiale forsterkere som for eksempel anerkjennelse og ros fra andre, belønnende eller aversive tanker, og automatiske forsterkende hendelser, understøtte denne kontrollen. Automatiske kontingenser knyttes til at atferden generer emosjonelle responser, f. eks at man opplever en godfølelse knyttet til det å følge en regel, følelser av å handle i tråd med egen overbevisning osv., eller negative følelser knyttet til det å ikke følge regelen.

Selvkontrollsituasjoner må dermed involvere verbale beskrivelser eller regler, hvor atferd i nåtid først produserer, ofte kumulative, forsterkere i fremtiden og hvor selvkontrollatferden i nåtid i tillegg må forekomme på bekostning av andre atferder som ville gitt en mer umiddelbar forsterkende effekt. Det å finne frem til gode og opprettholdende proksimale forsterkningskontingenser i selvkontrollerte valg, vil være avgjørende for å på sikt kunne få atferden under kontroll av automatiske kontingenser. Skinners definisjon av selvkontroll, er knyttet til valg mellom handlingsalternativer hvor individet passer på sin helse og posisjon i samfunnet gjennom utøvelse av slik selvkontroll (Skinner, 1953), og selvkontroll er atferd som manipulerer variabler som den kontrollerte atferden er en funksjon av. Variabler kan for eksempler manipuleres ved bruk av kontroll teknikker i form av fysiske begrensninger (gjøre en atferdsrespons mulig eller ikke mulig), stimulusendringer (f. eks unngåelse av foranledninger), deprivering eller metning, manipulering av emosjonelle betingelser (som i strategier for å håndtere sinneutbrudd), aversiv stimulering (f. eks alarmklokker), medikamenter, operant betinging (selvforsterkning), straff, og alternativ atferd (gjøre noe annet) (Skinner, 1953).

Avhengighet i et valgperspektiv

Sentrale teorier om avhengighet i et valgperspektiv, beskrives i det følgende; *The matching law* (Herrnstein, 1961), avhengighet som *melioration* (Herrnstein & Prelec, 1992a),

Rachlins relative avhengighetsteori (Rachlin, 2000, 2003) og teorien om rasjonell avhengighet (Becker & Murphy, 1988).

The matching law.

En grunnleggende atferdsteoretisk valgmodell er Herrnsteins *matching law,* avledet fra en studie hvor to samtidige variable intervallskjemaer ble benyttet for å undersøke hvordan duer fordelte atferd mellom ulike responsalternativene (Herrnstein, 1961). Funnene i studiene beskriver hvordan relativ frekvens av atferd samsvarer med relativ frekvens av forsterkning for denne atferden. I henhold til *matching* fordeles atferd med andre ord i samsvar med den frekvensen/mengden av forsterkning som de ulike alternativene gir (Vuchinich & Heather, 2003). Atferd som allokeres til en gitt aktivitet vil, være en samlet funksjon av forsterkningen fra denne aktiviteten, og forsterkning fra alle andre kilder. Modellen er en molar beskrivelse av atferd i det den forsøker å redegjøre for allokering av atferd over tid, til ulike alternativer (fremfor et molekylært perspektiv som søker å forklare forekomsten av enkeltresponser og relaterer dem til endringer i forsterkningsbetingelser fra øyeblikk til øyeblikk) (Vuchinich & Heather, 2003). I atferdsøkonomi er slike molare perspektiver nyttige, i det de kan bidra til å forstå repeterende atferdsmønstre og individets preferanse for ett alternativ fremfor et annet. Avledet fra Herrnsteins teori vil en kunne si at valg mellom alternativer handler om at atferden konkurrerer med tilgjengelige og samtidige forsterkere. Når forsterkningen øker for en aktivitet, vil individet bruke mer og mer tid på dette valgalternativet. Andre samtidige og tilgjengelige forsterkere for andre typer atferd (konteksten), er med andre ord av stor betydning i valgsituasjoner (Mazur, 2002). I et senere valgforsøk fant Herrnstein og Loveland (1974) at duer alltid valgte det forsterkningsskjemaet med den hyppigste forsterkerleveringen, når valgforsøkene ble utført med variable ratioskjemaer. Utelukkende preferanse ble utviklet for det valgalternativet med hyppigst forsterkerlevering. Disse funnene førte frem til en videreutvikling av *the matching law* i form av teorien om *melioration* (Mazur, 2002).

Melioration.

Allokeringen av atferd til eskalerende rusmiddelbruk og avhengighetsutvikling, kan ses i lys av *melioration,* som refererer til individets økende innsats og tid mot valgalternativet med størst lokal nytteverdi (Mazur, 2002). *Melioration* kan bidra til å forstå beslutningstaking i mange situasjoner og hvordan preferanse oppstår for bestemte valgalternativer. *Melioration* forutsetter valg mellom to uforenlige alternativer, og relatert til avhengighet vil alle ikke-rusmiddelbruk aktiviteter være uforenelige valgalternativer til rusmiddelbruk/misbruk (Vuchinich & Heather, 2003). Teorien om *melioration* innebærer at repeterende valgs aggregerte produkt er ikke-optimale (ikke rasjonelle), sett i lys av personens egen preferanse (Herrnstein & Prelec, 1992a; Mazur, 2002). Herrnstein and Prelec (1992b), kaller slike repeterende valg mellom alternativer for distribuerte valg. Når personer klager over egne valg (i.e. jobber for mye, ser for mye TV, tilbringer for liten tid med barna), så vil denne misnøyen ofte handle om slike distribuerte valg, heller enn enkeltstående valg. *Melioration* beskriver prosessen hvor fordelingen av valgene mellom alternativer, stabiliserer seg på et slikt ikke-optimalt nivå, og noen ganger på det verst tenkelige ekvilibrium, som i fullt utviklet avhengighet hvor avhengighetsatferden overstyrer andre valg fullstendig. Dette skjer ved at de enkeltstående valgene er kjennetegnet av lokal nyttemaksimering. Det alternativet med høyest nytteverdi velges gang på gang, og disse valgene kan styre personen inn på *the primrose path* (Herrnstein & Prelec, 1992b; Rachlin, 2000). *The primrose path-metaforen ble benyttet av* Shakespeare allerede i Hamlet (1600) for å illustrere det enkle og fornøyeliges livets vei til undergangen. Metaforen illustrerer hovedelementet i *melioration*; at rusmiddelbruk (lokal nyttemaksimering) reduserer lokal og global nytteverdi av slik rusmiddelbruk, og samtidig reduserer rusmiddelbruk nytteverdien av alle andre ikke-rusmiddelbruk aktiviteter, til stabilisering på et nivå med lav subjektiv nytteverdi for individet.

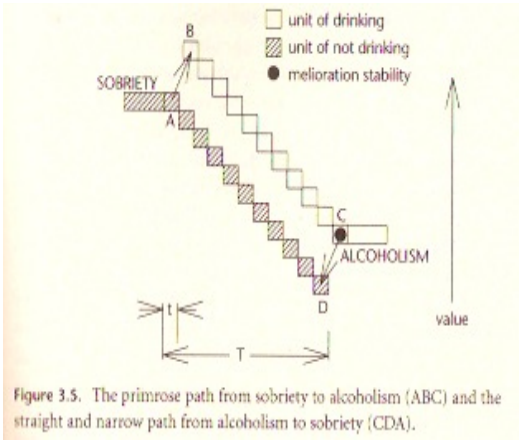

Figure 3.5. The primrose path from sobriety to alcoholism (ABC) and the straight and narrow path from alcoholism to sobriety (CDA).

Figur 1. The primrose path (Rachlin, 2000, p. 73)

I figuren er enkeltstående tilfeller av drikking eller avholdenhet illustrert som firkanter. Hos en alkoholiker vil det å drikke i dag (blank firkant) være forbundet med høyere subjektiv verdi, enn det å ikke drikke i dag (markert firkant). Samtidig vil valgene av drikking over tid danne et mønster som gradvis reduserer lokal og global nytteverdi av drikking, til atferden stabiliserer seg, i dette eksempelet, på et nivå av avhengighet. Denne allokeringen av atferd knyttet til valg i nå-tid, vil være sensitiv til lokal nytteverdi (personen velger mellom spesifikke alternativer som f. eks å ta en drink i dag, eller avstå fra å drikke i dag), samtidig som valget er insensitiv til nytteverdi i et globalt perspektiv (f. eks at drinken i dag er forbundet med et avhengighetsmønster med lav subjektiv verdi for personen) (Herrnstein & Prelec, 1992b; Rachlin, 2000).

Distribuerte valg, *melioration* og *the primrose path* knytter seg til valg mellom ulike alternativer og til ambivalens. Det skilles på enkel og kompleks ambivalens (Rachlin, 2000), hvor enkel ambivalens knyttes til valg mellom to klart definerte alternativer på forskjellige tidspunkter (f. eks kr. 100,- nå, eller kr. 200,- senere). Kompleks ambivalens knyttes til valg mellom et klart definert alternativ nå, og et mer diffust, abstrakt tilgjengelig alternativ senere. Kompleks ambivalens kan således knyttes til atferdsmønstres aggregerte produkter, som for eksempel i en alkoholikers valg mellom en drink i dag, eller de mer kumulative positive konsekvensene av avholdenhet over tid (god helse, stabil livssituasjon, sosial tilhørighet m.

m.). Paradokset i slik ambivalens er at det å drikke i dag vil for en alkoholiker ha høyere subjektiv verdi, enn det å avstå fra å drikke i dag. Rachlin (2000) illustrerer dilemmaet ved å peke på at for å fortsette å være i en lykkelig tilstand, så må alkoholikeren hver gang velge det minst verdifulle alternativet (det fremtidige, abstrakte men lykkelige A4-liv, fremfor en drink i dag) (jfr *Figur 1*).

Relativ avhengighetsteori.

Rachlin´s (2000) relative avhengighetsteori er en forlengelse av Herrnstein and Prelec (1992b) "primrose path" teori, og bygger på økonomiske begreper om substitutter i avhengighet (Vuchinich & Heather, 2003). Økt etterspørsel etter en vare fører til redusert etterspørsel etter en vare som er gjensidig utbyttbar, og når prisen øker på en vare, vil etterspørselen etter varens substitutt øke. Eksempler på økonomiske substitutter kan være kaffe og te, havregryn og cornflakes osv. Hovedantakelsen i teorien er at rusmiddelbruk er gjensidig utbyttbar med sosial interaksjon, og individet maksimerer nytte ved å utøve den aktiviteten (rusmiddelbruk - sosial interaksjon) som har høyest nytteverdi (Vuchinich & Heather, 2003). Rusmiddelavhengighet knyttes til negativ avhengighet eller toleranseutvikling, hvor konsum av avhengighetsstoffet har den virkning at det fører til at fremtidig konsum (enkelttilfeller av rusmiddelinntak) reduseres i subjektiv verdi (prishabituering). Dette i sin tur fører til en økning i konsum for å kompensere for denne reduksjonen i nytteverdi (økt konsum for å opprettholde den totale verdien på et ønsket nivå) (Rachlin, 2003). Sosial interaksjon på den annen side, knyttes til positiv avhengighet, hvor engasjering i aktiviteten er forbundet med økt nytteverdi av sosial interaksjon (pris sensitivisering). Aktiviteter som f. eks å gå på teater, spille fotball, gå i operaen osv., er substitutter hvor man ikke umiddelbart oppnår høy verdi, men der repeterende engasjering i aktiviteten kan tenkes å generere økt sensitivisering og verdi av slik aktivitet.

Rasjonell avhengighetsteori.

Hvor de to foregående teoriene er avledet fra psykologien, så springer den rasjonelle avhengighetsteorien (Becker & Murphy, 1988) ut fra økonomisk teori (Vuchinich & Heather, 2003). Den rasjonelle avhengigheten er basert på antakelsen om rasjonelle valg, som i klassisk økonomisk tenkning er en grunnleggende antakelse. Valgene er rasjonelle i betydningen av at beslutninger om konsum i nåtid inkluderer de fremtidige konsekvensene av dette konsumet. I henhold til den rasjonelle avhengighetsteorien vil en sentral antakelse knytte seg til at nivået på rusmiddelbruk i personens historie og i nåtid, reduserer nytteverdien av slik rusmiddelbruk (som i *melioration* og i relativ avhengighet). Samtidig vil nytteverdien fra andre aktiviteter også reduseres som følge av dette konsumet (Vuchinich & Heather, 2003). Rasjonell avhengighet innebærer at rusmiddelmisbrukere maksimerer nytte (Becker & Murphy, 1988), og gjør rasjonelle valg knyttet til bruk eller avholdenhet (overveielse av ulike valgalternativer, kortsiktige og langsiktige konsekvenser, kostnader og ulemper osv.) (Madden, Bickel, & Jacobs, 1999). Diskontering forutsettes i rasjonell avhengighet å være eksponentiell. Dvs at diskontering av utsatte forsterkere er konstant relativt til tidsutsettelsen. Høy grad av diskontering øker sannsynligheten for konsistente preferanser for SS, men lav grad av diskontering relateres til konsistente preferanser for LL (Bickel & Marsch, 2001). Dette innebærer at individer med høy grad av diskontering av utsatte forsterkere, vil ha høyere risiko for å utvikle avhengighet (Madden et al., 1999).

