Now is the time for reward! The developmental relationship between cognitive-motivational factors and adolescent substance use
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CHAPTER 1

GENERAL INTRODUCTION
1.1 Adolescents and Substance Use

There is no shortage of scientific, governmental or media attention for the issue of substance use among adolescents. The reason for this attention is a well-documented history of substance use among adolescents that is risky, harmful, deteriorates future health and career prospects and is associated with later addictive behaviors (Fergusson, Lysnkey, & Horwood, 1994; Pedersen & Skrondal, 1998). Adolescence appears to form a crucial and vulnerable developmental period marked by an increased tendency to engage in risky behavior. Relatively recently proposed theories state that neurocognitive aspects of the adolescent developmental period cause this increased tendency (Gladwin, Figner, Crone, & Wiers, 2011; Steinberg, 2008). Specifically, delays in the maturation of cognitive control compared to the development of motivational systems would create a situation where adolescents are less likely to inhibit risky actions. In the realm of substance abuse there are a number of theories suggesting that individuals have increased susceptibility to addictive behaviors during adolescence. However, there remain many gaps in our knowledge about interaction between cognitive factors, such as reward-response behavior, and environmental factors, such as parenting styles, and their joint development during adolescence. This dissertation intends to highlight and address some of these gaps by presenting empirical results from a longitudinal online sample of Dutch early adolescents.

The Netherlands has in the past been identified as one of the highest scoring countries in adolescent use of alcohol (Hibell et al., 2004; Van Dorselaer et al., 2013). In recent years, this ranking has changed, with the prevalence of alcohol use among 12-year-olds falling from 71% in 2003, to 17% in 2013 (Van Dorselaer et al., 2013). This contrast is less extreme among 16-year-olds, with prevalence of alcohol use having fallen from 90% in 2003 to 79% in 2013. This indicates that a majority of adolescents still experience onset of alcohol use during early adolescence. Those Dutch adolescents that drink are also very prone to binge drinking (or heavy episodic drinking, defined as drinking 5 or more drinks on one occasion as a girl, or 6 or more drinks as a boy, see Wiers, Hoogeveen, Sergeant, & Gunning, 1997), with 80% of drinking 16-year-olds indicating at least one binge during the past month. Unlike in many other nations, onset of alcohol in the Netherlands occurs at roughly the same age for both boys and girls.

Similar to alcohol use, the prevalence of cigarette smoking has decreased, with 22 percent of adolescents aged 12-16 indicating cigarette smoking in 2013, compared to 46 percent in 2011. Furthermore, cannabis use in the Netherlands has dropped strongly. Eight
percent of adolescents aged 12-16 reported marijuana use in the past year in 2013, compared to 14 percent reporting marijuana use in 2001 (Van Dorsselaer et al., 2013). Despite these reductions in prevalence of adolescent substance use, it remains clear that excessive and harmful substance use still occurs in the Netherlands. Among psychologists, it is considered important to unravel the possible factors and interactions contributing to the perseverance of excessive substance use among adolescents.

Recent efforts to curtail adolescent use of alcohol in the Netherlands have focused on encouraging parental alcohol-specific rules, and increasing the minimum legal age (Koning et al., 2009). First, strict parental alcohol-specific rules were encouraged after research on Dutch adolescents revealed that application of strict rules about alcohol use strongly predicted the development of adolescent alcohol use (Van Der Vorst, Engels, Deković, Meeus, & Vermulst, 2007). Before the encouragement of stricter norms was instituted nationwide, Dutch parents often believed strict parental rules were ineffective at preventing alcohol use. Following years of campaigning from health organizations, results from the 2009 Health Behaviors in School-aged Children (HBSC) survey showed that in a sample of 7000 adolescents and their parents, Dutch parents became much stricter in applying alcohol-specific rules (Van Dorsselaer et al., 2009). Meanwhile, an experimental study had demonstrated that teaching parents to set more strict rules concerning their young adolescents’ alcohol use was effective when combined with a universal prevention (the healthy school and substances) that in itself was not effective in preventing escalation of alcohol use in adolescence (Koning et al., 2009). This general rise of parental strictness about alcohol was associated with an increase in the average age of onset of alcohol use in this sample. However, as described previously, those who do engage in alcohol use still frequently do so excessively. It remains unexplored whether consequences of parental rule changes are specific to certain individuals or whether all Dutch adolescents are helped equally by the introduction of this policy. Second, as of the year 2014, the legal minimum age for alcohol consumption in the Netherlands was raised from 16 years to 18 years. Increasing the minimum legal age for alcohol consumption had previously proven effective in reducing alcohol use among adolescents in the United States (O’Malley & Wagenaar, 1991).

