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Social dynamics of substance use through minds and models

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- Maarten W. J. van den Ende performed the literature review.
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- Maarten. W. J. van den Ende handled the data, performed the analysis, and contributed to the writing.
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Non-Scientific Summary

Progress in psychological theories has slowed down in recent decades. Advancements in computing power, however, have opened avenues for novel methods to study systems representing human behaviour. In this thesis, I focus on the formalisation of psychological theories of addictive behaviours. Formalisation, meaning putting theories in structured, mathematical frameworks, could have multiple advantages; as mathematical models require clear and precise definitions, they can help clarify ambiguities in psychological constructs and theories. These formal models can be used to simulate systems more complex than before, enlightening on how small interactions or changes can result in systemwide emergent behaviour. Additionally, these models produce clear predictions which can test hypotheses and help guide future empirical data. By studying and better understanding these models, whilst showing these models are an accurate representation of what is really happening, we can gain a deeper insight into human behaviour and develop more effective interventions.

There are many challenges; however, human behavior is so complex that all theories and models can only be approximations that capture certain aspects of reality. In addition, testing and verifying these models require more extensive data the more complex the model is, quickly reaching limitations. However, a prime example of its effectiveness lies in studying larger systems where simple individual models interact with one another, leading to emergent behaviors at the system level that are often easier to validate. Therefore, addictive behaviors within the context of social interactions presents a promising avenue for exploration.

The initial step in conducting research is to thoroughly understand what has already been accomplished in the field. As I began my PhD, I undertook a literature review focusing on substance use and its interactions with the social environment. In addition to contemporary theories, I concentrated mainly on existing formal, mathematical models, which could serve as valuable starting points for my work and inform about different approaches people have taken. With no background in psychology, this review was a lengthy but enlightening process; I previously underestimated the ambiguity of verbal theories and the challenges of verifying them, which create a space for discussion in psychology.

The literature review showed that behavior can be approached from the smallest scale upward, for example, by simulating dopamine release and focusing on reinforcement learning in the limbic system. Alternatively, one could explore the extensive field of behavioral economics, with its emphasis on rationality and decision-making, and adapt its concepts to account for the seemingly irrational, self-destructive behaviors associated with addiction. On a broader scale, some psychological theories adopt a phenomenological approach. Instead of delving into the underlying processes, these theories abstract the

brain's functions and focus on the interactions among different phenomena and how these interactions shape behavior.

In addition to psychological theories, I looked at how the fields of sociology and complexity science approach the social environment's effects. This perspective shifts the focus from individual internal processes to the interactions between many individuals within a larger system. However, I found a significant gap: these fields often lack cohesion. Psychological models, while providing accurate descriptions of specific aspects of substance use, tend not to account for the impact of the social environment. Conversely, social models are frequently disconnected from psychological theoretical foundations. This disconnect led me to conclude that no existing model successfully integrates both a psychologically sound internal model and dynamic effects of the social environment.

With the goal of developing a robust simulation framework, the next chapter discusses the software package *DyNSimF*, designed to integrate and simulate internal psychological models alongside a dynamic social environment. By conceptualizing each individual as a node within a network that can both give and receive information from its connected peers, these internal models can tap into their local social contexts and adapt their behaviors accordingly. As each node embodies its distinct model, the actions of one node can influence others, thereby generating a complex web of interactions among individuals and their environments. This approach allows for the simulation of a dynamic social environment simply by defining the underlying psychological model. The chapter discusses how the software works; requiring a set of equations for the internal models that account for information from neighboring nodes, as well as potentially incorporating rules governing changes in the network structure.

The next chapter explores to what extent one's social environment affects individuals' drinking behaviour. Here I make the basic assumption that individuals are more likely to copy their drinking behaviour to their local social connections.

Therefore I developed a model that classifies individuals into three categories: abstainers, moderate drinkers, and heavy drinkers. Then, the probability of an individual changing their drinking category is influenced by the proportion of individuals in their local social environment who belong to a different category. Additionally, I incorporated a term representing external influences on drinking behavior not captured by social dynamics alone; unlike the transmission of a virus, where contact with an infected individual is essential, people can adjust their drinking habits without direct interaction. Using *DyNSimF*, I simulate many individuals, which are all connected to other individuals, and then depending on their proportion of each category, each timestep they may or may not change their drinking behaviour. Then, at the next timestep, her connections have different proportions, and as a result she also influences her social connections' behavior.