Temporal diskontering

Selvkontrollsituasjoner oppstår ofte i hverdagslivet til enkeltindivider, og disse situasjonene er kjennetegnet av interessekonflikten i valg mellom kortsiktige eller langsiktige konsekvenser av det alternativet som velges (Mazur, 2002). Når Lisa står overfor valget mellom en joggetur eller å sette seg foran fjernsynet med sjokoladeskålen i kveld, velger hun mellom en liten forsterker som er tilgjengelig på kort sikt (Tv og sjokolade), og større positive

og kumulative gevinster på et senere tidspunkt (god fysisk form og god helse som følge av regelmessig jogging og trening). Man kan forenklet si at valget av joggeturen i kveld vil være et selvkontrollert valg (valg av LL), og motsatt vil valget av fjernsyn og godteri være et impulsivt valg (valg av SS). Et viktig karakteristikum ved slike impulsivitets-, og selvkontrollsituasjoner er at individets preferanse for en forsterker endrer seg, og kan reverseres over tid. Slik preferansereversering oppstår som følge av den tidsmessige avstanden til forsterkeren, dvs. den tidsmessig utsettelsen eller avstanden til forsterkeren faktisk blir tilgjengelig, endrer forsterkerens verdi eller effektivitet (Ainslie, 1975, 2012; Green, Myerson, & McFadden, 1997; Rachlin, 2000). Når tidsmessig avstand til begge forsterkerne øker, vil dette føre til at den relative verdien for begge alternativene endrer seg, individet vil være tilbøyelig til å velge det senere, men større forsterkeralternativet. Når den mindre forsterkeren (SS) gjøres tilgjengelig, vil preferanse reverseres til fordel for denne, og individet velger SS fremfor LL (Mazur, 2002). Preferansereversering gir sterke argumenter mot teorier knyttet til optimalisering, idet slike teorier predikerer at individer vil velge ett av de to alternativene konsistent for å optimalisere nytteverdi på lang sikt Mazur (2002).

Diskontering relateres altså til fenomenet hvor den subjektive verdien av en forsterker reduseres som følge av at leveringen av denne er utsatt i tid, såkalt temporal diskontering (*delay discounting*). Diskontering relateres også til situasjoner der subjektiv verdi av en forsterker reduseres som følge av hvor stor usikkerhet det er knyttet til om forsterkeren blir tilgjengelig eller ikke, såkalt sannsynlighetsdiskontering (*probability discounting*) (Green & Myerson, 2004; Madden & Bickel, 2010). En persons grad av diskontering kan beregnes ut fra hvor raskt den subjektive verdien reduseres i takt med at tiden øker til levering, eller i takt med at usikkerheten øker (diskonteringsrate) (Green & Myerson, 2004; Mazur, 1987; Myerson, Green, & Warusawitharana, 2001; Weatherly, 2014). I denne artikkelen er ikke sannsynlighetsdiskontering nevneverdig berørt, da hovedfokus er på temporal diskontering.

Hyperbolsk diskontering og preferansereversering.

Måten endringer i subjektiv verdi beskrives er viktig for å forstå preferansereversering. To modeller er beskrevet i litteraturen, den eksponentielle, og den hyperbolske diskonteringsmodellen (Ainslie, 1975; Ainslie & Haslam, 1992; Loewenstein, 1992; Mazur, 1987). En eksponentiell modell forutsetter at diskontering skjer i en konstant rate relativt til tidsutsettelsen. Hyperbolsk diskontering relateres til en relativ økning i grad av diskontering i takt med at tidsutsettelse til forsterkeren blir tilgjengelig reduseres (Green & Myerson, 2004). Det lengre utsettelse dess mer avflatet og saktere reduksjon i subjektiv verdi. Den hyperbolske diskonteringsfunksjonen kan i følge Mazur (1987) beregnes med følgende formel:

$$Vd = \frac{V}{(1+kd)}$$

Figur 2. Hyperbolsk diskontering

I formelen er *Vd* den subjektive verdien av en fremtidig forsterker *V*, og *d* er tidsutsettelsen (delay) til levering, og hvor *k* representerer den ukjente parameteren diskonteringsrate (grad av diskontering). Den hyperbolske modellen er ofte benyttet i studier på temporal diskontering, fremfor den eksponentielle, idet den i følge forfatterne har vist seg å bedre være i stand til å redegjøre for variansen i dataene fra ulike forsøk (se f.eks Bickel & Marsch, 2001; Green & Myerson, 2004; Green et al., 1997; Madden et al., 1999).

En vanlig benyttet prosedyre i studier på temporal diskontering er såkalte *adjusting amount-procedures (Bickel & Marsch, 2001)*, hvor deltakeren velger mellom en umiddelbart tilgjengelig forsterker (SS) og en forsterker som er utsatt i tid (LL), og hvor SS varieres systematisk, mens LL holdes konstant. Prosedyren gjentas for ulike tidsutsettelse variabler, og ut fra deltakerens endringer i preferanse (*Vd*) beregnes grad av diskontering (*k)* og man kan da illustrere en person grad av diskontering grafisk over flere tidsutsettelses variabler. Jo høyere *k*, jo høyere grad av diskontering fremviser personen i valgsituasjonene. En valgprosedyre i praksis kan illustreres ved for eksempel en studie av Bickel, Odum, and Madden (1999) som

gjennomførte en undersøkelse med sigarett røykere og sammenlignet diskonteringsrate med en gruppe ikke-røykere og en gruppe eks-røykere. Diskontering ble undersøkt ved at deltakerne ble presentert for 27 hypotetiske valg mellom mindre umiddelbare pengebeløp (SS), og større utsatte pengebeløp (LL). Pengebeløpene varierte fra $1000 og ned til $1, og var trykket på index-kort. Tidsutsettelsen til pengene kunne mottas, kom også frem av kortene (1 uke, 2 uker, 1 mnd., 6 mnd., 1 år, 5 år, 25 år). Deltakerne ble presentert for to kort, hvor det ene kortet representerte LL som for penger var fast $1000, mens det andre representerte SS som systematisk ble variert. For eksempel, det første valget var mellom $1000 nå, eller $1000 om en uke. Ved dette valgte alle deltakerne $1000 nå. Deretter ble neste SS-kort snudd, og deltakeren valgte mellom $990 eller $1000 om en uke, deretter $960 vs. $1000 osv., og helt ned til $1 vs. $1000 om en uke. Deretter ble valgene presentert på nytt i stigende rekkefølge. Punktet for likegyldighet ble bestemt ut fra hvor deltakerne skiftet preferanse fra SS til LL i synkende rekkefølge, og omvendt fra LL til SS i stigende rekkefølge. Likegyldighetspunktet ble beregnet som gjennomsnittet av de to summene. Deretter ble prosedyren gjentatt for alle syv tidsutsettelsene, og *k*-verdier ble kalkulert ved hjelp av både eksponentiell og hyperbolsk beregning. I denne studien ble i tillegg samme prosedyre gjentatt for røykergruppen og eks – røykergruppen, men da med valg mellom hypotetiske sigaretter, hvor verdien på hypotetiske penger og sigaretter på forhånd var beregnet å være lik. Dataene fra studien viste at nåværende røykere fremviste høyere grad av diskontering enn både eks-røykere og aldri-røykere, og eks-røykere og aldri-røykere viste seg å ikke ha signifikante forskjeller i diskontering. Røykerne viste i tillegg høyere diskontering for sigaretter enn for penger, og den hyperbolske modellen viste seg å passe for dataene i større grad enn den eksponentielle modellen. Denne studien ga interessante funn hva gjelder at sigarettrøykere på lik linje med rusmiddelavhengige i tidligere studier viste større grad av diskontering enn kontrollgrupper. Med bakgrunn i disse funnene diskuterte forfatterne hvorvidt forhøyet diskonteringsrate kan

være en reversibel tilstand i nikotinavhengighet, og understreker behovet for longitudinelle studier med røykere som slutter å røyke for å undersøke dette videre. Funnet knyttet til at avhengighetsstoffet (sigaretter) ble diskontert i større grad enn penger hos røykere, indikerte at diskontering varierer med type forsterkere, og var også konsistent med andre studier som viste samme effekt for heroin vs. penger blant heroin avhengige (Madden, Petry, Badger, & Bickel, 1997). Forfatterne diskuterte også muligheten for at abstinenseffekter for avhengighetsstoffer kan ha betydning for disse funnene.

Temporal diskontering som underliggende prosess over en rekke forstyrrelser.

Temporal diskontering er relatert til rusmiddelavhengighet, både som en underliggende prosess, og er også foreslått som et mål på beslutningstaking i en rekke forstyrrelser og lidelser hvor impulskontroll er et gjennomgående tema (Bickel, Koffarnus, Moody, & Wilson, 2014; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013). Dersom det viser seg at intervensjoner kan endre grad av diskontering, kan det ha implikasjoner for behandling av en rekke tilstander. Forhøyet diskontering av fremtidige forsterkere er vist i en rekke studier og over en rekke atferdsforstyrrelser, og dette gir støtte til antakelsen om at diskontering kan fungere som et mål på uhensiktsmessig og usunn beslutningstaking over et bredt spekter av tilstander hvor impulsivitet er et sentralt kjennetegn. Forhøyet grad av diskontering er f. eks demonstrert i avhengighetsstudier på alkohol (Bobova, Finn, Rickert, & Lucas, 2009), kokain (Camchong et al., 2011; Coffey, Gudleski, Saladin, & Brady, 2003; Kirby & Petry, 2004), heroin og opioider (Kirby & Petry, 2004; Madden et al., 1999), tobakk og nikotin (Baker, Johnson, & Bickel, 2003; Bickel et al., 1999; Odum, Madden, & Bickel, 2002). Forhøyet diskontering knyttes også til for eksempel patologisk spilling (Andrade & Petry, 2012; Ledgerwood, Alessi, Phoenix, & Petry, 2009), ADHD (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001), ved Schizofreni (Heerey, Robinson, McMahon, & Gold, 2007) og til antisosial atferd hos voksne (Bobova et al., 2009). Videre, til kognitive prosesser

som ved redusert intelligens og redusert kapasitet i arbeidsminne (Bobova et al., 2009). Weatherly (2014) trekker i en oversiktsartikkel frem at diskontering er et utbredt fenomen, og andre varierte livsområder er blitt gjenstand for forskning på diskontering, som personlige forhold, helsebeslutninger, miljøpolitikk m. m. Variasjonsbredden av ulike populasjoner hvor forhøyet diskontering av fremtidige forsterkere er demonstrert, gir støtte til antakelsen om temporal diskontering som en underliggende prosess over en rekke tilstander og atferdsforstyrrelser.

Temporal diskontering og impulsivitet.

Korrelasjoner mellom mål på diskontering, og på impulsivitet er gjennomført i flere studier. Ulike kartleggingsverktøy på impulsivitet som har vært benyttet, er selvrapportering som måler ulike skalaer på impulsivitet. Ofte benyttet er *Eysencks IVE scale* og *Barratt´s Impulsiveness Scale* (se f. eks Andrade & Petry, 2012; Bickel & Marsch, 2001; Coffey et al., 2003). Ofte beskrives diskontering og impulsivitet som synonymer, men det er nok riktigere å beskrive de som relatert til hverandre. Det viser seg i studier å være relativt god korrelasjon mellom grad av diskontering og på selvrapporterte beskrivelser av impulsivitet (Green & Myerson, 2004). I diskonteringsforsøk kan valget av SS over LL, indikere et impulsivt valg, og motsatt ved valg av en LL over SS, kan dette indikere et selvkontrollert valg. F. eks vil tendensen til å velge umiddelbare alternativer over utsatte alternativer, være assosiert med impulsivitet.

***Magnitude* effekt.**

Studier i temporal diskontering har vist en såkalt *magnitude*-effekt. Når størrelsen på en utsatt forsterker øker, varierer graden av diskontering seg motsatt av størrelsen på forsterkeren. I en studie av Green et al. (1997) ble 24 universitetsstudenter presentert for ulike valgsituasjoner med hypotetiske penger tilgjengelig nå eller etter en tidsutsettelse. Tidsutsettelsene varierte fra 3 måneder og opp til 20 år, og 24 valgsituasjoner ble presentert

for hver tidsutsettelse. Dette ble i sin tur gjentatt med fire ulike størrelser på den utsatte forsterkeren ($100, $2.000, $25.000 og $100.000). I hver økt ble deltakerne bedt om å angi sin preferanse for enten SS eller LL, hvor summen på SS varierte systematisk enten i stigende eller synkende mellom 1% og 99% av LL. Likegyldighetspunkter ble identifisert og beregnet for hver tidsutsettelse, og *k*-verdier ble kalkulert fra både den eksponentielle og hyperbolske modellen. Dataene fra denne studien viste at grad av diskontering reduseres når størrelsen på den utsatte forsterkeren øker. Dette matchet både på gruppe og individnivå, og den subjektive verdien av LL økte under variablene $100, $2000 og $25.000. Imidlertid fremkom ikke ytterligere økning fra $25.000 til $100.000, slik at når størrelsen på forsterkeren økte til over $25.000, fremkom ikke en ytterligere *magnitude* effekt. En sentral avledning av funnene på at det eksisterer en *magnitude* effekt, er at personer i økende grad vil foreta selvkontrollerte valg når størrelsen eller mengden forsterkning øker. Imidlertid er denne økende selvkontrollen begrenset da resultatene også viser en at reduksjonen i diskontering stabiliseres når størrelsen på forsterkeren når et visst punkt (i denne studien ingen signifikante forskjeller i diskonteringsrate ved $25.000 og $100.000) (Green et al., 1997).

***Sign* effekt.**

Sign effekt er et observert fenomen i temporal diskontering og refererer til at diskontering har vært vist å være høyere for forsterkere, enn for valgsituasjoner som involverer tap av tilsvarende mengde forsterker/goder (*loss aversion*). For eksempel vil subjektiv verdi av å motta 10 dollar om en uke, diskonteres i større grad enn subjektiv verdi av å miste 10 dollar om en uke. Slike *sign effekter* har blitt vist i studier på temporal diskontering (Bickel & Marsch, 2001; Chapman, 1996).