Substance use data from the Netherlands indicate that knowledge of environmental and cognitive factors related to substance use may result in strategies to prevent early adolescent substance use. Furthermore, the discussed intervention research offers insights into developmental pathways potentially leading to excessive substance use as an outcome. Nevertheless, substance use in turn may also influence these developmental pathways. This
dissertation aims to address gaps in the knowledge on the joint development of these factors. The remainder of this chapter will discuss major theories of adolescent development and substance use, the utilization of this knowledge and the current issues that remain unaddressed. Chapter 2 will provide the details of the longitudinal internet-based survey used to gather empirical data to answer these questions, while Chapters 3-7 will report empirical results pertaining to specific research questions. Chapter 8 will recap these findings and place them in the context of ongoing research, provide suggestions and recommendations for future research both from the perspective of conducting longitudinal internet-based research and from specific research results. Finally, we discuss potential implications for interventions and preventive efforts.

1.2 Theories of Risk-Associated Adolescent Development

1.2.1 Neurocognitive Development

Many people regard adolescence as a tumultuous age range where individuals perform many risky behaviors with a number of potentially harmful outcomes. While it is true that adolescents take far more risks on average than adults, scientists have also pointed out that a large number of adolescents experience adolescence without significant harmful outcome (Steinberg & Morris, 2001). Further, among adolescents whose harmful behavior does result in continuing harmful outcome, there are not always clear indications that the behavior originated purely in adolescence as a consequence of adolescence or a manifestation of a trait originating before adolescence (Moffitt, 1993). Nevertheless, scientific evidence has indicated that adolescence is a critical period of growth that is accompanied by vulnerabilities. These vulnerabilities are presumably related to brain changes that increase risk of later disorders (Bardone, Moffitt, Caspi, Dickson, & Silva, 1996), including addiction (Chambers, Taylor, & Potenza, 2003).

Research on brain development during adolescence has focused on the relatively late maturation of cognitive control, compared to social affective and reward related brain systems. Scientists have demonstrated that while subcortical brain regions relevant to cognitive processes related to reward sensitivity and motivation mature around early adolescence (Galvan et al., 2006; Gladwin et al., 2011; Van Leijenhorst et al., 2010), cortical brain regions supporting cognitive control mature later, towards young adulthood (Crone & Ridderinkhof, 2011; Gladwin et al., 2011). These changes are associated with a temporary increase in sensitivity to reward possibly underlying the increased propensity for risk behavior (Steinberg
et al., 2008). These neurocognitive developments highlight why adolescence is a crucial period when examining the development of addictive behaviors.

Adolescence is also a period in which specific executive functions continue to develop. The nature of executive functions, like those of many other cognitive and personality features typically described, is multifaceted. Researchers have distinguished between several aspects that together function to allow the individual to excel at tasks that require concerted effort over an extended period of time in tasks of higher cognitive demand. Such functions include working memory and response inhibition. Working memory is viewed as a general limitation on an individual’s capacity to process information (Engle, 2002). The processing of active information includes the ability to manipulate this information, protect it from interference against other irrelevant information, flexibly switching between tasks employing that information and maintaining attention on that information. Related to this, response inhibition refers to the capacity to inhibit motor responses that become inappropriate or incorrect. Lack of executive functions and the resultant lack of cognitive control have been shown to predict risk behavior such as increased alcohol use (See for reviews: De Wit, 2009; Peeters, Vollebergh, Wiers, & Field, 2014; Verdejo-García, Lawrence, & Clark, 2008).