However, without some data to validate the model, it is impossible to determine whether it accurately represents the real world, and thus impossible to study the model or infer anything about how the real world might work. Especially for a model that abstractises the system so much, we need data to see whether we can study the system. After an extensive search, the Framingham Heart Study dataset was found containing data over time of individuals' drinking behaviour, and uniquely, it also contained social connections with other individuals within the town of Framingham of which many were

also involved in the dataset. This meant that I could investigate individuals drinking over time as well as their social connections' drinking behaviour, and see whether the model is able to represent what is happening in the data. And if so, the calibrated parameters of the model can tell a lot about our way of approaching the interactions of social dynamics and drinking behaviour. First of all, I found that classifying drinking into three classes is better than two, while categorizing in four classes does not add much. In addition, a stability analysis shows that the cutoff for number of drinks per week (based on health impact) matches the cutoff observed from the behaviour of individuals. Second, it became clear from the data that heavy drinkers as well as abstainers cluster together significantly. Most importantly, I found that both abstainers as well as heavy drinkers have a significant effect to make others copy that drinking. In addition, for each additional abstaining connection, the likelihood of a heavy drinker to manage quitting increases with 50%.

After obtaining and thoroughly processing this unique dataset—including wrangling, aligning, and other necessary preparations from the previous chapter, I knew the data could be interesting for analyses wider than just the primary objectives of the PhD research. The richness of the data allowed for fully data-driven analyses that could offer valuable insights into the dynamics of individual behavior and their social environments. Thus, in the following chapter, I apply novel psychometric network models on this temporal data.

The results consist of three main interaction-networks which demonstrate how an individual's job status, cigarette use, and drinking habits interrelate with one another, as well as with the number of connections that are either abstinent or heavy drinkers. For example: the first result gives information such as: 'when an individual over a certain period of time drinks more, they also tend to smoke more'. The second reveals effects across a population, such as: 'individuals with higher job status generally smoke less'. The last one is extra interesting, as it gives temporal effects such as: 'individuals who increase their smoking over time, have reduced total social connections over time as well'.

Many of these findings align with and corroborate on established knowledge, however, particularly for the older population represented in my dataset, these results were not widely covered in literature. For instance, the co-occurrence of smoking and drinking is confirmed, along with the observation that individuals with higher socioeconomic status (SES) typically consume more alcohol, even though they engage less frequently in binge drinking. Additionally, new insights emerged: not only does an individual's drinking behavior influence their social surroundings, but even for these older individuals, people adjust their social connections to better align with their drinking habits.

The last chapter is the result of brainstorms and collaborations that started in the first initial of my PhD, and is something over time I have over time become more and more invested in. As the review revealed no psychological, theory-based model was found which was able to incorporate the social environment, we set out to develop our own. The goals here were to develop a general model, that could explain different addictive behaviours only needing to adapt certain parameters, and able to explain certain key phenomena observed such as incentive sensitization (the heightened motivational response to a substance following repeated exposure), tolerance (requiring more of a

substance to achieve the same effect), relapse and recovery, peer pressure, and community forming among users. All these notions combined in a model makes it already the most extensive one; however, additionally, the model is able to incorporate interactions with a social environment- something which I have shown previously this cannot be ignored.

This model takes the main idea of dual-process as a start, imagining an individuals decision making to result from two main systems; appetitive motivation, which reflects impulsive behaviors driven by immediate rewards, and a controlling system, which embodies the part of the brain that keeps in mind long term goals and risks. Consumption increases the appetitive motivation, both in short term (drinking one beer makes you feel like having more) as in long term (sensitization), affected by type of drug as well as individual factors such as genetic vulnerabilities. Motivation to control consumption can kick in immediately, or allow for some consumption before it ramps up (only after the third drink tomorrow will be impacted). This control has a maximum though, different for each individual. This is one of the areas where the social environment can have an impact; surrounded by abstainers, this control is increased. Similarly, there are physical limitations to actually obtaining a substance, for example hard drugs are easier to come by when in a social environment with other users.