Temporal diskontering av hendelser i fortid.

Det er observert at diskontering også forekommer for hendelser tilbake i tid. I en studie av Yi, Gatchalian, and Bickel (2006) gjennomførte 27 studenter en valgprosedyre hvor

diskontering av fortidige og fremtidige hendelser, *magnitude* effekter og *sign* effekter ble undersøkt. Diskontering av hendelser i fortiden ble avdekket, og at denne type diskontering var tilsvarende temporal diskontering av fremtidige hendelser. I tillegg ble også *sign* effekter funnet i diskonteringen av fremtidige så vel som fortidige hendelser, og *magnitude* effekter ble funnet også å gjelde i fremtid så vel som fortid, men da kun for forsterkere (ikke ved tap av forsterkere).

Nevroøkonomi (*Neuroeconomics*)

Mange forsøker å forstå det nevrologiske grunnlaget for beslutningstaking, og et mål i nevrovitenskap er å forstå mekanismer i problemløsning gjennom å undersøke hvilke områder i hjernen som aktiveres, og interagerer i ulike situasjoner. I beslutningstaking vil f. eks forholdet mellom affektive og kognitive prosesser være av interesse, og forholdet mellom automatiserte og kontrollerte prosesser (Camerer, Loewenstein, & Prelec, 2005). Nevroøkonomi er forskningsfeltet hvor man forsøker å integrere atferdsøkonomisk forskning, og kognitiv psykologi og nevrovitenskap (Koffarnus et al., 2013; MacKillop et al., 2012). Nyere forskning innen nevrovitenskap kan videre bidra til økt forståelse av valgprosesser i et økonomisk og atferdsøkonomisk perspektiv (Camerer et al., 2005). Nevrobiologiske mekanismer i valgsituasjoner har blitt undersøkt ved hjelp av fMRI skanning (*functional Magnetic Resonance Imaging*) i ulike studier på temporal diskontering, og denne forskningen har gitt innsikt i spesifikke hjerneområder som er involvert i diskonteringsprosesser og beslutningstaking (Ballard & Knutson, 2009; Bickel, Pitcock, Yi, & Angtuaco, 2009; Kable & Glimcher, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004). For eksempel gjennomførte McClure et al. (2004) et valgeksperiment med 14 studenter, hvor deltakerne foretok valg mellom forsterkere som varierte i mengde og tidsutsettelse, under fMRI skanning. Valgalternativer som ble presentert var hypotetiske forsterkere i penger som varierte mellom $5 til $40, og leveringstid som varierte fra i dag og opp til 6 uker fra i dag.

Resultatene fra fMRI skanningen viste økt aktivering i de limbiske og paralimbiske hjerneområdene under valg av umiddelbare forsterkere (ventral stratium, ventromedial prefrontal og posterior cingulate cortex), mens i alle valgsituasjoner, inkludert vanskelige valg og valg av utsatte forsterkere, viste skanningen økt aktivitet i prefrontal cortex (dorsolateral prefrontal cortex og posterior parietal cortex). Disse hjerneområdene knyttes til eksekutive funksjoner som refleksjon, kognitiv kontroll, økonomiske analyser og vurderingen av fremtidige konsekvenser av valg (McClure et al., 2004). Understøttet av studien til Ballard & Knutson (2009) gir disse funnene indikasjoner på at to hjerneområder er involvert i overveielsen av valgalternativer i beslutningstaking (Ballard & Knutson, 2009; Bickel et al., 2007; Koffarnus et al., 2013; McClure et al., 2004). Relatert til hyperbolsk diskontering gir dette mening, og kan tolkes som en konkurranse mellom affektive og kognitive prosesser, hvor forhold som påvirker disse systemene i den ene eller andre retningen, vil påvirke i hvilken grad personen gjør impulsive valg (Camerer et al., 2005).

Når det gjelder rusmiddelmisbruk, er disse modellen med to konkurrerende hjerneprosesser interessante, idet det impulsive systemet er lokalisert til de dypere strukturene av hjernen hvor rusmiddeleffekter gjør seg gjeldende gjennom forstyrrelser i de dopaminerge nervebanene i dette systemet (McClure et al., 2004). I neurobiologisk forskning har man som hovedfokus at rusmiddeleksponering over tid endrer hjernens strukturer og funksjoner knyttet til motivasjon og belønning i de limbiske og dopaminerge baner fra ventrale områder som nucleus acumbens og amygdala (Robinson & Berridge, 2008). Hvis valgsituasjoner involverer en konkurranse mellom det impulsive og det eksekutive, reflekterende systemet, så vil denne tilførselen av rusmidler nødvendigvis forstyrre den naturlig dopamintilførselen og balansen i disse systemene, og påvirke beslutningstakingsprosessen. Neurobiologisk forskning gir således viktige bidrag i neuroøkonomisk og atferdsøkonomisk forståelse av funn i studier som viser forskjeller i diskontering mellom for tiden avhengige og tidligere avhengige, og at

avhengighetsstoffet diskonteres i høyere grad enn f. eks penger (Bickel & Marsch, 2001; Odum, Madden, Badger, & Bickel, 2000).

Diskusjon

I denne artikkelen har jeg forsøkt å beskrive fenomener knyttet til avhengighet i et valgperspektiv, med utgangspunkt i atferdsøkonomisk teori og forskning. Det har vært naturlig å berøre øvrige innfallsvinkler fra klassisk økonomisk tenkning, atferdsanalyse, nevroøkonomi og nevrobiologi. Å finne mekanismer som kan bidra til forståelsen av etablering og opprettholdelse av avhengighet, og utfordringer knyttet til tilbakefall, samt finne frem til mekanismer som kan bryte disse valgmønstrene, kan få betydning for utvikling av gode behandlingsstrategier. Det har vært vist til at mekanismene i impulsive valg og repeterende kontrolltap som assosieres med rusmiddelavhengighet, kan relateres til preferansereversering og hyperbolsk diskontering av utsatte forsterkere. I ulike forsøk er slik hyperbolsk diskontering demonstrert, og det er videre vist at rusmiddelavhengige fremviser høyere grad av diskontering, enn ikke rusavhengige under valgprosedyrer i ulike studier. Videre er det vist til at forhøyet diskontering er korrelert med en rekke avhengighetstilstander, og andre atferdsforstyrrelser og psykiske lidelser. Hyperbolsk diskontering betegnes som et viktig mål på impulsivitet, og bidrar til å forstå hvordan avhengighet etableres og vedlikeholdes. Samtidig vil hyperbolsk diskontering kunne relateres tilbakefallsproblematikk (i.e. når rusmidler under gitte omstendigheter igjen blir umiddelbart tilgjengelige vil personens subjektive verdi av det å ruse seg overstige verdien av langtidseffektene ved å avstå). Det atferdsanalytiske perspektivet bidrar til å forstå motivasjon og preferanse for rusmidler, sett i forhold til funksjon og rusmidlenes (høypotente) forsterkende effekter på atferden. Videre gir atferdsanalysen viktige bidrag til forståelsene av hvordan atferd i nåtid kan komme under kontroll av fremtidige konsekvenser, og at selvkontroll forutsetter verbale beskriver/ regelstyring både som diskriminative stimuli, men også som viktige motivasjonelle

operasjoner. Nevroøkonomisk forsking bidrar til forståelsen både av rusmidlers effekt på nervesystemet (nevrobiologi) og av de nevrale prosessene knyttet til hyperbolsk diskontering.

Avledet fra dette, synes følgende implikasjoner å tre frem i utviklingen av ulike behandlingsintervensjoner.

Totalavhold

Spørsmålet om totalavhold er påtrengende her. Det er et viktig dilemma for rusmiddelavhengige å ta stilling til, samtidig som det vil være et faglig standpunkt å ta for ulike behandlingstilbud. Ofte uttrykkes normalisert rusmiddelbruk i form av kontrollert bruk og i sosiale situasjoner, som et mål eller ønske hos personer som ønsker å bli kvitt sin avhengighet. I henhold til teoriene om *melioration*, og *primrose path*, vil slik rusmiddelbruk kunne være et risikoprosjekt da enkeltstående rusinntak kan være forbundet med atferdsmønstre av misbruk og avhengighet. Avholdenhet fra rusmidler kan videre være en forutsetning for at grad av diskontering reduseres og gjør personen i økende stand til å utvikle mønstre av selvkontrollerte valg. Flere prospektive studier har gitt resultater som indikerer dette (Landes, Christensen, & Bickel, 2012; Secades-Villa, Weidberg, Garcia-Rodriguez, Fernandez-Hermida, & Yoon, 2014). Studier viser videre at forhøyet diskontering blant aktive rusmiddelavhengige sammenlignet med eks-rusmiddelavhengige og aldri-avhengige, og at avhengighetsstoffet diskonteres i høyere grad enn andre valgalternativer (penger) (Bickel & Marsch, 2001; Madden et al., 1997). Disse funnene gir grunnlag for å ytterligere forfekte avholdenhet som en viktig forutsetning for gode behandlingsresultater. Særlig relevant er dette poenget knyttet til forhøyet diskontering. Det er fortsatt et lavt antall prospektive studier, men de ser ut til å bekrefte at avholdenhet over tid reduserer individuell grad av diskontering. Samtidig har man etter hvert ervervet seg solid kunnskap om at forhøyet diskontering er et kjennetegn ved pågående og vedvarende rusmiddelavhengighet, og en viktig implikasjon vil være et betydelig fokus på hjelp til å avstå fra rusmidler. Et faglig standpunkt knyttet til

totalavholdenhet, underbygges av nevroøkonomisk og nevrobiologisk forskning. Pågående eksponering for rusmidler på nervesystemet antas å forstyrre dopamintilførselen i nervesystemer involvert i beslutningstaking, og dermed forstyrre balansen mellom de hjerneområder som underligger impulsivitet og selvkontroll (i.e. det impulsive og eksekutive systemet). Fra et nevroøkonomisk ståsted vil denne forstyrrelsen kunne bidra til at konsistente preferanser for umiddelbare forsterkere utvikles, hvor automatiserte prosesser overtar og stenger av for kontrollerte prosesser eller kognitiv fungering. Rusmiddelmisbruk kan i dette ses som automatisert atferd som er lite tilgjengelig for personen selv (liten bevissthet og innsikt i egne fungeringer, bedømmelser og valg) (Camerer et al., 2005). Avholdenhet synes å være en forutsetning for å avlaste et overveldet impulsive system og åpne opp for kontrollerte hjerneprosesser (eksekutive funksjoner). Valg som er kontrollerte i denne sammenheng, vil være styrt av beskrivelser av fremtidige konsekvenser av egne valg. Automatiske valg inneholder ikke slike beskrivelser av konsekvenser (i.e. utenfor bevisst kontroll), og kan således ikke ta kontroll over beslutninger.

En viktig utfordring knytter seg til å legge til rette for proksimale og effektive forsterkere, i fravær av direkte-virkende kontingenser, hva gjelder selvkontrollerte valg. Hvordan hjelpe personer til å oppnå økt kontroll over atferd i nåtid? Operante behandlingsintervensjoner som Contingency Managment (CM), har vist at systematisk forsterkning av avholdenhet, har hatt gode effekter i behandlingssammenhenger (se f. eks Higgins & Petry, 1999; Silverman, 2004). Det å etablere effektive forsterkningskontingenser knyttet til avholdenhet vil være en viktig implikasjon for behandling.

Utforske ambivalens

Kompleks ambivalens kjennetegnes ved at valget av et avholdenhetsmønster er knyttet til abstrakte og diffuse konsekvenser i fremtiden. For rusmiddelavhengige i en behandlingssituasjon, vil det være forbundet med utfordringer at atferd i nåtid skal kunne

komme under kontroll av (beskrivelser av) fremtidige konsekvenser av valgene man tar. Muligens er disse fremtidige hendelsene vanskelige å forestille seg, de kan være høyst usikre og lite troverdige. Oppvekst og læringshistorie vil spille en viktig rolle i forhold til hvordan en tenker om fremtiden, og i hvilken grad man er i stand til å forestille seg et liv uten rusmiddelbruk. Tydelig konseptualisering av fremtidige hendelser, og analyser av fremtidige konsekvenser av valg i nåtid vil være et viktig virkemiddel i behandling, og kan relateres til det Rachlin kaller for restrukturering av valgalternativene ved å relatere nåtidige valg til fremtidige konsekvenser (inkludere mer kontekst) (Rachlin, 2000).

Selvkontroll

Øving av selvkontroll er en viktig implikasjon idet selvkontrollerte valg er en forutsetning for å kunne mestre sin avhengighet. Når preferansereversering oppstår, må den håndteres av personen. Behandling må inkludere strategier for å mestre situasjoner hvor slik preferansereversering oppstår. I behandling vil f. eks et selvkontrollfokus kunne knyttes opp til funksjonelle analyser av avhengighetsatferd. Utforsking av foranledninger (hvilke omstendigheter og diskriminative stimuli gir anledning for rusmiddelinntak), hvordan påvirker ulike motivasjonelle operasjoner som f. eks abstinens-symptomer, deprivasjon, ulike hendelser som gir ubehag og negative følelser osv., og hvilke forsterkende hendelser er tilstede under rusmiddelinntak. Funksjonelle analyser vil kunne gi viktig informasjon om alternativ atferd, virkningsfulle strategier og selvinstruksjoner i det å ta kontroll over avhengighetsatferden.