1.2.2 Personality

Personality differences in adolescence have been identified as a key person-centered factor in the prediction of risk taking behavior. A number of personality profiles have been identified as risk-associated, most prominently those relating to impulsivity and sensation seeking (Woicik, Stewart, Pihl, & Conrod, 2009). Impulsivity refers to the tendency to act without thinking, and is characterized by the inability to inhibit automatic responses. Sensation seeking is defined as the desire to explore and experience new and intense stimuli, and is characterized by reward sensitivity. In general, impulsivity has been regarded as a consistent and strong predictor of engaging in risk behavior (Evenden, 1999), however, as previously mentioned, the context in which risky behavior is performed matters greatly to adolescents regardless of their level of motor impulsivity. While many aspects of impulsivity are interrelated to various degrees, distinctions in aspects of impulsivity are greatly relevant to explaining adolescent behavior. This is because adolescent behavior is typically characterized by an increased sensitivity to reward. Indeed, research on longitudinal trajectories of impulsivity and sensitivity to reward has demonstrated that while motor impulsivity gradually decreases from childhood to adulthood, sensitivity to reward undergoes a temporary increase.
in adolescence (Steinberg et al., 2008). Further distinctions are made in aspects of impulsivity which are each related in some fashion to substance use behavior, which will be discussed in further detail in chapter 1.3.1 and 4.1.

One brief questionnaire used to measure personality traits that have been established as risk-associated is the Substance Use Risk Profile Scale (Woicik et al., 2009). The design of this questionnaire involved the psychometric evaluation of questions measuring traits that were most strongly associated with substance use outcomes. The SURPS further includes two traits that have been associated with risk of addiction via a more internalizing route (Conrod, Pihl, Stewart, & Dongier, 2000; Sher, Walitzer, Wood, & Brent, 1991), namely hopelessness and anxiety sensitivity. While externalizing individuals characterized by impulsivity or sensation seeking may be motivated to use substances to promote a positive mood, the latter internalizing individuals may be more motivated to use substances to alleviate a negative mood. While a large amount of literature has linked all these traits to substance use internationally (Castellanos-Ryan, O'Leary-Barrett, Sully, & Conrod, 2013; Conrod, Castellanos, & Mackie, 2008; Woicik et al., 2009), studies in the Netherlands have shown that in Dutch adolescent populations, only sensation seeking and hopelessness predicted the early onset of substance use (Malmberg et al., 2010). In fact, anxiety sensitivity predicted delayed onset. While the SURPS has been useful in establishing the most severely at-risk personality traits, other personality traits potentially play a role in the development of addictive behaviors. For instance, while impulsivity and sensation seeking are defined as two separable traits, there exist many varieties of behaviors typically characterized as impulsive. Examining the unique relation of these varieties of behaviors, both those self-reported and those assessed behaviorally, to the onset of substance use is one of the goals of this dissertation.

1.2.3 Parental Influences

In the case of adolescent alcohol use, scientists have examined the effects of a type of parenting style referred to as strict alcohol-related rule setting (Van Der Vorst, Engels, Meeus, & Deković, 2006). This form of rule setting is referred to in Chapter 1.1 in the context of Dutch substance use policy. Strict alcohol-related parental rules refer to explicit statements and rules that are verbally expressed to the child, which may include communications as “We do not allow drinking outside the home”, “We do not allow drinking hard liquor” or “We do not allow drinking at all”. In that sense, they differ from attitude expressions such as “Alcohol is bad for you”. It has been shown that strict alcohol-related rule setting is associated with
reduced alcohol use in Dutch young adolescents, and that alcohol-specific rule setting is prospectively predictive of onset of alcohol use, regardless of age (Koning et al., 2009; Van Der Vorst et al., 2006; Van Der Vorst et al., 2007). One of the goals of this dissertation is to examine whether the effect of personality factors is moderated by strict alcohol-related rule setting.

1.3 Individual-Differences Theories of Substance Use in Adolescence

1.3.1 Aspects of Impulsivity

Several dimensions have been distinguished among which aspects of impulsivity may differ from each other (Nees et al., 2011). Most of these aspects are related to risk behavior and substance use. It is important to recognize that many of these aspects overlap, although they may still uniquely predict distinct outcomes. Dimensions of variation include level of measurement (behavioral and self-reported), motor impulsivity versus impulsive decision making, type of cognition (“Hot”, or immediate and motivated, and “Cold”, or deliberated and reward-neutral), and type of motivation (reward sensitivity versus punishment insensitivity). There is overlap in these dimensions, but typically each can be related to differential outcomes. This makes recognizing their distinctions and understanding implications for substance use and addictive behaviors all the more important.