With this model, we first show that we can explain the initial phenomena. Uniquely, we show how behaviour of abstainers, 'healthy', moderate users as well as the slow descent into addiction emerges from the model, by simply adjusting the parameter values representing the social environment, individual factors and the type of drug. We then show how in a social network, our model predicts hard to obtain drug users to cluster together, and how some drugs such as alcohol and cocaine are often co-occurring, whilst vaping might replace cigarette use. My co-author Jesse is continuing on the model, and I sincerely hope more researchers will take this framework and will contribute and build on top of it.

Coming back to the goal layed out in the beginning, with this model, a foundational step toward a formalized, mathematical description of substance use and its interactions with the social environment has been made. While this model would require more extensive data than is yet available to calibrate, this model already establishes mathematical relationships among constructs such as sensitization, tolerance, the addictiveness of various drugs, and the influence of the social environment on these factors. It can facilitate the generation of testable hypotheses, which, once validated, can refine the model further, eventually leading to a better understanding of substance abuse and thus contribute to better, more effective strategies for its reduction and management.

Niet-Wetenschappelijke Samenvatting

In de afgelopen decennia is de vooruitgang in de ontwikkeling van psychologische theorieën wat aan het vertragen. Gelukkig heeft de snelle ontwikkeling van computationele rekenkracht nieuwe mogelijkheden geopend om systemen die menselijk gedrag presenteren te bestuderen. In dit proefschrift richt ik me op de formalisatie van psychologische theorieën over verslavingsgedrag. Formalisering, wat betekent dat theorieën in gestructureerde en wiskundige kaders worden geplaatst, kan meerdere voordelen bieden. Door theorieën in gestructureerde, wiskundige kaders te plaatsen, kunnen we ambiguïteiten in psychologische concepten en theorieën verduidelijken. Deze modellen maken het mogelijk complexere systemen te simuleren en geven inzicht in hoe kleine interacties kunnen leiden tot emergent gedrag binnen een systeem. Daarnaast produceren deze modellen heldere voorspellingen die hypothesen kunnen testen en richting aan toekomstig empirisch onderzoek kunnen geven. Door het bestuderen en beter begrijpen van deze modellen, aangetoond dat deze modellen een nauwkeurige weerspiegeling zijn van wat in werkelijkheid gebeurt, kunnen we een dieper inzicht in menselijk gedrag verkrijgen en effectievere interventies ontwikkelen.

Er zijn echter ook uitdagingen; menselijk gedrag is zo complex dat alle theorieën en modellen slechts benaderingen kunnen zijn die bepaalde aspecten van de werkelijkheid vangen. Bovendien vergt het testen en verifiëren van deze modellen steeds meer uitgebreide data, wat vaak een limiterende factor is. Een goed voorbeeld waar deze methode veel potentie heeft, ligt in het bestuderen van grotere systemen waarin eenvoudige individuele onderdelen met elkaar interacteren, wat leidt tot emergente gedragingen op systeemniveau die vaak gemakkelijker te valideren zijn. Daarom biedt het bestuderen van verslavend gedrag in de context van sociale interacties een veelbelovend onderzoeksgebied.

De eerste stap in het doen van onderzoek is om ervoor te zorgen dat je goed begrijpt wat er al bereikt is in het veld. Aan het begin van mijn PhD heb ik een literatuurstudie gedaan met als focus verslavend gedrag en de interacties hiermee met de sociale omgeving. Naast hedendaagse theorieën richtte ik me voornamelijk op bestaande formele, wiskundige modellen, die als waardevolle uitgangspunten voor mijn eigen werk konden dienen en informatie gaven over verschillende benaderingen van mensen in het veld. Zonder een achtergrond in de psychologie was deze revisie een lange maar leerzame ervaring; ik had de onduidelijkheid van verbale theorieën en de uitdagingen om ze te verifiëren onderschat, wat ruimte geeft voor discussies en onduidelijkheden.