Øve eksekutive funksjoner – redusere grad av diskontering

I forskningslitteraturen om temporal diskontering er det økende interesse for spørsmålet om i hvilken grad diskonteringsrate lar seg påvirke og endre gjennom planmessig intervensjon. Psykologiske intervensjoner som f. eks fremtidig tenkning og planlegging (Black & Rosen, 2011; Peters & Buchel, 2010) og systematisk trening i arbeidsminne (Bickel, Yi, Landes, Hill,

& Baxter, 2011) har vist at graden av diskontering reduseres når slike eksekutive funksjoner stimuleres. Nevroøkonomisk forskning bidrar til økt fokus på viktigheten av å engasjere hjerneområder i prefrontal korteks som et virkemiddel i det å få til en reduksjon i grad av diskontering. Bruk av kognitive metoder som systematisk retter seg mot oppøvelsen av eksekutive funksjoner, vil i denne sammenheng kunne få solid empirisk støtte fra studier på temporal diskontering. Endring i grad av diskontering som følge av intervensjon gir videre behandlingsoptimisme hva gjelder impulsivitet og kontrolltap. Hvis forhøyet diskontering er en reversibel tilstand, kan intervensjon som reduserer slik diskontering bidra til vellykkede behandlingsforløp for personer med rusmiddelavhengighet.

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Delay discounting as an underlying process in addiction: A review of variables affecting individual rates of discounting and delay discounting in the light of neuroeconomics – Implications for treatment

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Abstract

Delay discounting refers to the decrease in subjective value of a reinforcer, as a result of the delay until the reinforcer is delivered. Such delay discounting has been the focus of behavioral economic inquiry in various studies on substance use and addictive behaviors, and neuroeconomic research contributes to the understanding of delay discounting as a key measure of impulsivity, which is involved in addiction and in other disorders. In this paper, the latest research related on delay discounting and substance dependence, and neuroeconomic research on delay discounting, is reviewed. The paper's sample of articles report several findings supporting that delay discounting is a relevant measure of impulsivity in addiction, as well as in other behavioral disorders. The review highlights variables affecting delay discounting in people with dependency problems, emphasizing the variables that may be associated to changes in such discounting. In addition, recent studies of the neural basis of delay discounting processes contribute to a better understanding of behavioral processes in addiction, and support the notion of different regions of the brain to be involved in decision making, and in impulsive and self controlled choices. Finally, possible implications for treatment are discussed, focusing abstinence from the drug as a key-variable in treatment, and the importance of designing interventions targeting the executive systems in regions of prefrontal cortex of the brain, involved in future planning and behavioral control.

Key Words: Addiction, behavior economics, changing delay discounting, delay discounting, impulsivity, neuroeconomics, self control, temporal discounting, treatment.

Introduction

Background

Delay discounting is considered a core process in addiction (Ainslie, 2010). It has a clear connection with the complex and more abstract construct of impulsivity and refers to the decrease in subjective value of a reinforcer, as a result of the delay until the reinforcer is delivered (Bickel & Marsch, 2001). Increasing delay until actually receiving the reinforcer decreases the reinforcer's control of the behavior (Johnson et al., 2010), and delay discounting contributes to the understanding of various situations in which individuals show preference for immediate, but smaller reinforcers over larger, but delayed reinforcers (i.e. impulsive choice) (Bickel & Marsch, 2001). Delay discounting has been the focus of inquiry in various studies on substance use and addictive behaviors (Green & Myerson, 2004). The procedures for calculating individual degrees of discounting (*k*-values) are based on behavioral tasks that measure to which degree a reinforcer loses its value due to the temporal delay from present time. Various studies show that most individuals prefer the immediate over the delayed alternative when the two alternatives are being equal in value (e.g. receiving $1000 now or $1000 in one month). By adjusting systematically the choice options over a variety of delay (e.g.; receiving $ 920 now vs. $ 1000 in one week, one month, three month and so on), it is possible to calculate to which degree an individual discount future choice options relative to the temporal delay of the reinforcers receipt (Bickel & Marsch, 2001; Johnson et al., 2010). By calculating individual discount rates and quantifying the degree to which an individual discounts future choice options over a variety of delays, we obtain an important measure of impulsivity (Johnson et al., 2010).

The relevance of delay discounting for understanding addictive behavior

Delay discounting contributes to the understanding of addictive behavior. It helps to explain how an individual show preference for the immediate reinforcing effects of drug use

(e.g. euphoria, withdrawal relief, reduction in negative mood and emotional turbulence), rather than choosing the later but more abstract alternative resulting from abstinence from the addictive drug (e.g. better health, healthier social relationships, security in financial income and occupational opportunities) (Heinz, Peters, Boden, & Bonn-Miller, 2013; MacKillop et al., 2011; Rachlin, 2000). The fact that future gains and benefits are discounted in value, relative to the more proximate (smaller reinforcer value and sooner delivery) alternatives in choice situations can be illustrated as preference reversals resulting from delay. Individuals may have no problems abstaining from substance use, when the addictive drug is not immediate available, and they may proclaim their wishes for future abstinence and a willingness to change their habits, commit themselves to a treatment program and so on (Bickel, Madden, & Petry, 1998). However, when the effects and consequences of drug use become immediately available, the very same person may experience a preference reversal, resulting in lapse into substance abuse. Then, the descriptive term preference reversal is appropriate (Madden, Bickel, & Jacobs, 1999). Substance dependent individuals do select the brief, immediately available effects of drug use over the variety of delayed, but obviously pro-social future consequences of abstinence (Madden, Petry, Badger, & Bickel, 1997).

It is typical of preference reversal that the subjective value of a reinforcer does not decrease at a constant rate as delay increases, but fits a more hyperbolically shaped decline in subjective value. Such hyperbolic discount functions has been observed consistently in various studies with humans (Rachlin, Raineri, & Cross, 1991), and also in non-human research (Madden et al., 1997; Mazur, 1987). This hyperbolically shaped decline indicates that discounting is not a constant parameter, but that rate of discounting increases when time until delivery of the reinforcer decreases. The shorter time delay, the steeper discount rate. Hyperbolic discounting represents an alternative explanation to the exponential discounting model, where discounting occurs at a fixed rate relative to delay. This perspective informs

economic models of addiction, like the rational theory of addiction proposed by Becker and Murphy (1988), which explains impulsive behavior by increased or large rates of discounting (Bickel & Marsch, 2001). The rational model, however, does not predict preference reversal, as described above. The hyperbolic model of delay discounting does. Thus, hyperbolic discounting may contribute to the understanding of phenomena related to loss of control and impulsive choices. On Friday morning, when both choice alternatives are distant in time, Lisa expresses preference for the self controlled choice option of abstaining from drugs (i.e. future benefits like work, good health, family etc.). However, on Friday evening, when drugs become immediate available, her preference reverses, now in favor of taking drugs (smaller sooner reinforcer), resulting in her making an impulsive choice.

In research on delay discounting, the hyperbolic model of discounting is well documented, and numerous studies show that this model displays a better fit (i.e. accounts for more of the variance, according to authors) than the exponential model (see for instance Bickel & Marsch, 2001; Green, Myerson, & McFadden, 1997; Madden et al., 1999). Various adjusting choice procedures have been employed (Bickel & Marsch, 2001; Green & Myerson, 2004). Participants repeatedly state their preference for either one out of a series of two alternatives. The delayed choice option is the larger later reinforcer of a fixed magnitude (e.g. $1000 in one week), and the immediate alternative is a smaller sooner reinforcer to be received immediately. The smaller sooner reinforcer is then systematically adjusted, until the participant show equal preference between the smaller sooner and larger later alternative. The point where preference is equal indicates the participant´s point of indifference at a specific delay (e.g. $820 at the one-month delay). The procedure of finding the indifference points is repeated for a variety of delay conditions, often ranging from one day and up to 25 years (seven delay intervals are common; 1 week, 2 weeks, 1 month, 6 months, 1 year, 5 years, 25 years). A participant´s rate of discounting can then be calculated using the hyperbolic

equation based on Mazur (1987), derived from the indifference points obtained by the adjusting choice procedure;

$$Vd = \frac{V}{(1+kd)}$$ *Figure 1*: Hyperbolic discounting

In the equation, *Vd* represents the discounted value (the indifference point) of *V*, the delayed amount. *k* represents the rate of discounting, and *d* is the delay period to the receipt of *V* (Bickel & Marsch, 2001).

Various studies have shown some other important phenomena of delay discounting, in addition to the phenomena regarding the hyperbolic function in delay discounting. These are a *magnitude effect* (Green et al., 1997), the sign effect (Bickel & Marsch, 2001; Chapman, 1996) and that delay discounting also is related to the valuation of past events or the memory of past events. (Bickel, Yi, Landes, Hill, & Baxter, 2011; Yi, Gatchalian, & Bickel, 2006).

The *magnitude effect* refers to findings that the degree of discounting systematically varies as the amount or magnitude of a delayed reinforcer is varied (Green et al., 1997). That is, with increasing amount of a delayed reinforcer, an inverse effect is seen on discounting (declining rates of discounting due to the increase in the magnitude of the reinforcer). This variable affecting rates of discounting indicates a possible effect on self control, in that when the magnitude of a delayed reinforcer increases, the person will show an increase in self controlled choices (Green et al., 1997).

The *sign effect* refers to the construct of loss aversion, and means that the discounting of subjective value of a reinforcer is greater than the discounting of a loss of comparable magnitude. For instance, the value of getting $10 in one week is discounted at a higher rate than the value of losing $10 in one week. The sign effect has been demonstrated in studies on delay discounting (Bickel & Marsch, 2001; Chapman, 1996).

Yi et al. (2006) conducted a study trying to find similarities in discounting of future and past outcomes, and found that delay discounting was related to the valuation of past

events. Twenty seven college students were assessed using an adjusting choice procedure over a variety of delay conditions, investigating discounting of past and future events, including possible magnitude effects and sign effects (regarding losses and gains for future/past events). Past discounting was detected in this study, and in addition they found that past discounting was very similar to discounting of future events, in that the hyperbolic model provided a good fit. Further, they found a magnitude effect regarding reinforcers (not for losses) in both past and future conditions, and a sign effect also related to past events, similar to that of future outcomes of choices.

Delay discounting across dependencies and other disorders

Excessive discounting of future rewards has been found to be related to lifetime problems with alcohol (Bobova, Finn, Rickert, & Lucas, 2009; MacKillop et al., 2010), cocaine (Camchong et al., 2011; Coffey, Gudleski, Saladin, & Brady, 2003; Kirby & Petry, 2004), heroin (Kirby & Petry, 2004; Madden et al., 1999) and to other drugs. Research has further produced evidence for increased delay discounting in dependency problems like smoking (Baker, Johnson, & Bickel, 2003; Bickel, Odum, & Madden, 1999; Odum, Madden, & Bickel, 2002), gambling (Andrade & Petry, 2012), and to various disorders such as childhood conduct disorders and adult antisocial behaviors (Bobova et al., 2009). Increased delay discounting is also found to be related to cognitive processes, correlating with lower intelligence and lower working memory capacity (Bobova et al., 2009).

Discounting in the light of neuroeconomics

Addiction is associated with the loss of behavioral control (i.e. preference reversals) (Camchong et al., 2011) as demonstrated in behavioral studies on delay discounting (Kirby & Petry, 2004). Such loss of control, deficits in self-regulation and impulse control, are related to abnormalities in neural networks in the brain. Abnormalities are found in the limbic system associated with reinforcement/rewards, and in frontal cortex networks that are

involved in self- regulation and cognitive processes (Camchong et al., 2011; Goldstein & Volkow, 2002). Researchers in the field of neuroeconomics have made advances towards identifying the underlying neural basis of intertemporal choice, expanding the understanding of why substance dependent individuals discount future choice options at the observed rates. By the use of brain imaging tools such as functional Magnetic Resonance Imaging (fMRI), activation in brain regions of interest can be measured in various experimental choice situations (Bickel et al., 2007). Neuroeconomic research has identified two competing neural systems that are involved in intertemporal choice and discounting processes, called "the competing neural system theory or account" (Bickel et al., 2007; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004). This view is based on the hypothesis that an impulsive system localized to brain regions in the limbic areas like the amygdala and nucleus accumbens, is reacting to stimuli and related to emotional and physiologically responses. The hypothesis is that the impulsive system is competing with an executive system localized to regions of the prefrontal cortex, that is involved in future planning, deliberate cognition and control processes. In terms of delay discounting, this view holds that when the impulsive system overwhelms the executive system and weakens the influence from these regions of the brain, such as in drug dependency, excessive discounting may be seen as a neural emphasis on the immediate choice alternative (Bickel et al., 2007).

This was demonstrated in an experiment by McClure et al. (2004), were participants in a study made series of binary choices of smaller sooner reinforces (SS) versus larger later reinforcers (LL). The choice procedure was conducted while participants´ brains were scanned using fMRI. The result from this study showed that the limbic regions (the impulsive system, labeled the "β" areas rich in dopaminergic activity) exhibited increased activation during choices of SS reinforcers. The Prefrontal and Parietal areas of the brain (i.e. the executive system, labeled the δ areas implicated in deliberation processes and cognitive

control), showed increased activity during choices of the Larger Later reinforcers. These findings support the two competing systems hypothesis. The results from this study may help to explain how impulsive behavior are related to other factors as well as time and proximity, such as seeing, hearing and smelling etc (e.g. the sudden craving following the smell of eggs and bacon). That is, if impulsivity is related to activation in the limbic system, then impatience could be evoked as a result of other factors activating that system as well (McClure et al., 2004).

For this paper, an important goal has been to review the latest research in the behavioral economic field of addiction and substance dependence, in order to identify variables affecting delay discounting in people with dependency problems, emphasizing the variables that may be associated to changes in such discounting. Another goal is to incorporate the latest findings regarding the neural basis of delay discounting processes, to see how these findings may contribute to a better understanding of behavioral processes in addiction, and to discuss how this may contribute to future treatment interventions.