First, behavioral measurement versus self-report measurement refers to the notion of measuring an aspect of behavior either by observing it directly based on performance on a task, or asking the participant to indicate their self-assessment of that aspect. Critics of self-report measures have advocated that self-report measures are vulnerable to interpretation biases such as the tendency to manage impressions to either themselves or others (Dovidio & Fazio, 1992) and the human need to attribute cause and reason to their past behavior (Nisbett & Wilson, 1977). In addition, they may be vulnerable to social desirability bias. Furthermore, behavioral measures are related differentially to substance use as well as to other aspects of substance-specific cognition (see for details, Chapters 4 and 6).

Second, motor impulsivity versus impulsive decision making refers to the distinction of reactionary behavior versus planned behavior and the differential impact aspects of impulsivity may have on these behaviors (Du, Green, & Myerson, 2002). Motor impulsivity refers to the inability to prevent the execution of a spur-of-the-moment, but inappropriate action. Impulsive decision making refers to the preconceived tendency to opt for a course of action that is more immediately rewarded, but may in the future lead to suboptimal
consequences. Distinct behavioral measures exist to assess each aspect separately. However, they should still be considered related to each other and to other notions of cognition such as executive functions. The measurement and effect of these aspects is described in detail in Chapter 4.1.

Third, hot versus cold cognitions refer to aspects of impulsivity that are either motivationally charged or motivationally neutral. A typical finding has been that hot cognitions relate more strongly to adolescent risk behavior, possibly due to adolescence being characterized as a period of increased sensitivity to reward. Hot cognitions may be more relevant to behavior when there is need for immediate decisions, and when engaging in that behavior would lead to immediate reward (Metcalfe & Mischel, 1999). Such reward may come either from peers encouraging that type of behavior (and the adjoining anticipation of improved social standing from those peers) or from the anticipated rewarding properties of psychoactive substances. Using cold cognitions reflects using economical maximization strategies when considering complex future reward scenarios. These cognitions may influence risk behavior too: for example, in the decision to stay at home and study for a test or visiting a relative. As with the previous distinctions, it is currently largely unknown how these individual aspects contribute to the onset of substance use and to what degree they each overlap with each other and self-report aspects of impulsivity.

Fourth and finally, there are the distinctions between types of reinforcement, referred to here as the distinction between reward sensitivity as opposed to punishment insensitivity when relating these distinctions to risk behavior outcomes. Reward sensitivity refers to the degree to which behavior is guided by the anticipation of reward consequences. Punishment insensitivity refers to the lack of consideration given to potential negative outcomes. Individuals possess each of these traits in varying quantities. Furthermore, it has been shown that they differentially relate to different aspects of risk behavior: while reward sensitivity has been related to substance abuse, punishment insensitivity is a better predictor for conduct disorder (Castellanos-Ryan, Rubia, & Conrod, 2011; van Hemel-Ruiter, de Jong, Oldehinkel, & Ostafin, 2013). Interestingly, being sensitive to reward or insensitive to punishment are not the only conceivable ways in which these aspects of impulsivity may relate to risky outcomes. The other earlier mentioned risk-associated personality traits anxiety sensitivity and negative thinking may also involve dysfunctional punishment sensitivity, where an overwhelming sense of anticipated punishment may cause an individual to seek immediate relief from that situation, for instance by smoking (Conklin & Perkins, 2005). This would lead to the internalizing
behavior referenced earlier. The degree to which measurements of these aspects of impulsivity correlate and jointly or separately predict substance use is covered in more detail in Chapter 4.

