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Chapter 14
Using Serious Games to (Re)Train Cognition in Adolescents

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Abstract Cognitive training has been studied in the context of many psychological disorders, including attention deficit hyperactivity disorder (ADHD), anxiety, depression, and addiction. While several studies have found clinically relevant training effects, both in preclinical (experimental) and in clinical settings, cognitive training is often experienced as rather boring. Therefore, several studies have recently started to integrate serious gaming techniques into cognitive training paradigms to enhance motivation to train, especially among younger subjects. In this chapter, we discuss the relevant theoretical frameworks supporting both the trainings and the gamification techniques, review several attempts that have been made so far, and discuss the progress that has currently been made. The chapter will end with a number of recommendations, based on published evidence, as well as our own experience in this field.

Keywords Cognitive training • Substance use • Adolescents • Serious games

14.1 Introduction

Although any game that is used for a serious purpose, other than mere entertainment, can be viewed as a *serious game*, many are developed with the specific purpose of improving motivation on a serious task, such as a training or educational experience, by making it more enjoyable. For example, there has been a recent surge in the development of video games aimed at improving (mental) health (Kato 2010). Many of these *games for health*, as they are often called, are aimed at adolescents and

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young adults, as gaming is very popular among those age groups (Entertainment Software Association 2014). But adolescence is also a sensitive period when it comes to mental health, potentially making serious games especially effective at this age. The question central to this chapter is, how can the scientific evidence for cognitive training principles be used as a basis to effectively improve mental health in adolescents, using serious gaming techniques? In the following section, an overview will be presented detailing what is currently known about cognitive training, underlining the importance of using the right principles or paradigms. In the third section, we will take a closer look at the role of motivation in adolescents. The fourth section will describe the current state of affairs of cognitive training games aimed at adolescents, and the final section will finish off with some recommendations regarding the development and study of these games.

14.2 Training Cognitive Processes

Adolescence is a developmental period characterized by a considerable increase in the prevalence of internalizing problems, such as anxiety and depression (Paus et al. 2008), as well as externalizing behavior, such as experimenting with risky behavior (Steinberg 2007). The European School Survey Project on Alcohol and other Drugs (ESPAD; Hibell et al. 2012) showed that almost 60% of the 100.000 students in the survey reported to have consumed at least one glass of alcohol at the age of 13 or younger, 2% had already been drunk at that age, and 18% had tried illicit drugs at least once during their lifetime. Although this behavior does not necessarily lead to mental problems, excessive contact with psychoactive substances at this age can lead to misuse, school dropout (Singleton 2007), and ultimately addiction problems later in life. As such, early intervention is important to prevent escalation. While there are numerous prevention and treatment programs available, which tend to focus on explicit education, their efficacy is sometimes limited (Werch and Owen 2002), which may in part be due to the fact that adolescents have a hard time reflecting on and making changes to their behavior in general.

Interestingly, recent evidence has emerged that many of these adolescent mental problems are associated with specific cognitive deficiencies, such as a weaker working memory capacity (WMC; Martinussen et al. 2005) or a tendency to selectively attend to information or approach stimuli that strengthen the problematic behavior (Bar-Haim et al. 2007; Peckham et al. 2010; Wiers et al. 2013). For example, many anxious people have a tendency to attend to negative or threatening information (Bar-Haim et al. 2007), whereas heavy alcohol users selectively attend alcohol-related information (Field and Cox 2008). Similarly, an approach bias has been found for alcohol-related cues in heavy drinkers (Field et al. 2008; Wiers et al. 2009) and for cannabis cues in cannabis users (Cousijn et al. 2011; Field et al. 2006).

Training, or retraining, these cognitive processes can be effective in decreasing symptoms. We can distinguish between two closely related types of cognitive

training (Wiers et al. 2013). First, there are training paradigms aimed at modifying the maladaptive cognitive biases (cognitive bias modification, CBM). These training procedures are usually disorder specific, as they often involve stimuli (i.e., pictures, words) related to the disorder. For example, attentional bias modification in long-time heavy substance users has been associated with a reduction in drinking (Fadardi and Cox 2009) and a significantly longer time to relapse (Schoenmakers et al. 2010). Similarly, Amir et al. (2009) and Schmidt et al. (2009) showed a decrease in anxiety symptoms in clinically anxious patient groups (for a recent review, see Kuckertz and Amir 2015). Another type of CBM, aimed at modifying automatically activated action tendencies to approach or avoid disorder-related stimuli, was effective in reducing alcohol intake directly after training (Wiers et al. 2010). When this type of retraining was added to regular therapy for alcoholism, relapse 1 year after treatment discharge was reduced with 13 % in patients who received this type of training, compared with those who received sham training or no training in addition to regular treatment (Wiers et al. 2011). This finding was recently replicated in a large study ($N > 500$), with evidence for statistical mediation (the clinical change was mediated by the change in automatic action tendencies) and moderation (patients with a strong approach bias profited more from this training than those without a strong approach bias, Eberl et al. 2013). In addition to training attentional bias and approach bias, positive memory biases have also been targeted with different methods, such as evaluative conditioning (pairing the focal category alcohol with negative stimuli, Houben et al. 2010) and selective inhibition (pairing the focal category alcohol with an inhibition signal (Houben et al. 2011a, 2012), with initial promising results in heavy drinkers.