De literatuurstudie toonde aan dat gedrag vanuit verschillende kanten kan worden benaderd, bijvoorbeeld door dopaminevrijgave te simuleren of zich te richten op reinforcement learning van het limbisch systeem. Een andere manier is om de uitgebreide kennis in behavioral economics toe te passen, met een nadruk op rationaliteit en besluitvorming, en deze concepten aan te passen om rekening te houden met het schijnbaar irrationeel,

zelfvernietigende gedrag dat gepaard gaat met verslaving. Op een bredere schaal nemen sommige psychologische theorieën een fenomenologische benadering aan. In plaats van de onderliggende processen te bestuderen, abstracteren deze theorieën hersenfuncties en richten ze zich op interacties tussen verschillende fenomenen en hoe deze interacties gedrag vormen. Buiten psychologie keek ik ook naar onderzoek van sociologie en complexity science. Deze verschuiven de focus van interne processen van individuen naar interacties tussen veel individuen binnen een groter systeem. Ik vond een significante kloof tussen deze velden: psychologische modellen, die accurate beschrijvingen geven van specifieke aspecten van verslavend gedrag, rekenen vaak niet mee met de effecten van de sociale omgeving, en tegelijkertijd gebruiken sociale modellen meestal geen psychologische kennis of theoriën. Daarmee kwam ik tot de conclusie dat er nog geen model bestaat dat succesvol zowel een psychologisch theoretisch intern model als de dynamische effecten van de sociale omgeving integreert.

Met het doel om een robuuste simulatieframework te ontwikkelen, bespreek ik in het volgende hoofdstuk het softwarepakket *DyNSimF*, ontworpen om interne psychologische modellen te integreren en te simuleren in een dynamische sociale omgeving. Door elk individu als een knooppunt binnen een netwerk te conceptualiseren dat zowel informatie kan verstrekken aan als ontvangen van verbonden individuen, kunnen deze interne modellen de lokale sociale omgeving opnemen en hun gedrag hieraan aanpassen. Omdat elk knooppunt zijn eigen model vertegenwoordigt, beïnvloeden de acties van elk knooppunt dat van de anderen, wat leidt tot een complex web van interacties tussen individuen en hun omgevingen. Deze benadering laat toe om een dynamische sociale omgeving te simuleren door alleen maar de onderliggende psychologische modellen te definiëren. Het hoofdstuk bespreekt hoe het softwarepakket werkt, waarbij een set vergelijkingen voor interne modellen vereist zijn die rekening houden met informatie van naburige knooppunten, eventueel met extra regels voor veranderingen in de structuur van het netwerk.

Het volgende hoofdstuk onderzoekt in hoeverre de sociale omgeving drankgedrag beïnvloed. Hier ga ik uit van de basisveronderstelling dat individuen hun drankgedrag aanpassen om meer overeen te komen met dat van hun lokale sociale verbindingen. Om dit te doen heb ik een model ontwikkeld dat individuen in drie categorieën indeelt: niet-drinkers, matige drinkers en zware drinkers. In het model wordt de kans dat een individu zijn drankcategorie verandert beïnvloed door het percentage van individuen in hun lokale sociale omgeving die tot een andere categorie behoort. Daarnaast is er een term toegevoegd die externe invloeden op het drankgedrag beschrijft, omdat gedragveranderingen niet altijd worden veroorzaakt door sociale interacties alleen. Met *DyNSimF* simuleerde ik vele individuen die allemaal met andere individuen verbonden zijn en op basis van de verhoudingen van elke categorie, kan iedereen elke tijdsstap zijn drankgedrag veranderen. Hierop hebben hun connecties andere verhoudingen in de volgende tijdsstap en als gevolg daarvan beïnvloeden iedereen elkaars gedrag.