1.3.2 Implicit Cognitive Processes

One of the defining features of addictive behavior is that it is often experienced as counter to intention (Wiers & Stacy, 2006). For example, many people want to quit smoking for good (health) reasons, and only days later find themselves smoking again (for debate on the amount of intentionality involved, see Heyman, 2009; Köpetz, Lejuez, Wiers, & Kruglanski, 2013; Stroebe, van Koningsbruggen, Papies, & Aarts, 2013). In adolescents, there is often less desire to curb addictive behaviors (Wiers, Van De Luitgaarden, Van Den Wildenberg, & Smulders, 2005; Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013). Recently, to address this apparent conflict of goals, psychologists have defined a class of implicit cognitive processes, or automatically activated beliefs and automatic associations that serve to automatically trigger certain patterns of behavior. For such patterns, especially those that are engaged in spur of the moment actions, scientists have begun to refer to automatic processing components of cognition activated by association. These would serve to guide behavior unless consciously controlled processes prevent execution of these activated action-tendencies (Wiers et al., 2007).

The roles of consciously controlled as well as more automatically triggered processes are often described through dual process models (Gawronski & Bodenhausen, 2006; Strack & Deutsch, 2004). These models generally assume that behavior is determined as interplay between two qualitatively different classes of processes reflective and reflexive or impulsive processes. Reflexive processes are assumed to be effortless and immediate, whereas reflective processes require conscious effort and demand executive functioning resources. Therefore, when confronted with the opportunity to engage in rewarded behavior, a person must both have the ability and motivation to inhibit the reflexive response. Wiers and colleagues (2007) have adapted these dual process models into a general heuristic model applicable to the development of addictive behaviors (see Figure 1.1). This model outlines the cognitive processes involved in addictive behaviors and specifies the conditions under which controlled processes may successfully inhibit automatic actions. Here, we focus on the role of sensitization in strengthening automatic processes involved in substance use. The automatic processes mentioned are assumed to gain strength from repeated exposure to substance use. One way in which exposure may modify automatic appraisal is suggested by Incentive Salience
Figure 1.1: Heuristic Model of Addictive Behaviors

Note: From Wiers et al., 2007, “Automatic and controlled processes and the development of addictive behaviors in adolescents: a review and a model”. Of particular interest to the current thesis is the influence of substance use on processes of sensitization, and how automatic processes such as appraisal as emotional stimulus (represented in this thesis as Implicit Memory Biases and Attentional Biases) and Approach Action Tendencies (represented in this thesis as Approach Biases) in turn predict increases in substance use. Of further interest is the moderating role of Executive Functions in the relation between these automatic processes and resulting substance use.
Theory (Robinson & Berridge, 2001). It states that repeated exposure to substances which
directly trigger the dopaminergic pathways including the striatal regions of the brain, serve to
automatically strengthen attention and approach tendencies.

Support for elements of this model is provided by evidence for implicit memory
biases, attentional biases and approach biases in substance-addicted persons and heavy
drinkers. Automatic tendencies are assumed to result in a number of alcohol-specific cognitive
biases. Memory biases refer to the speeded retrieval of memory associations regarding
previously rewarded substances (Stacy, 1997; Wiers, Van Woerden, Smulders, & De Jong,
2002). Attentional biases refer to the tendency displayed by heavy drinkers and addicted
persons to focus attention more rapidly, and especially the slow disengagement of attention, on
rewarded substances (Field, Mogg, Zetteler, & Bradley, 2004; Mogg, Bradley, Field, & De
Houwer, 2003). Finally, approach biases refer to the action-tendency (Frijda, 1986) to engage in
approach behavior that leads to consumption of the rewarded substance (Field, Kiernan,
Eastwood, & Child, 2008). As an example of the latter bias, imagine reaching for a beer, and
drinking from this beer, while distracted by conversation with another person.

Additional evidence for the role of controlled processes comes from the findings in
adolescents and young adults that the role of automatic processes in predicting substance use is
moderated by executive functions, namely working memory and inhibition (Gre
nard et al.,
2008; Houben & Wiers, 2009; Peeters et al., 2012; Thush et al., 2008). These findings show
that automatically activated cognitive processes predict more variance in addictive behaviors in
individuals with relatively weak executive functions. Importantly, this evidence does not
feature data on light drinking young adolescents.