The findings and interpretations discussed above lead to the questions under review in this paper. Does recent research on delay discounting, support delay discounting as an important measure of impulsivity, which is involved in addictive behaviors? May an individual´s discount rate be altered due to interventions? Do advances in neuroeconomic research inform delay discounting and possible future treatment efforts?

Method

The initial criterion for inclusion in this review was any "peer reviewed study containing the key words: *Addiction* AND *Behavioral economics* AND *Neuroeconomics* AND *Temporal discounting*. Further criteria for inclusion were empirical studies on different drug use/abuse/addiction (alcohol included) and delay discounting. When the initial search was done, a quick review of the results indicated that

empirical studies on neuroeconomical/neurobehavioral correlates of delay discounting should be included in this review. Delay discounting studies on nicotine dependency were excluded, along with delay discounting studies on other behavioral disorders such as compulsive eating, obesity, gambling etc. Also, studies on probability discounting were excluded. Studies on delay discounting not associated to substance use/abuse/addiction were not considered relevant for my inquiry, and were excluded. The search result contained some studies regarding neuroeconomic examinations that did not have participants with any substance use disorders. Due to the questions of interest regarding delay discounting in the light of neuroeconomics, neuroeconomic studies were included regardless of whether they included a substance use disorder population.

I did my search in the Psych Info database on February the 25´th, 2014, and got a total of 55 "hits". Out of all of these articles, only 7 met my criterion for inclusion. Clearly, 7 articles was too small a number, and did not show a representative sample of relevant articles regarding my search terms. After trying out different combinations of search words, without getting any good representative sample, I decided to hold on to my initial search results. In addition to the 7 articles derived from this search, I also read the abstracts in Koffarnus' reference list (M. N. Koffarnus, D. P. Jarmolowicz, E. Mueller, & W. K. Bickel, 2013). This article showed up in my initial results of 55, and is a review of important findings in the research area of delay discounting and neurobehavioral processes. I reasoned that this recently conducted review would refer to other important empirical articles that would meet my criterion for inclusion. A systematic reading of this article´s reference list and the different references abstracts, yielded an additional 32 articles meeting the criteria for inclusion, showing a total of 39 articles. Excluding articles written before 2009 in order to review only the most recent research, I ended up with a total number of 31 empirical articles. Seven more empirical articles were excluded after a careful reading, due to population (i.e. delay

discounting not related to substance dependent participants), neuroeconomic inquiry (one study regarding blood glucose level), and method (one study that used a behavioral economic demand curve analysis).

I conducted my initial search and selection of some months ago, and thus I risked missing recently published studies relevant for this review. My specific concern was publications regarding alterations of discount rates due to any environmental interventions. I conducted an additional search at three databases ("Psyc Info", "Eric" and "Web of Science") at October 4´th 2014, applying the following search words: *Changing delay discounting* OR *Altering delay discounting*. The search yielded two candidate publications. While neither of which met my inclusion criteria regarding participants from a substance dependent population, I decided to include them two in the review, due to the relevance regarding changing discount rates as a result of intervention. Finally, I was not able to read one empirical article because it was not available in any of the accessible databases (Amlung & MacKillop, 2011), and unfortunately this study is not included in the review. This review then, is based upon reading 25 empirical articles.

1. Correlational studies on variables affecting discounting

a) Discounting related to dependency problems.

Several studies report findings that support previous research results regarding the role of delay discounting processes present in various addictive behaviors and across different substances. One study reported findings of increased rates of discounting across other disinhibitory problems (Bobova et al., 2009). The study aimed to assess delay discounting and its co-variation with different types of disinhibitory problems (in this study the prevalence of other drug-related pathologies/problems, childhood conduct disorder and adult antisocial behavior) often comorbid with alcohol dependency. This study used a sample of 426 participants, where 257 met the criteria of Alcohol dependence. In addition to the screening

session of drug history, personality and cognitive assessments, delay discounting was assessed by letting participants make choices in ascending and descending order, over six delay conditions ranging from one week up to one year. In this study, higher delay discounting was found to relate to all domains of such problems or disorders, not just one. In addition, the study showed that delay discounting was associated with lower scores on IQ measures, reduced working memory capacity, and higher trait impulsivity.

A study by Businelle, McVay, Kendzor, and Copeland (2010) showed that heavy smokers and individuals with substance use disorders discounted more than controls. Rates of discounting were compared across four identified groups of a) heavy smokers with substance use dependence (SUD), b) heavy smokers without SUD, c) never smokers with SUD, and d) a control group with no smoking/no SUD history. The data were collected from a larger study in 2008, investigating relationships between substance dependence and risk taking. Nearly 80% of the participants with substance use dependence had problems regarding multiple substance use dependency. An interesting finding in this study was the similarity in discount rates among smokers, individuals with dependency problems, and individual with both smoking and dependency problems, showing that smoking had a similar effect on delay discounting like other substances. This particular study also found that multiple substance abuse had no additive effect on delay discounting rates.

Heinz and his colleagues (Heinz et al., 2013) found significant correlation between the degrees of individual discounting rates and compulsive craving for Cannabis, early debut and earlier beginning of regular use. Delay discounting was further correlated with professional help-seeking in previous quit-attempts. However, they found no statistical evidence for their second hypothesis regarding whether higher degree of delay discounting could predict outcomes in cessation due to self-directed quit attempts. The population was military veterans drawn from a larger study, and who met the criteria for cannabis dependence. Subjects were

included in the study if they, at inclusion, reported a motivation to quit of at least 5 on a 10-point scale (10 indicating definite interest in quitting), and in addition reported that they were interested in trying to make a serious self-quit attempt.

In this prospective study, participants first met for inclusion and assessment on the day before they were to start their self-quit attempt. Participants should then return for follow up during the next six month, with weekly schedules the first month, and then monthly for the remaining months. In total, they met for assessments 10 times during a six months period, including pre-cessation. Participant assessment measures were demographics and self-reported substance use (quantity and frequency) at pre-cessation; including tobacco, alcohol and cannabis consumption three months prior to cessation attempt. Further, self-reported cannabis use was assessed at each follow-up appointments. Using a time-line follow-back interview, cannabis use information was used to determine lapse and relapse.

The results from this study suggest that delay discounting may have less relevance for cannabis than for other drugs. While the results indicate that delay discounting is sensitive to the development of cannabis dependency, in this study delay discounting was not found to reliably predict any cessation outcomes in participants.

A study by Johnson et al. (2010), support the Heinz et al. (2013) suggestion that delay discounting may have less relevance for cannabis. This study recruited participants from local newspaper ads. The hypothesis was that current marijuana dependent individuals would show increased delay discounting relative to non-users in a control group, and relative to a group with formerly cannabis dependent individuals. In addition, the study investigated whether individuals in the currently dependent group would show increased delay discounting when choosing between amounts of marijuana than for amounts of money. In one 2-3 h session, currently dependent individuals were asked to specify the amount in ounces of marijuana equivalent to $1000. The delay discounting assessment conducted in the study was a based on

Johnson and Bickel (2002), a delay discounting computer procedure for money and marijuana. Individual rates of discounting were calculated using the hyperbolic delay discounting equation model of Mazur (1987).

The data revealed a contrast with previous studies on drug dependent groups that discount more than non-user control groups, and their hypothesis regarding increased delay discounting for current marijuana dependent individuals was not supported. Current marijuana did in this study not discount future outcomes at a significantly higher rate than non-user controls. However, they showed a trend in steeper discounting of money more than controls, and more than former dependent individuals. Currently dependent individuals showed significantly greater tendency to increasingly discount amounts of marijuana over money. Another interesting result in this study was that delay discounting was more closely related to tobacco use, than to marijuana use.

Whether individual rates of discounting increase due to co-occurring dependency problems, has been a focus of inquiry in one other study in this review, in addition to the Businelle et al. (2010) study which showed no additive effect on delay discounting rates related to multiple substance abuse. Ledgerwood and colleagues (Ledgerwood, Alessi, Phoenix, & Petry, 2009) conducted a study on the role of impulsivity in pathological gambling. In addition to the measures of impulsivity in pathological gamblers compared to matched controls, they also compared impulsivity measures with pathological gamblers with or without a history of substance use disorders. One of several behavioral measures of impulsivity was a computerized delay discounting task according to the procedures in the study of Petry and Casarella (1999), on excessive discounting regarding substance abuse and gambling. Individual rates of discounting were measured by calculating the ”Area Under The Curve” (AUC) in accordance with Myerson, Green, and Warusawitharana (2001).

Ledgerwood and colleagues found, consistent with previous research findings, that on the delay discounting measures, individuals with pathological gambling showed significantly higher degrees of discounting of delayed reinforcers, than controls. However, when comparing the pathological gamblers who either did or did not have a history of substance use disorder, the results revealed no significant differences in discounting rates. These results were also supported by other behavioral measures of impulsivity in the study.

Increased delay discounting in other substance dependent populations has been demonstrated. Dierst-Davies et al. (2011) conducted a delay discounting investigation among homeless, no-treatment seeking substance dependent men who have sex with other men (S-D-MSM) and compared discounting measures with matched controls that were not substance dependent or homeless (MSM) (n=40, with 20 participants in each group). The individuals preferred drugs of addiction varied, and included methamphetamine, alcohol, cocaine and opioids. Indifference points were measured by procedures described in Madden et al. (1997), and rates of delay discounting was derived by the hyperbolic model. Consistent with the hypothesis, the S-D MSM group showed significant greater degree of delay discounting compared to controls. For instance, participants in the S-D MSM group discounted the subjective value of $ 1000 by 40 % at the point of two weeks delay, compared to controls that discounted the similar value by 35% at the point of a one-year delay.

The conclusion from the Dierst-Davies (2011) study is that findings are consistent with other studies on delay discounting in substance dependence populations, supporting that excessive discounting can be found over various substance use populations. Further, they conclude that for this particular population, the observed differences in delay discounting are important and may be relevant when designing appropriate interventions for people in risk and additionally hard to reach for various health services.

Craving.

MacKillop et al. (2010) sought to investigate delay discounting and two other behavioral economic variables' relationship to alcohol use disorders (AUD), those of the constructs of demand and of craving. By doing this investigation, they tried to integrate the role of craving in the behavioral economic approach to addictive behavior, in addition to the identification of variables of individual differences regarding discounting. Subjects were 61 heavy drinkers who were not included in treatment, not treatment seeking, and not having had any treatment during the previous 90 days. Subjects were assessed for delay discounting and demand for alcohol. Craving for alcohol related to the severity of Alcohol use disorders (AUD) was examined directly. All participants were in the range of AUD scores, and a good proportion of these could be diagnosed with a dependency. Further, an alcohol demand analysis was conducted by asking participants how many drinks they would drink in a typical drinking situation under various prize conditions. A delay discounting task was administered using a Monetary Choice Questionnaire (MCQ) (Kirby & Finch, 2010), investigating discounting under various levels of magnitude. Assessment of craving for alcohol was conducted, using a validated craving measure labeled PACS (Penn Alcohol Craving Scale) (Flannery, Volpicelli, & Pettinati, 1999).

Researchers found significant correlations between intensity of demand, delay discounting, and craving for alcohol, in relationship with the severity of alcohol use disorders. The data also displayed a magnitude effect in that the strongest delay discounting relationship were evident at higher levels of reinforcer magnitude. In addition the three individual variables; demand, discounting and craving, were found to intercorrelate, indicating that craving is related to the constructs of demand and discounting, and delay discounting correlates highly with the severity of alcohol abuse and dependency problems.

Discounting and consumption of other commodities.

In a study conducted in a residential treatment center, Kerwin, Farris, and Hantula (2012), conducted an investigation on ten women committed to treatment with their children. Kerwin and colleagues investigated risk taking, impulsivity and delay discounting based on the women's purchases in the simulated economy system of the treatment center, at the onsite token-economy store. In addition to measures on risk taking (BART) and self-report assessment of impulsivity (Eysenck Impulsivity Scale), a delay discounting adjusting choice procedure was conducted by having participants indicate preferences of money today vs money in the future. Two conditions of different magnitude were implemented, one in which participants chose between smaller amounts of money vs larger amount of $100 (smaller ranging from $0.10 to $99.99), and a second condition between smaller amounts of money vs a larger amount of $1000 (smaller ranging from $1.00 to $999.00). These measures were compared to the women's purchases of either high or low risk items (low: immediate cash and carry items, and high: delayed access/order from a catalogue). Within the two categories, items were labeled as either fast-moving (sold quickly at a low cost), and slow-moving (sold less rapidly). Whether purchases were intended for the mother or the child was also recorded.

The results from this study was that increased delay discounting did correlate with increased purchases of immediate accessible items, and in addition, more money spent on fast-moving commodities for their children (e.g. snacks, coloring books). However, the mothers seemed to both purchase slow- and fast-moving items for their children, indicating that while mothers made impulsive purchases of their own, they did consider their children´s needs in valuing both short term and long term items. As predicted, the women in this drug treatment and simulated economy setting made risky and impulsive decisions about purchases. Based on the exception of delayed purchases for their children, the authors discuss

the possibility of that mothers considered their children's wellbeing in a different way from their own wellbeing.

b) Discounting and social context.