Helaas is het zonder gegevens om het model te valideren onmogelijk om vast te stellen of het een accuraat beeld geeft van de werkelijkheid, en dus onmogelijk om het model te bestuderen en er conclusies uit trekken over hoe de werkelijkheid werkt. Met name voor een model dat het systeem in zulke mate abstracteert, zijn er gegevens nodig om na te gaan of dit mogelijk is. Na uitgebreid zoekwerk vonden we de Framingham Hart Study-dataset. Hierin zit onder meer data van drankgebruik van individuen over een periode

van 30 jaar. En uniek in deze dataset, is dat het ook sociale verbindingen met andere individuen binnen de stad van Framingham bevat. Veel van deze andere individuen waren ook betrokken in de studie, en dus is hun drankgebruik ook bekend. Dit betekent dat ik kon onderzoeken hoe zowel individuen als hun sociale verbindingen drinken over een lange tijd, en dus is het mogelijk te checken of het model kan nabootsen wat er gebeurt in de gegevens. En indien zo, kunnen de gecalibreerde parameters van het model veel vertellen over onze benadering van de interacties van sociale dynamiek en drankgedrag. Allereerst lieten de resultaten zien dat indelen van drinkgedrag in drie klassen beter is dan in twee, terwijl het categoriseren in vier klassen niet veel extra waarde toevoegt. Bovendien toonde een stabiliteitsanalyse aan dat de cut-off voor aantal drankjes per week gebaseerd op gezondheidseffect overeenkomt met wat ik zag in het gedrag van individuen. Ook bleek duidelijk uit de data dat zowel zware drinkers als niet-drinkers significant naar elkaar toe trekken, en in clusters bij elkaar verbonden zijn. Belangrijkst van alles, ontdekte ik dat zowel niet-drinkers als zware drinkers een significante invloed hebben om anderen te beïnvloeden dat drankgedrag over te nemen. Bovendien neemt de kans dat het een zware drinker lukt te stoppen met drinken toeneemt met 50% voor elk niet-drinkende sociaal contact.

Na het verkrijgen en grondig verwerken van dit unieke dataset, inclusief het verwerken, uitlijnen en andere nodige voorbereidende stappen die ik gedaan had voor het vorige hoofdstuk, wist ik dat de data interessant zou zijn voor andere analyses dan alleen voor de primaire doelstellingen van mijn PhD-onderzoek. De rijkdom van de data maakt volledige data-gedreven analyse mogelijk die inzichten kunnen bieden over de dynamiek van individueel gedrag en hun sociale omgevingen. In het volgende hoofdstuk voer ik nieuwe psychometrische netwerkmodellen toe op deze data.

De resultaten bestaan uit drie interactienetwerken, die aantonen hoe een individu's baanstatus, roken en drankgewoontes met elkaar en met het aantal sociale connecties dat abstinente of zwaar drinker is in verhouding staan. Het eerste netwerk biedt informatie zoals: 'wanneer een persoon over een bepaalde periode meer drinkt dan normaal, dan rookt hij ook vaker'. Het tweede toont effecten over de gehele populatie, zoals: 'individuen met een hogere baanstatus roken meestal minder'. Het laatste is extra interessant omdat het tijdelijke effecten bekijkt, zoals: 'individuen die over de tijd meer roken hebben over de tijd een minder totale sociale verbindingen'. Veel van deze bevindingen komen overeen met en bevestigen bestaande kennis, maar met name voor de oudere bevolking die in mijn dataset vertegenwoordigd is, zijn deze resultaten nog niet breed beschreven in de literatuur. Bijvoorbeeld: het samen gaan van roken en drinken wordt bevestigd, net als het feit dat individuen met een hoger sociaal economisch status (SES) vaak meer alcohol consumeren maar minder binge drinken. Daarnaast kwamen nieuwe inzichten naar voren: niet alleen beïnvloedt het drankgedrag van een individu het drankgedrag van zijn sociale omgeving, maar ook voor deze oudere individuen passen mensen hun sociale verbindingen aan door hun nieuwe sociale connecties beter overeen te laten komen met hun eigen drankgewoontes.