Dual process models have come under criticism in recent years. Critics have argued
that the proposed “systems” cannot be anatomically distinguished. Furthermore, many aspects
attributed to either system do not correlate well (Keren & Schul, 2009). Finally, it fails to
specify what constitutes motivation to engage in substance use versus motivation to abstain.
To address this lack of specificity, Gladwin and colleagues (2011) propose a process-model
based on the notion of dual-processing in adolescents. In this model, encountering a stimulus
prompts an immediate weighing of potential responses in an automatic way. The motivational
value attached to each potential outcome and the costs of engaging in each potential response
are evaluated for the duration of the decision making process. Within the span of time
involved in decision making, the value of outcomes involving substance use is initially strong.
According to the model, as time progresses, reflective outcomes that involve abstaining are
slower to have motivational value attached to them (cf. Cunningham & Zelazo, 2007). As deliberation continues, however, the motivational value attached to the reflective response would be stronger than the value attached to the reflexive response. Executive functions in this model would carry a role of allowing delay of execution of any particular response until all ramifications and potential benefits are considered. Responses in this scenario are distinguished only by immediacy and impulsivity in activation, not by associative or syllogistic nature. As such, it does not necessitate the specificity of motivation and allows for conscious learning to affect behavior. This model can therefore be integrated with explicit aspects of motivation that are predictive of substance use, such as self-reported coping motives and social motives (Cooper, 1994), which would add motivational value to the reflexive response. It follows from this perspective that the role of reflexive responses is expected to be strongest in adolescents that are least able to delay response, such as when working memory is low. Indeed, evidence for the role of cognitive biases has come mainly from populations already heavily drinking, at-risk or substance addicted (Peeters et al., 2013). Therefore, the role of these responses in guiding the behavior of light drinkers or their role during the onset of substance use remains largely unknown. One goal of the current thesis is to examine the role of alcohol-specific cognitive biases in a general population of young adolescents. Furthermore, we also examine whether cognitive biases are developmentally related to aspects of impulsivity, as the assumption of a reflexive system suggests.

1.4 Current issues: Development of Cognitive and Motivational Processes and Substance Use.

It is important to gain insight in the role of the various cognitive and motivational processes in the development of addictive behaviors. Many such predictors may be characterized both as potentially causal to substance use, as well as being a potential consequence of alcohol use. The latter is believed to be especially true for substance-specific cognitions. The most informative way to study the development of processes associated with the development of substance use is to assess these processes in adolescents and follow them longitudinally in the period prior to, and of, onset and escalation of substance use. In the studies described in this thesis, we assessed cognitive motivational processes hypothesized to be related to the development of substance use in young adolescents and follow their subsequent development, as well as the development of substance use. We assessed measures of personality and implicit and explicit cognitive motivational processes (attentional bias,
approach bias, memory associations), as well as an environmental variable (parental alcohol-specific rule-setting).

The nature of developmental factors involved in adolescent substance use is often complex and interactive. From that perspective, studying relationships between variables over time is crucial. For example, while alcohol use is in many Western nations fairly normative, especially during the college years, far fewer adults continue to consume alcohol in similar quantities after adolescence. Additionally, not all adolescents consume the same substances, or in the same quantity as others. Their consumption is also not always related to harmful consequences. Specific personality traits may require certain environmental conditions to express themselves (even gene expressions are often situation-specific, see Pieters, Burk, Van der Vorst, Wiers, & Engels, 2012) and may be further modified by continuing substance use to create a downward spiral of losing control. Furthering insight into the specific interplay between predictors of substance use over time as well as the interrelation with continuing substance use has been identified as a key research target by several scientists (Coskunpinar & Cyders, 2013; Rutter et al., 1997; Zucker, 2008).

It is recognized that some factors may influence the onset of substance use, and potentially be affected by substance use in turn (De Wit, 2009). Whether that means that these factors existed previous to the onset of substance use as latent traits (in the non-statistical meaning of latent), or whether that means they developed via exposure as a consequence of alcohol use or whether both processes enhance each other, remains to be examined. If the latter is the case, the existence, severity and effect of these automatic factors may still not be apparent until substance use becomes more problematic and until individuals indicate that their substance use is out of their control or counter to intention. However, whichever is the case, virtually no empirical evidence exists to support one of these theoretical possibilities at this point. The applicability of many of these factors to young adolescents, especially those who have very little substance use experience, is unknown. To address this concern, this dissertation describes a number of studies that investigate the interplay of several factors in the prediction of the development of substance use.