How does context affect individual discounting of delayed reinforcers? One study investigated the role of both delay discounting and social discounting (defined as the effects of social context on discounting of delayed reinforcers), compared to cigarette smoking and level of alcohol use (Bickel et al., 2012). They managed to contact a large number of individuals (n=796), who responded on delay discounting questionnaires for individual reinforcers (me now, me later), and for reinforcers for the group (we now, we later; me now, we later). Individual discounting rates were calculated across various social contexts. Participants chose between hypothetical amount of money now, or at a specific delay, and *k*-values were estimated for each discounting measures across delay conditions. Data derived from this study showed that smokers discounted larger later reinforcers at a higher rate than controls, under all conditions. Further, the participant with a drinking problem (i.e. categorized as problem drinker) showed higher rates of discounting than non-problem drinkers under the individual condition. Under the social conditions however, no such differences was detected.

c) Changes in discounting due to different commodities.

The interaction between intertemporal choice and types of commodities has been studied by comparing how different variables affecting rates of discounting. In a study investigating decision-making among 47 treatment seeking cocaine dependent individuals, Bickel et. al. (2011) found that under various conditions offering different commodities (in this study; hypothetical money and hypothetical equated amounts of cocaine), the commodity did alter discount rate in the choice situations. That is, when drugs (cocaine) in this study were offered as the later commodity, discount rates increased. Rates of discounting were most

rapid under the Money – Cocaine condition (when choosing between hypothetical money now and hypothetical cocaine later).

2. Studies on changing discounting due to interventions

In delay discounting research, there seems to be an increasing interest in the possibility that an individual´s rate of discounting may be altered as a result of intervention or manipulation. Research on neurocognitive processes has stimulated further inquiry regarding this matter, such as the findings suggesting that discounting is related to the valuation of both past (memory) and future events (see for example Bickel, Yi, Kowal, & Gatchalian, 2008).

Bickel et. al. (2011) investigated the functionality of discounting and memory. They asked whether it might be possible to decrease the discounting of future events by increasing an individual's ability to remember past events. They randomly assigned 27 in-treatment adults with stimulant addiction to working memory training or to a control training group, and several cognitive behaviors as well as delay discounting were assessed prior to, and after training. Participants were assigned to either an experimental training group, or to a control training group. In the training group participants were given working memory tasks with monetary reinforcement for performance, while in the control group participants were given working memory tasks, and cued in giving the correct response. This was done in order to not engage working memory. The reinforcement in the control condition was yoked with performance in the active training group, and also the participants in were yoked with another participant in the other group, regarding gender and memory profile. Seven assessments were collected from participants before and after the memory training session. These included assessments of behavioral symptoms related to frontal lobe damage, working memory by a letter-number sequencing assessment, balloon Analog Risk Task (decision-making under risk), a learning by trial and error task (go-no/go), episodic memory assessment, verbal learning and memory assessment, and an assessment of delay discounting using a

computerized choice procedure. The memory training session was conducted using four memory-training programs, and included memorizing series of numbers and words, and categorizing words into different categories. All participants went through 1 pre-, and 1post-training session and 4 to 15 training sessions.

Participants in the group that received active memory training decreased their rates of discounting (*k*-value) on average by 50 %. Significant correlation between delay discounting and working memory performance was detected. In addition, the number of training sessions in the active training group was significantly negatively correlated with measures of discount rate at the post training assessment. An important conclusion from this study was that the observed change in discounting resulted from the reinforced working memory training.

Black and Rosen (2011) assessed the effect of a money management intervention, asking how this intervention affected delay discounting in participants and whether these effects could be correlated with any changes in substance abuse. 90 psychiatric patients with substance use histories (alcohol or cocaine) were assigned to the either the treatment program, or to a control group. The treatment period was for 36 weeks. Cocaine use and delay discounting was measured during the intervention, and a follow up measure of cocaine use was conducted after 52 weeks. The treatment component in this study was labeled ATM (Advisor-Teller Money Manager), and consisted of encouraging participants to make monthly budgets, describe long-term goals, and develop short-term spending plans. They received instructions in planning, and their budget adherence was monitored. Drug tests were conducted every week. A counseling component was available, were participants reviewed circumstances of their drug-use. Participants could, if they wanted, deposite money into an account, and the money manager offered storage of checkbooks and ATM. Participants in the control conditions received a workbook. They were encouraged to meet a counselor weekly for reviewing their monthly budgeting. However, in the control condition, participants did not

receive any feedback regarding their spending, and were not supervised regarding substance use.

The study found that delay discounting and cocaine use in participants receiving the treatment, was significantly decreased compared to those participants in the control condition, suggesting decreased abstinence is correlated with greater delay discounting measures. The authors concluded that the ATM treatment program had an effect on participants in that it decreased rates of delay discounting, and also reduced their substance use.

Another study aiming to investigate possible changes in discount rate due to intervention, was conducted by Landes et al. (2012), who did a secondary analysis with data from two outpatients treatment trials for opioid dependent individuals. The analysis was based on Christensen et al. (2012) and Chopra et al. (2009) (Landes et al., 2012). Subjects were 272 patients from two separate clinical trials who met the criteria for opioid dependency, and the inclusion criteria for Buprenorphine maintenance treatment. Patients committed to an outpatient treatment period of twelve months. A delay discounting task was conducted at start (baseline), and at the end of the treatment period. A total of 159 participants completed both the assessment at baseline and at the end of the treatment period. Participants went through an assessment session regarding behavioral, psychological and drug-taking measures. They completed a functional analysis of their drug use, and a treatment plan was designed in order to achieve abstinence. All participants received Buprenorphine during the period, and were randomly assigned to either of four treatments (three of them containing a contingency management component, and the fourth was a treatment based on standard counseling. Participants further delivered urine samples at each visit, screening for drug use. Delay discounting trials were conducted according to Johnson and Bickel (2002), with delays ranging from one day, up to 25 years (seven delay points). Indifference points were identified,

and measures of discount rates were obtained by the hyperbolic equation, and the AUC procedure.

On average, rates of delay discounting in participants decreased after completing the treatment program, compared to baseline. The decreases showed to be independently from which out of the four treatments that was received, and also independently of which treatment trial participants was submitted to. Additionally, three times more of the individuals displayed a decrease from baseline assessment, than those who showed an increase, at the end of the treatment. No significant correlation of delay discounting measures was found due to participants overall abstinence during the treatment period, although the participants on average documented high percentages of negative urine samples. That is, a percentage of the participants managed to abstain from drugs over the whole twelve weeks, and those individuals did exhibit a decreasing trend in discounting compared to baseline. However, no significant correlation was evident between abstinence and delay discounting data.

One recent study investigated changes in rates of discounting related to smoking status in treatment seeking cigarette smokers, using a longitudinal design assessing rates of delay discounting at baseline (prior to treatment), and at the end of a six week cognitive-behavioral group treatment program (group attendance once a week). Participants were completing an assessment again, at 12 months follow-up (Secades-Villa, Weidberg, Garcia-Rodriguez, Fernandez-Hermida, & Yoon, 2014). 80 participants, meeting criteria for at least smoking 10 cigarettes pr. day (mean 19,33), completed the baseline assessment, treatment and assessment at treatment end, and the follow –up assessment. Delay discounting rates were assessed using a computerized adjusting choice procedure, and participants made choices between hypothetical amounts of money ranging from $1000 at a fixed delay, and amounts of smaller amounts of money (down to $5) immediately available, at 7 different delays ranging from one

day up to 25 years. Indifference points were identified and individual rates of discounting were calculated using the hyperbolic model.

The data obtained from the study showed no significant effects on delay discounting rates after six weeks of treatment. 61 % of the participants reported abstinence (self report measures were backed with CO2 breath measures) after six weeks at treatment end (self report of abstinence was defined as not even one puff the last 24 hours). At the follow-up session, 35% of participants reported abstinence (not even a puff for the last 7 days). The results revealed a significant decrease in delay discounting rates among abstinent participants compared to those who were smoking 12 months after baseline. Thus, although no significant time effect was detected for the whole sample at six weeks and twelve months, a significant effect was detected regarding smoking status at twelve months. These results indicate that any changes in delay discounting rates, may require a longer period of abstaining from smoking (no significant decrease after six weeks, but significant effect after twelve months). Further, the decrease in discount rates among those who successfully manage to quit smoking supports the notion that delay discounting can be considered to be a reversible state that can be altered as a function of successful smoking cessation, that is the results suggest that delay discounting has the characteristics of a state, rather than a pre-existing trait variable. The authors further discusses possible factors that may affect the observed decreases in delay discounting, such as; a) that abstinence may promote activities that are healthier and may in turn affect the rate of delay discounting, such as training, dieting and so forth, and b) that abstinence in itself may reduce neural activation in impulsive brain regions and stimulate the more executive regions of the brain, that may contribute to the observed decrease in delay discounting rates among the abstainers.

Further, one study investigated whether delay discounting, distress tolerance (i.e. the ability to stay in contact with feelings that are uncomfortable) and psychological flexibility,

would show changes due to a brief acceptance based intervention (Morrison, Madden, Odum, Friedel, & Twohig, 2014). Students were initially screened for delay discounting rates, where indifference points and measures of AUC was calculated. Participants that showed a delay discounting rate below 0.4 AUC, which indicates steep discounting, were included in the study and assigned to either a training group or a wait list control group. The dependent variables were measured by the use of a delay discounting adjusting choice procedure, a ”distress tolerance scale” (measuring beliefs of felling upset or distressed) and an ”Acceptance and Action Questionnaire” (Bond et al., 2011), measuring the participants feelings of avoidance and psychologically inflexibility. The delay discounting procedure was conducted using an adjusting choice procedure, with a fixed delayed amount of $1000, and systematically adjusting the smaller sooner amount of money, ranging from $100, and down to $1, totally 27 different amounts. The delay conditions ranged from one week and up to 25 years (7 delay conditions). Three sessions were conducted at T1; assessment/baseline conditions. The control group was then dismissed and the training group went through an acceptance-based intervention lasting 60 – 90 minutes. The acceptance training was based on a cognitive treatment program and sought to increase participants willingness to experience any discomfort. One week after, at T2, all participants went through the same assessment but only those in the waitlist control group went through the intervention. At T3 (one more week after T2), the waitlist control group participants met for only assessment.

The results from this study showed a reduction in rates of delay discounting for those in the training group at T2, and in addition as well for the participants in the control group one week after they had received the training (assessed at T3). A significant decrease in distress intolerance was detected after all participants had been assessed after receiving training, and for the measures of flexibility, the data showed a trend toward significant increase in this ability. The data suggest that delay discounting rates did change after completing the brief

acceptance based intervention, and that a decrease in delay discounting was significantly correlated with increased tolerance of experiencing distress and uncomfortable feelings. Changes in psychologically flexibility were also detected.

Although this study reports limitations and some weaknesses, the results are promising in showing how interventions may alter the degree to which an individual discounts subjective value of a future reinforcer, and how these kind of psychological interventions may affect impulsivity in choice situations.

3. Neuroeconomics: Neurobehavioral correlates of delay discounting

Recent investigations in the field of neuroeconomics have focused on whether hyperbolic-like discounting of delayed outcomes, is a result of the interaction of two separate neural systems: one system specialized in valuing immediate reinforcers, and the other system specialized in the valuation of delayed reinforcers (Bickel et al., 2007; McClure et al., 2004) (see description in introduction).

a) Studies in the light of the competing systems view.

One study on cocaine dependent individuals used fMRI scan to assess functional connectivity in five regions of the neural networks of anterior cingulate cortex (ACC), aiming to identify abnormalities in those networks associated with poor self-regulation and impulse control (Camchong et al., 2011). They found that in cocaine dependent individuals, the connectivity within one area of ACC was stronger than in controls. The specific ACC network was within regions of the brain hypothesized to be involved in social processing and the ability to understand other´s thoughts as well as ones own thoughts (labeled the ability of *mentalizing*) (Camchong et al., 2011). In addition, the study revealed that the abnormalities in that specific ACC area, found in the cocaine dependent individuals, was positively correlated with increased delay discounting as well as behavioral measures of impulsivity. These assessments were based on a reversal learning task and a delay discounting task. Thus, increased delay

discounting in cocaine dependent individuals may be associated with abnormalities in neural connectivity, in frontal regions of the brain.

The question regarding differences in neurobiological processes, was focus of an inquiry conducted by Bickel, Pitcock, Yi, and Angtuaco (2009). By using both delay discounting behavioral assessments and fMRI scanning under decision taking, they investigated choice responses under three conditions involving Real money Gains, Hypothetical Money Gains, and Hypothetical Money Losses. They found no within-subject differences in discounting between equal amounts of a real and hypothetical money gain, and no significant within subject differences were found in discounting of gains and hypothetical money losses. One important finding in this study is that subjects discounted real money and hypothetical money equally, and the neural correlates of these conditions showed similarities in regions of the brain associated with discounting processes (i.e. the limbic system and the executive system).

This study shows similarities in both behavioral outcomes, and in the neural activation under various discounting conditions, such as hypothetical or real valuing of future outcomes, and of hypothetical future gains and losses. Further, no differences in neural processes regarding real vs. fictive future outcomes was detected. The authors note that from an evolutionary point of view this makes sense, since humans often have to consider future outcomes and make plans, and it would be surprising if the brain would use different neurological processes for those outcomes that occur and for those who don´t.

In one study, Meade et.al (2011) demonstrated that currently cocaine dependent individuals displayed smaller neural activation in frontoparietal brain regions compared to both recovered cocaine abusers (in remission for at least the last year prior to participation) and a control group with no history of drug/cocaine dependencies. Participants in the study were all HIV positive adults, (n=39), in all three groups. Indifference points and individual *k*-

measures were calculated based on participants' choices in a delay discounting task. Hard choices vs easy choices was detected for each participant, and presented to him or her during another delay discounting task under fMRI scan.