Het laatste hoofdstuk is het resultaat van brainstormen en samenwerkingen die begonnen zijn in de eerste fase van mijn PhD, en is een model waar ik steeds meer geïnteresseerd in geraakt ben. Omdat ik in de review geen psychologisch gebaseerd model dat de sociale omgeving ook kon integreren vond, besloten we om ons eigen model te ontwikkelen. De doelstellingen hier waren om een algemeen model te ontwikkelen,

dat verschillend verslavingsgedrag kan verklaren door allen maar de parameters aan te passen, en dat in staat is om bepaalde belangrijke fenomenen te verklaren zoals incentive sensitization (de verhoogde motivatieve respons op een stof na herhaaldelijk blootstelling), tolerantie (meer van een stof nodig hebben om hetzelfde effect te krijgen), terugval en herstel, peer pressure en gemeenschapvorming onder gebruikers. Al deze concepten gecombineerd maken het al het meest uitgebreide model dat bestaat; bovendien is het model in staat om interacties met een sociale omgeving op te nemen, wat iets is dat ik eerder hebt getoond dat niet genegeerd kan worden.

Dit model begint met de hoofdgedachte van een dual-process, met het idee dat het besluitvormingsproces van een individu het resultaat is van twee abstracte hoofdsystemen: appetitive motivatie, die impulsief gedrag reflecteert, gedreven door onmiddellijke beloning, en een controle systeem, wat de hersengedeeltes vertegenwoordigt die langetermijn doelen en risico's in gedachten houden. Consumptie verhoogt de appetitive motivatie, zowel op korte termijn (drinken van een biertje geeft dorst naar meer) als lange termijn (sensitization), beïnvloed door het type drug en individuele factoren zoals genetische kwetsbaarheden. Motivatie om consumptie te controleren kan onmiddellijk inzetten, of enige consumptie toestaan voordat het begint (pas na het derde drankje zal ik morgen echt spijt hebben). Deze controle heeft echter een maximum, verschillend per individu. Dit is een van de gebieden waar de sociale omgeving invloed kan uitoefenen; omgeven door niet-drinkers wordt de invloed van het controle systeem verhoogd. Op soortgelijke wijze zijn er fysieke beperkingen aan het daadwerkelijk verkrijgen van een drug: zware drugs zijn gemakkelijker te verkrijgen in een sociale omgeving met andere gebruikers. Met dit model tonen we eerst aan dat we de oorspronkelijke fenomenen kunnen verklaren. Uniek is het om te laten zien hoe het verloop van niet-drinkers, 'gezonde' gematigde gebruikers, en hoe de geleidelijke daling naar verslaving uit het model voortkomt en verschilt bij verschillende substanties en sociale omgevingen. We tonen vervolgens aan hoe in een sociaal netwerk ons model voorspelt dat gebruikers van zware drugs vaak bij elkaar clusteren en hoe bepaalde drugs zoals alcohol en cocaïne vaak samen voorkomen, terwijl vaperen misschien de sigaretten gebruik zou kunnen vervangen (of alleen maar meer maken). Mijn co-auteur Jesse zet het werk aan het model voort, en ik hoop heel erg dat meer onderzoekers dit framework zullen gebruiken en erop verder gaan bouwen.

Terugkerend naar het doel gesteld aan het begin, is met dit model een fundamentele stap gemaakt richting een formele, wiskundige beschrijving van verslavend gedrag en hun interacties met de sociale omgeving. Hoewel dit model meer uitgebreide data nodig zou hebben dan nu beschikbaar is om het te verifiëren, heeft het wel al wiskundige relaties tot stand gebracht tussen constructen zoals sensitization, tolerantie, de verslavingsgevoeligheid op verschillende stoffen en de invloed van de sociale omgeving op deze factoren. Ook kan het het testbare hypothesen genereren, die, eenmaal gevalideerd, kunnen bijdragen aan verfijning van het model, en daarmee uiteindelijk tot een beter begrip van verslavend gedrag en daardoor bijdragen aan effectievere strategieën voor vermindering en management.

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Karoline, I still remember the day in summer, when the lockdowns were on break, when I saw you sitting by yourself in an office in the basement, and I decided for us that it was time for me to join you. Little did we know that this would result in a long and close friendship. Over the years your presence, sense of humor and likemindedness greatly contributed to my enjoyment being at work, and I so so enjoyed having you join me on the crazy projects we did together. Having you on my side made all the difference during the tougher times of the project, and I do already kind of look back happily at our happy anxious time driving towards, and driving back exhausted and dangerously a certain far away place.