1.5 This Thesis

The aims of this thesis are to examine (1) the interaction between environmental and cognitive predictors in the onset and escalation of alcohol use, (2) the role of aspects of impulsivity and their relation to onset of substance use (with a focus on alcohol use), (3) the
role of executive functions and their relation to the onset of alcohol use, (4) whether these aspects of impulsivity prospectively relate to alcohol-specific cognitive biases, and (5) what the developmental relation is between cognitive biases and alcohol use in a general, non-heavy-drinking population of Dutch young adolescents. We examine these research questions by providing measurement of aspects of cognition, personality and environment related to the development of substance use as well as of the amount of substances used at each time wave.

Chapter 2 describes the online survey in detail. It describes how decisions were made that allowed for the relatively automatic testing of participants. It also describes the survey sample, the measures included, and the visual presentation of the survey. Finally, it describes the motivational aspect of participation and how reward mechanisms were integrated in the survey experience to encourage continued participation.

Chapter 3 covers the interrelation between a key internal predictor (risk-associated personality), and a key external predictor (parental alcohol-specific rule-setting). It furthermore distinguishes between the prediction of drinking in any quantity on the one side, and the prediction of truly heavy drinking on the other. The following hypotheses are tested: First, we predicted lower odds of drinking, especially heavy drinking, as a main effect of parental rule-setting. Second, we predicted higher odds of drinking, especially heavy drinking, as a main effect of risk-associated personality traits. Third, an interaction effect, such that scoring high on risk-associated personality traits would be more predictive of drinking when a lack of parental rule-setting occurs.

Chapter 4 covers the differentiation of a number of aspects of impulsivity, behavioral and self-reported, previously associated with substance use. The outcome measure used was the onset of three types of substance use (alcohol, smoking and cannabis use) during the survey period. The following hypotheses were tested: First, we predicted that self-report aspects of impulsivity and sensation seeking would predict the onset of all types of substance use. Second, we predicted that behavioral aspects of impulsivity and sensation seeking would additionally predict onset when self-report measures were accounted for.

Chapter 5 covers the relation between measures of executive control and the onset of alcohol use as well as the onset of binge drinking. Two measures of executive control, specifically one of working memory and one of response inhibition, were used to predict odds of onset in a discrete-time survival analysis. The hypothesis tested was that weak working memory and response inhibition would each predict the onset of both drinking and binge
drinking in a joint sample of adolescents enrolled in regular education and adolescents enrolled in special education.

Chapter 6 covers the relation between impulsivity, alcohol-specific cognitive bias and alcohol use. It investigates whether alcohol-specific cognitive biases emerge as a consequence of alcohol use or whether they emerge as an alcohol-specific proxy of impulsivity. Additionally, it investigates whether these alcohol-specific cognitive biases prospectively predict later alcohol use. Measures of alcohol-specific attentional biases as well as measures of alcohol-specific approach biases are included. The hypotheses tested were the following: first, we predicted that both self-report and behavioral impulsivity and sensation seeking would prospectively predict the presence of alcohol-specific cognitive biases. Second, we predicted that earlier substance use would additionally predict the presence of alcohol-specific cognitive biases when impulsivity was controlled for. Third, we predicted that alcohol-specific cognitive biases would prospectively predict the amount of alcohol consumed, but not the onset of alcohol use.

Chapter 7 covers an investigation of the joint development between one type of alcohol-specific cognitive bias (approach bias) and alcohol use. Furthermore, it investigates whether these growth relations apply equally when participants relatively low on response inhibition are compared to participants relatively high on response inhibition. It uses a parallel process growth model that test whether the intercept or growth of both bias and alcohol use are associated with each other. The following hypotheses are tested: first, we predicted that the intercept of bias (or the basic level of bias displayed equally across time) would be associated both to the intercept of alcohol use as to the growth of alcohol use. Second, we predicted that growth of bias would be associated both to the intercept of alcohol use and to the growth of alcohol use. Third, we predicted that these relations would be stronger in adolescents with poor working memory capacity.

Chapter 8 offers a general discussion of the findings. It summarizes the chapters covering empirical findings. Furthermore, it reflects on decisions made in Chapter 2 and how they may have influenced the results. It discusses research implications for the findings and offers recommendations for future research goals and methodology.