The findings from this study indicate that chronic cocaine use is associated with impairments in neural functioning while choosing options in a delay discounting task. Deficits were detected by smaller increases in activation in executive networks for the currently active cocaine users during easy and hard choices, which may reflect or contribute to increased impulsivity. Regarding this population, this is important due to the possibility that this increased discounting and impulsive behavior may affect HIV positive cocaine abusers to engage in further risky behavior (e.g. drug use, risky sex, no treatment adherence). However, while displaying minimal activation in prefrontal regions associated with executive functioning, the viral implications (HIV) on the neural system may be a variable in this study in that the virus may cause deficits in those brain regions. But overall, since the network involved in executive functioning requires neural activation in the fronto-parietal regions of the brain, the results from this study support the involvement of such an executive system in decision-making regarding later valued options.

A demonstration of how the executive system is involved in intertemporal choice situations, was done by cuing participants in future thinking during a delay discounting task while conducting a fMRI scan (Peters & Buchel, 2010). The researchers hypothesized that future thinking may affect intertemporal choice processes, due to the notion that such thinking and imagination may underlie the ability to value and make choices with delayed benefits. Participants underwent a delay discounting task in the fMRI scanner, and the experimenters presented cues to evoke future thinking. These cues were based on a pre-scan interview that identified real future events coming up in the individual participants life the next seven months. During the pre-scan interview, participants ranged the different events based on

relevance, valence and arousal scores from 1 to 6. The future events were then organized by the experimenters, and 7 such events at different delays for the upcoming seven months was designed individually. Specific cue-words was identified and presented for the participant during the choice tasks in the scanner (subject-specific-tags like; “vacation Paris”, “birthday John”). Delay discounting task were conducted twice for each participant, one with and one without the subject-specific tag cues presented (control condition).

The results from these two conditions revealed that participants showed significant lower rates of discounting in the episodic future thinking condition, compared to control condition. In a post interview, many participants reported that associations were evoked by the cue-words, spontaneously and automatically. The results suggests that spontaneous episodic thinking during the choice situation reduces discount rates, and that activation of brain regions in the executive system due to manipulations are correlated with decreases in discount rates. They further found increasingly activation in brain regions associated with executive functioning, during the episodic condition compared to control condition (Peters & Buchel, 2010).

MacKillop et al. (2012) reported findings from an fMRI study on delay discounting among nicotine dependent individuals, regarding different kinds of commodities. They conducted a preliminary study using fMRI scanning in order to investigate differential activation in various brain regions associated with delay discounting of two commodities, one of monetary reinforcers and the other for the addictive commodity of cigarettes. 13 nicotine-dependent participants that had no intention of any cessation attempts for the next twelve months, were assessed four times (two for each commodity) with a Monetary Choice Questionaire (MCQ) based on the work of Kirby, Petry, and Bickel (1999), simultaneously with a fMRI scan in order to measure activation in various brain regions of interest. One of the choices participants made during the delay discounting tasks, was randomly selected and

given to the participant, either at the end of the session or after a delay, based on the actual choice that was selected. This neuroeconomic approach to understand delay discounting regarding nicotine dependence, showed that reduced discounting and impulsive choices were associated with activations in brain regions associated with the executive system, in prefrontal cortex (PFC) and the anterior insular cortex (AIC). That is, activations in these brain areas was inversely correlated with impulsive choices in that lesser activation was correlated with an increase in delay discounting, and inversely, greater activation was related to a decrease in impulsivity during the choice tasks. Thus, the data acquired supports the hypothesis of a dual system competition in temporal choice situations. In addition, significant evidence was detected between the two commodities in specific brain areas of interest. That is, a general activation was detected for both commodities, but distinct networks were activated for different reinforcer type or commodity (for instance, the left hemisphere was increasingly active for cigarette rewards compared to monetary rewards, and opposite, the right hemisphere for monetary rewards) (MacKillop et al., 2012).

As an alternative to the competing dual system view, one study questions this and suggests a single system view (Kable & Glimcher, 2010). According to the authors of this study, their results from both behavioral tests and functional magnetic resonance imaging (fMRI) were inconsistent with the dual system view. Instead they suggest an alternative model of the neuroeconomics of discounting, that they labeled “ASAP” (an “As Soon As Possible” effect) were subjective value has a hyperbolic decline relative to the soonest reinforcer available. They found that a small number of brain areas involved in the valuation of both immediate and delayed outcomes, operates like a common pathway were subjective values guides choices (in contradiction with the view that two separate neural systems are involved in a trade-off between choices for immediate vs delayed outcomes.

b) Delay discounting of losses.

Whether the discounting of future losses and future gains share common neural mechanisms, was investigated by Xu et al. (2009). Subjects in this study were twenty graduate students in China. Xu and colleagues used behavioral discounting assessment in combination with fMRI scanning, searching for neural activation regarding the discounting of future losses as well as for gains. Important issues in the study were whether brain activation would be asymmetric in the discounting of gains and losses, and whether specific neural systems are involved in the valuation of immediate losses? They further sought to investigate whether the temporal discounting of losses is related to an interaction between two neural systems, similar to the view of the dual system theory regarding delay discounting of future gains. The behavioral assessment showed a significantly larger percentage of smaller/sooner choices of losses than for gains, giving reduced discounting rates for future losses compared to the discounting of future gains. This result is consistent with previous findings of a *sign effect* (Bickel & Marsch, 2001).

The neuroimaging data revealed that brain regions associated with economic decision-making, showed significant activation across all decisions regarding both losses, and gains. They demonstrated that the discounting processes of gains and losses are recognized by asymmetric neural mechanisms. The finding, according to the authors, supports the theory that separate neural systems are at work in the valuation of immediate and delayed monetary gains. In addition, the data indicated that the valuation of immediate and delayed losses also involves activation in separate neural systems, giving support for the hypothesis that such mechanisms are involved in the discounting of losses.

c) Changing discounting due to neural manipulation.

Advances in technology have made it possible to conduct experiments by directly manipulating specific brain areas of interest. Transcranial magnetic stimulation (TMS), is one

such method of using electromagnetic waves manipulating neural activities in specific brain regions (M. N. Koffarnus, D. P. Jarmolowicz, E. T. Mueller, & W. K. Bickel, 2013). Two such studies using such electromagnetic stimulation met the inclusion criteria in the present review. One of the studies used electromagnetic stimulation to the right dorsolateral prefrontal cortex (dlPFC), a region known to be involved in the executive system of future planning and valuation of delayed outcomes. Subjects were 14 young and healthy participants, and the researchers aimed to investigate the potential role of this brain region in impulsive decision-making (Cho et al., 2010). A Theta burst stimulation (TBS) was used to examine whether such stimulation led to changes in delay discounting rates. Participants conducted a delay discounting task 3 minutes after completing the TSB sessions. Participants where tested under three conditions, continuous, intermittent TBS, and one control condition. The TBS Magnetic stimulator provided burst stimulation at 50 Hz pulses– that directly inhibited the regions in dorsolateral prefrontal cortex (dlPFC). The delay discounting task, was based on the Kirby et al. (1999) computerized discounting task.

The results from this study demonstrated a significant difference in measured *k*-values after participants underwent continuous TBS compared with intermittent and control conditions, leading to the conclusion that continuous TBS-induced inhibition of the right dlPFC, reduces individual discounting. It is worth mentioning that the magnitude of this changes in discount rates was mean – 36.88 %. The direct and continuous manipulation of the activation in the dlPFC region, had an impact on the choices participants made in that they reduced impulsive choices, and increased participants choices of larger later reinforcers. This study´s findings provides insight and possible support of the competing neural system model, and in addition insight into the role of dlPFC in the executive system regarding choice and valuation processes of future outcomes at various delays.

The other study showed interesting results regarding the left prefrontal cortex (Figner et al., 2010). This study conducted 15 min sessions of 1-Hz low frequency repetitive Transcranial Magnetic Stimulations (rTMS) to the brain regions of lateral prefrontal cortex (LPFC), either the right or the left. 52 participants were designed to either a right, left or a control group, making choices between SS and LL (18 SS / LL, and 18 not-now were both SS and LL was delayed). Tasks were administered both immediately after rTMS, and again 30 minutes later. Participants in the left LPFC group, showed significantly increased preference for immediate, impulsive choices, compared to the right LPFC group and control group, immediate after rTMS disruptions of the brain region assigned for the different groups, indicating that the left lateral prefrontal cortex plays a central role in the underlying neural basis for self control processes in intertemporal choice situations.

d) Gray matter volumes.

One study examined volumes of grey matter in executive brain regions related to behavioral control and future planning, and asked whether differences in such volumes of gray matter in those areas are related to preference for immediate reinforcers (Bjork, Momenan, & Hommer, 2009). 29 healthy adults were assessed by a delay discounting task, and gray matter in fronto-cortical regions was calculated using MRI scan, controlling for age and brain volumes. The researchers tested their hypothesis that reduced volumes of gray matter in fronto-cortical regions, would correlate with the degree of delay discounting in participants. They found that greater tendencies to choose the immediate choice options (i.e. impulsivity), was correlated with smaller volumes in gray matter in two regions of the executive system (inferolateral frontal and dorsolateral frontal cortex). Thus, increased delay discounting in individuals is correlated with lesser gray matter volumes in the brain areas of the executive systems, suggesting that development in those regions may structurally impact the rates of discounting in individuals.

Discussion

In this paper, I have sought to review the latest research in the behavioral economic field of addiction and substance dependence. I wanted to identify variables affecting delay discounting in people with dependency problems, emphasizing the variables that may be associated to changes in such discounting. In addition, I have reviewed recent studies of the neural basis of delay discounting processes, in order to see how these findings may contribute to a better understanding of behavioral processes in addiction, and to discuss possible implications for treatment interventions.

This paper's sample of articles report several findings supporting that delay discounting is a relevant measure of impulsivity in addiction, as well as in other behavioral problems and disorders. The studies under review reveal several interesting findings regarding variables affecting and even altering individual discount rates. The neuroeconomic findings of neural correlates in various delay discounting studies may extend the understanding of the behavioral processes of addiction.

Addiction and delay discounting

Consistent with previous studies finding delay discounting to be related to addictive behaviors, several studies in this review report that substance dependent people discount future rewards more steeply than people with no such dependency history do. Steeper rates of delay discounting are reported among people with substance dependence and across various disorders (Bobova et al., 2009), across various substances (Businelle et al., 2010; Dierst-Davies et al., 2011), and across dependencies (i. e pathological gambling, smoking) (Businelle et al., 2010; Ledgerwood et al., 2009). A possible exception for dependency problems regarding cannabis/marijuana was detected in two studies (Heinz et al., 2013; Johnson et al., 2010), which found no significant increase in delay discounting compared to not dependent control participants. Steeper delay discounting regarding the addictive drug

compared to money, was found in the Johnson et al. (2010) study. Delay discounting is found to be related to future losses as well as for future reinforcers, as Xu et al. (2009) found a sign effect regarding greater discounting of gains than for losses. Also, greater delay discounting (i.e. impulsivity) was found to be related to structural differences regarding reduced gray matter volume in the brain regions of executive functioning (Bjork et al., 2009). The issue regarding delay discounting measures based on hypothetical vs. real monetary reinforcers, was addressed in the Bickel et al. (2009) study, finding equal discounting measures and similar neural functioning for both the two conditions. Additive effects were not found in any of the studies that compared discount rates across dependencies. That is, individual rates of discounting seems to be relatively stable on an individual level regardless of single or multiple dependencies, co-occurring smoking or gambling problems and so forth (Businelle et al., 2010; Ledgerwood et al., 2009). While we can assume, based on this information, that excessive discounting is present among a variety of dependencies, there is no evidence of a further increase in discounting due to multiple problems (co-occurring dependencies). This could indicate that elevated discounting may be a behavioral marker across various conditions involving impulsive behavior, but that there is no support of delay discounting to serve as a severity index regarding multiple, co-occurring dependencies. However, previous studies have showed increase in rates of discounting to be related to the severity of addictive behavior (i.e. quantity of drug use) (for review, see Bickel, Koffarnus, Moody, & Wilson, 2014). This matter should be focus of further inquiry.

The findings in both the Heinz et al. (2013) and the Johnson et al. (2010) studies, that cannabis or marijuana dependencies may be unlike other drug dependencies in that delay discounting seems to be of less relevance for this population than for other substances of use, calls for further research in order to confirm such differences in discounting regarding this population. However, the Johnson et al. (2010) study also showed results consistent with

other previous studies regarding how tobacco users, opioid-, and crack/cocaine – dependent individuals discount their drug at a steeper rate than with money, in that current marijuana users discounted marijuana significantly more than money. The study reviewed here from Bickel et al. (2011), also showed a greater tendency to discount the drug of addiction (cocaine) compared to money, suggesting that properties of the commodity may be an important variable that alters rates of discounting in choice situation. This finding is informed by other neuroeconomic studies. For instance, the study from MacKillop et al. (2012) revealed a distinct neural activation regarding different commodities, in addition to a general common neural activation. That is, different regions of the brain were activated in delay discounting tasks on either hypothetical money or the addictive commodity of cigarettes. This suggests both that discounting is different and greater for the addictive commodity than for other commodities, and that the discounting of the addictive commodity seems to be related to distinct and different neural activation in brain regions of interest.

Further, delay discounting correlate to the constructs of craving and demand. The findings in MacKillop et al. (2010) support the assumption that delay discounting is related to a decision-making bias toward smaller sooner reinforcers over larger later reinforcers (i.e the loss of control, not able to abstain or limit drinking when opportunities to drink are present). In addition, craving for alcohol seemed to play a role in this regard (related to discounting), and should further motivate behavioral economic studies that include the role of craving.