Het is lastig iemand te vinden die me zo goed begrijpt en aanvoelt als jij Ria, en ik vind het zo fijn dat we zulk goede vrienden zijn geworden. Het is zo leuk mee te mogen maken wat het leven naar jou toe gooit en hoe goed je ermee om gaat, en ik ben blij dat je zo veel met me deelt en dat je me cool genoeg vind om mee om te gaan.

Jill, ik wil je bedanken voor je geduld voor de keren dat even langskwam, altijd precies net als jij lekker je flow had gevonden, al ik weet dat je t stiekem vooral heel gezellig vond. Ik zweer dat je me van de dood gered hebt in Turkije en je bent de enige die zonder moeite ook mij even lekker op mn plaats kan zetten. We hebben heerlijk gelachen over de jaren en ik ben heel blij dat ik heb mogen leren kennen hoe jouw brein eigenlijk echt werkt.

Ik had nou nooit gedacht dat, nu ik binnen heb mogen treden in jouw wereld, Michelle, dat dat zulk gezellig, warm en blije wereld is. Ik heb heel erg genoten van onze gesprekjes in het Nederlands, en hoop nog vaak curly fries met je eten!

Julius, its kind of crazy we became friends seeing each other like once a month for two days, but sometimes thats just what happens when you match so well, the level at which we can chat and laugh is unmatched, and you quickly turned into a very valuable friend.

In het laatste jaar heb ik heel fijn en productief samengewerkt met je, Jesse, en ik ben heel blij dat je verder gaat waar mijn werk stopt, ik heb er volle vertrouwen in dat je heel vette volgende stappen gaat maken!

Frantisek, its been amazing to see you develop as a human, you have a great sense of humor and I've loved seeing you further your life. You will never be able to beat me in pullups though.

René, collaborating with you has been a lot of fun, and we've had an amazing time in Singapore and Bali together, wish we could do it again.

Alessandra and Ting, thank you for making an exception for me by allowing me to drop by the office at all times for some support, interesting chats, or even nail or hair makeovers.

Maarten, we hebben ons door de jaren heen ontwikkeld tot de meest stabiele en zekere vriendschap die ik heb, het is geweldig te zien hoe je je hebt ontpopt als vader en

daarmee zet je een prachtig voorbeeld voor me. Het is heel fijn te weten dat we altijd op elkaar aan kunnen, nu en in de toekomst. Elmer, ookal ben je nu op verre afstand, als we elkaar weer zien is het altijd meteen zoals t vroeger ook was. Aron, we zijn samen begonnen aan het PhD avontuur, en het is leuk te zien hoe onze wegen nu verder gaan, kom maar snel terug naar Nederland hoor. Guy, halfway through you were pivotal in an important decision, and I thank you for that!

Ik wil de boys en t meisje uit Limburg bedanken, het is uniek hoe we zo'n goede vriendengroep zijn gebleven en ik ben heel dankbaar dat jullie me, ondanks dat ik wat vaker afwezig ben, het gevoel geven er nog helemaal bij te horen.

Iris, ik wil je van harte bedanken dat je het hebt aangedurfd de prachtige illustraties voor mijn boek te maken. Nu ik deze woorden schrijf, zijn de meeste illustraties net binnengekomen, en ik kan je niet genoeg zeggen hoe blij ik ermee ben. Je creativiteit brengt mijn boekje echt tot leven, en ik kan niet wachten de geprinte versie te zien!

Ik ben zo blij dat ik nadat ik de inhoudelijke versie ingeleverd had besloten heb om toch maar een nieuwe hobby te beginnen en daarmee jou heb ontmoet, lieve Gina. Ik ben dankbaar voor je support in de laatste fases van het tot stand brengen van het boekje en de voorbereiding op de verdediging. Ik heb het zo gezellig met je en je voelt me zo goed aan, en ik ben ontzettend blij jou nu aan mijn zij te hebben.

Ik wil ook graag mijn ouders, zussen en broertje bedanken voor de onconditionele liefde en support gedurende mijn PhD maar ook daarvoor, jullie hebben me met zo'n goede, gesteunde en sterke basis het volwassen leven in geholpen, dat deze PhD ook een beetje van jullie is.