Finally, social context seems to affect the degree to which a person discounts future choice options and makes decisions. The results from Bickel et al. (2012) that problem drinkers did not show increased discounting compared to non-problem drinkers under social conditions, but significantly more rapidly under the individual condition, support the relevance of social situations regarding development of addictive behavior patterns. From a neuroeconomic perspective this is interesting, and neuroeconomic research may be

informative in the investigation of various differences that underlie (pathological) valuation of reinforcers. If social context does affect discounting processes, then Bickel and colleagues' study´s results should be replicated in further research on delay discounting. In order to trying to understand addictive behavior, a specifically area of interest regarding delay discounting would be the role of social context in individual´s initiation of regular substance use and abuse, and in situations regarding lapse and relapse.

State or trait – implications for treatment

Whether delay discounting should be considered a state or a trait, is an important discussion regarding the designing of prevention and treatment interventions. Clearly, if delay discounting is to be regarded a stable trait, and if such pre-disposition for impulsivity in choice situations plays an important role in development of dependency problems, then this will affect how we attribute causal explanations to addictive behaviors. Then, impulsivity is the reason for Lisa abusing drugs and getting addictive problems. On the other hand, a more state-like perspective would require a different attribution regarding causes. Delay discounting viewed as a mutable state in individuals, rather than a stable trait, may motivate research to increasingly focus the contingencies involved in decision-making (i.e. social context, the role of craving and so forth). In turn, a state like perspective, if confirmed, may affect how prevention and treatment are designed.

Several studies in this review have focused on how delay discounting may be altered as a function of treatment interventions or manipulation of the contingencies in various choice situations. All these studies reported significant changes in rates of discounting due to different variables. While two of these studies compared and found delayed discounting to be correlated with treatment outcomes and dependency status (i.e. completion of treatment and successful cessation significantly correlated with decreased rates of discounting) (Landes et al., 2012; Secades-Villa et al., 2014), others discovered changes in rates of discounting as a

function of psychological interventions (W. K. Bickel et al., 2011; Black & Rosen, 2011; Morrison et al., 2014; Peters & Buchel, 2010). These studies results are promising, and may support the notion of delay discounting to be a mutable state that can be altered by changing the conditions that influence people´s choices. The findings of variables affecting rates of discounting have implications for treatment of various dependency problems. I will highlight two such variables, and discuss them in the light of the neuroeconomic findings that have been reviewed in this paper.

Abstinence from the drug – a key variable?

Some of the studies in this review support this statement. For instance, they found an indication that abstinence affects rates of discounting in the Landes et al. (2012) study. Secades-Villa et al. (2014) found that those who abstained from smoking showed a significant decrease in delay discounting compared to those who did not manage to quit their smoking. Combined with studies showing that people with dependencies discount future reinforcers to a greater degree compared to non-dependent populations, and that people with substance dependencies display steeper discounting for the addictive drug compared to other commodities, abstinence from substances should be considered to be of great importance regarding treatment outcomes. If rate of discounting predicts the maintenance of dependency problems, then treatment indeed should focus on interventions that help people to abstain from drug taking behavior. Also, the results from Secades-Villa et al. (2014) suggests that a significant decrease in rates of discounting requires a longer period of abstinence.

Related to the notion of two competing neural systems model influencing choice situations and delay discounting, abstinence seems to be of importance. From a neurobiological perspective, the continuing supply of drugs does disturb the natural supply of dopamine in limbic regions of the brain, leading to structural and functional alterations in neural pathways (Robinson & Berridge, 2008). This perspective contributes to behavioral and

neuroeconomic findings showing differences in rates of discounting between people that are active drug users compared to those who are not. From a neuroeconomic point of view, it seems reasonable that this exposure of drugs on neural systems influence the balance between impulsive and executive functioning, and affects decision making toward biasing smaller immediate reinforcers over larger later reinforcers. Neuroeconomic findings of neural abnormalities in frontal regions of the brain (i.e. the executive system) in cocaine dependent individuals choosing between options in a delay discounting task, support the view that ongoing drug addiction has a direct effect on neural activity, and impairs cognitive control and future planning (Camchong et al., 2011; Meade et al., 2011).

In the light of the importance of managing to abstain from substance use, treatment interventions have to consider the contingencies of reinforcement, in order to help substance dependent people to such abstaining from drug use over time. One of the problems regarding delayed outcomes is in fact that they are delayed and discounted in value, and exerts minimal control over behavior in real time. How to design treatments in which abstaining from drugs could have proximate and effective reinforcer value? How to "bridge the gap" between choices of today, and the future benefits of those choices? These are important questions regarding treatment, and regarding future research. As for future research, questions regarding the role of abstinence from drugs on delay discounting should be focus of further inquiry in longitudinal and prospective studies.

Executive functioning.

According to findings in some of the studies described in this paper, regarding changing delay discounting as a function of intervention/manipulation, executive functioning such as thinking, imagination, future planning and so on plays a crucial role in the ability to value and make choices of delayed reinforcers in delay discounting tasks. The approaches described in Bickel et al. (2011), Black and Rosen (2011), Morrison et al. (2014) and Peters

and Buchel (2010) target these executive functions (i.e. working memory, acceptance based training, future planning and so forth) and describe significant effects of reducing delay discounting rates among participants that received the training/interventions. Brain regions involved in these executive functions are identified in the neuroeconomic studies described in this paper, as well as in previous research (for instance McClure et al., 2004). The findings suggest that systematic training of executive functioning should be an important issue in various treatment interventions. Derived from these findings, treatment interventions that increase activation of brain regions of prefrontal cortex involved in executive functioning predicts a decline in persons´ rates of discounting and an increase in peoples´ abilities to consider future choice options and affecting subjective value of delayed reinforcers. Treatment should include future planning, training in working memory, and increasing tolerance for discomfort; negative emotional states; distress, and so forth. Two studies showed effects on rates of discounting from manipulating specific brain regions involved in executive functioning by using electromagnetic stimulation (Cho et al., 2010; Figner et al., 2010). These studies suggest that engaging these neural connections in the areas of prefrontal cortex may lead to a decrease in the discounting of future choice options. Although electromagnetic stimulation has been effective in producing such effects, the practical use of such methods in treatment is probably far away, if ever an alternative. Still, the results in those two studies give important knowledge of how psychological interventions may target brain regions of executive functioning specifically, reducing delay discounting and impulsive choice.

Two questions regarding these effects call for further inquiry. One is whether the effects on rates of discounting will persist over time, and another is whether these effects on delay discounting predict any treatment outcomes. These are clearly important questions for further research, and prospective studies should be designed in order to monitor changes in rates of discounting over periods of time.

Conclusion

Research on delay discounting related to various substance use disorders and other dependency problems, is relevant and important in developing efficient prevention and treatment interventions. Delay discounting research could inform advances in clinical settings, and promote interventions based upon empirical findings and support. It seems clear, based on the findings in this review, that individual rates of discounting can be altered as a function of altering contingencies in people's decision-making under various conditions. Such alterations of discounting the subjective value of future reinforcers may be related to the involvement of various executive functions (i.e. future thinking, planning, activation of working memory, increased ability and willingness to experience discomfort and distress and so forth). Engagement of such functioning may predict increases in self-controlled choices (i.e. less impulsivity).

However, this review did not incorporate the role of probability discounting, only temporal discounting. Probability discounting could address issues regarding people with addictions learning history related to experiencing losses and insecurity, histories of neglect, possible abuse and insecurity in their relationship to adult caregivers during childhood and early youth and adulthood, which has not been the focus of this paper. Probability discounting could address issues regarding insecure environments, frequent losses of reinforcers and insecurity in actually receiving delayed outcomes (because caregivers could not be trusted). This may partially account for excessive discounting (i.e. a preference for immediate smaller reinforcers is a rational strategy of survival). Another issue is that of limitations in imagination and attractiveness of delayed outcomes. Are delayed and cumulative beneficial reinforcers such as improved health, security in occupation and income, stability in family relations and so on, considered to be achievable for the person? If these outcomes of abstaining from drugs are insecure, unrealistic and perhaps hard to imagine, they

also may be less credible. However, as described in the Black and Rosen (2011), higher valuation of future reinforcers may be achieved by concrete conceptualizations of future events. The intervention in this study showed that regular future planning (budget planning) did have an effect on how future choice options was valued, suggesting that judgments of probability are influenced of the description of such an event. In this study, clear and concrete repeated descriptions correlated with an increase in both the valuation and possibly the likelihood of future events.

The papers reviewed here suggest that leading treatment toward the concrete arrangement of contingencies in order to help people abstaining from drugs; implementing systematic interventions on executive functioning such as systematically review and conceptualizing future events and reinforcers/losses-outcomes of ones choices of today; systematic training in working memory and future planning, and training in distress and acceptance of uncomfortable feelings, may all be relevant directions to pursue.

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Table 1. *Empirical Studies 2009 – 2014, Included in the Review*

Year	Authors	Title	Journal
2011	Amlung & MacKillop	Delayed reward discounting and alcohol misuse: The roles of response consistency and reward magnitude	Journal of Experimental Psychopathology
2011	Bickel, Landes, Christensen, Jackson, Jones, Kurth-Nelson & Redish	Single- and cross-commodity discounting among cocaine addicts: the commodity and its temporal location determine discounting rate	Psychopharmacology
2011	Black & Rosen	A money management-based substance use treatment increases valuation of future rewards	Addictive Behaviors
2014	Morrison, Madden, Odum, Friedel & Twohig	Altering impulsive decision making with an acceptance-based procedure	Behavior Therapy
2014	Secades-Villa, Weidberg, Garcia Rodriguez, Fernandez-Hermida & Yoon	Decreased delay discounting in former cigarette smokers at one year after treatment	Addictive Behaviors
2012	Bickel, Jarmolowicz, Mueller, Franck Carrin & Gatchalian	Altruism in time: Social temporal discounting differentiates smokers from problem drinkers	Psychopharmacology
2009	Bickel, Pitcock, Yi & Angtuaco	Congruence of BOLD Response across Intertemporal Choice Conditions: Fictive and Real Money Gains and Losses	The Journal of Neuroscience
2011	Bickel, Yi, Landes, Hill & Baxter	Remember the Future: Working Memory Training Decreases Delay Discounting Among Stimulant Addicts	Biological Psychiatry
2009	Bjork, Momenan, Hommer	Delay Discounting Correlates with Proportional Lateral Frontal Cortex Volumes	Biological Psychiatry

2009	Bobova, Finn, Rickert & Lucas	Disinhibitory psychopathology and delay discounting in alcohol dependence: Personality and cognitive correlates	Experimental and Clinical Psychopharmacology
2010	Businelle, McVay, Kendzor, & Copeland	A comparison of delay discounting among smokers, substance abusers, and non-dependent controls	Drug and Alcohol Dependence
2011	Camchong, MacDonald Iii, Nelson, Bell, Mueller, Specker & Lim	Frontal Hyperconnectivity Related to Discounting and Reversal Learning in Cocaine Subjects	Biological Psychiatry
2010	Cho, Ko, Pellecchia, Van Eimeren, Cilia & Strafella	Continuous theta burst stimulation of right dorsolateral prefrontal cortex induces changes in impulsivity level	Brain Stimulation
2011	Dierst-Davies, Reback, Peck, Nuño, Kamien & Amass	Delay-discounting among homeless, out-of-treatment, substance-dependent men who have sex with men	The American Journal of Drug and Alcohol Abuse
2010	Figner, Knoch, Johnson, Krosch, Lisanby, Fehr & Weber	Lateral prefrontal cortex and self-control in intertemporal choice	Nature Neuroscience
2013	Heinz, Peters, Boden & Bonn-Miller	A comprehensive examination of delay discounting in a clinical sample of Cannabis-dependent military veterans making a self-guided quit attempt	Experimental and Clinical Psychopharmacology
2010	Johnson,Bickel, Baker, Moore, Badger & Budney	Delay discounting in current and former marijuana-dependent individuals	Experimental and Clinical Psychopharmacology
2010	Kable & Glimcher	An “As Soon As Possible” Effect in Human Intertemporal Decision Making: Behavioral Evidence and Neural Mechanisms	Journal of Neurophysiology
2012	Kerwin, Farris & Hantula	Consumer choices of women in residential drug treatment: An analysis of risk and impulsivity	Journal of Applied Social Psychology
2012	Landes, Christensen & Bickel	Delay discounting decreases in those completing treatment for opioid dependence	Experimental and Clinical Psychopharmacology

2009	Ledgerwood, Alessi, Phoenix & Petry	Behavioral assessment of impulsivity in pathological gamblers with and without substance use disorder histories versus healthy controls	Drug and Alcohol Dependence
2012	MacKillop, Amlung, Wier, David, Ray, Bickel & Sweet	The neuroeconomics of nicotine dependence: A preliminary functional magnetic resonance imaging study of delay discounting of monetary and cigarette rewards in smokers	Psychiatry Research: Neuroimaging
2010	MacKillop, Miranda, Monti, Ray, Murphy, Rohsenow, McGeary, Swift, Tidey & Gwaltney	Alcohol demand, delayed reward discounting, and craving in relation to drinking and alcohol use disorders	Journal of Abnormal Psychology
2011	Meade, Lowen, MacLean, Key & Lukas	fMRI brain activation during a delay discounting task in HIV-positive adults with and without cocaine dependence	Psychiatry Research: Neuroimaging
2010	Peters & Buchel	Episodic Future Thinking Reduces Reward Delay Discounting through an Enhancement of Prefrontal-Mediotemporal Interactions	Neuron
2009	Xu, Liang, Wang, Li & Jiang	Neural mechanism of intertemporal choice: From discounting future gains to future losses	Brain Research