Second, there are more domain-general cognitive control functions, such as WMC and impulse inhibition, collectively called executive functions (EFs). Deficits in EF are implicated in many psychological disorders, such as addiction, attention deficit hyperactivity disorder (ADHD), and autism spectrum disorders (ASDs), but also internalizing disorders such as anxiety and depression. These EF deficits are related to functional impairments and specific problem behaviors (Hosenbocus and Chahal 2012). The three components of the executive system that have received the most research attention are working memory, inhibition, and cognitive flexibility (Diamond 2013). Meta-analyses have shown that the working memory and inhibition of school-age children and adolescents with ADHD are mostly impaired (Martinussen et al. 2005; Wilcutt et al. 2005). Executive impairments have also been reported in school-age children with ASD on measures tapping planning, inhibition of prepotent responses, and self-monitoring (Robinson et al. 2009). Although these EF deficits have been consistently found in ADHD and ASD and are related to functional impairments and specific problem behaviors, they are not specific enough for use as clinical markers for these disorders (Geurts et al. 2004; Hosenbocus and Chahal 2012). In addiction these cognitive control functions are needed to regulate the impulsive reactions involved in the substance-related biases. There is some evidence that when inhibition (Houben and Wiers 2009; Peeters et al. 2012) and WMC (Grenard et al. 2008; Thush et al. 2008) are weak, they can fail in their regulatory function, leading to an imbalanced cognitive system (Wiers et al.

2007). However, support for a causal relationship, where impaired control functions are a result of adolescent substance use, is weak (Wiers et al. 2015).

Impairments in EF have also been linked to problems with self-regulation and the development of disruptive behavior problems such as found in oppositional defiant disorder (ODD) and conduct disorder (CD; Schoemaker et al. 2013). Results regarding working memory performance in children and adolescents with ODD and CD, however, are less consistent than those found in youth with ADHD. Although cognitive deficits are widely recognized to be an important component of anxiety (Moran 2016), fewer studies have assessed the relation between EF deficits and internalizing problems such as anxiety and depression. Anxiety, both self-reported as well as experimentally induced, is thought to restrict WMC by competing with task-relevant processes. According to cognitive theories, anxiety problems are related to impairments in attention processes.

Just as cognitive biases can be influenced through targeted training, cognitive control functions can also be strengthened through training, with the best results in children with relatively weak WMC (Holmes et al. 2009), such as children with ADHD (Klingberg 2010). While cognitive training effects do not always generalize to other cognitive abilities (Shipstead et al. 2012), increasing WMC can also lead to reduced drinking in problem drinkers with strong automatic positive associations with alcohol (Houben et al. 2011b). Training working memory in adolescents in order to improve their executive attentional control also resulted in positive changes in symptoms of trait and test anxiety, increased inhibitory control, and reduced attention to threat (Hadwin and Richards 2016).

Interestingly, these two types of cognitive processes are intimately intertwined in several disorders. For example, when cognitive control is low, the impulsive processes tend to better predict the maladaptive behavior (Wiers et al. 2013). Although there is ample evidence in favor of cognitive training (for more elaborate reviews, see Klingberg 2010, Wiers et al. 2013), it is not without controversy. Some authors (e.g., Cristea et al. 2015, Emmelkamp 2012) note that the quality of the evidence in support of CBM is limited, with reported changes pertaining mainly to the targeted biases, but limited or no effects on mental health outcomes. Similarly, the notion of strengthening cognitive functions through training has also been subject of recent debate (e.g., Shipstead et al. 2012). While this chapter is not a place to repeat this debate on the efficacy of cognitive training, it may help to distinguish between the nature of the training studies that show or refute cognitive training effects with regard to the experimental settings. Importantly, while effects have generally been limited in single-session studies with unmotivated participants (usually heavy-drinking students who do not wish to reduce their drinking (e.g., Schoenmakers et al. 2007) or community smokers who do not wish to quit (Kerst and Waters 2014)), studies in which cognitive training has been delivered to clinical samples as add-on to regular treatment (Eberl et al. 2013; Schoenmakers et al. 2010; Wiers et al. 2011) have yielded significant improvements in clinical outcomes.

To conclude, although cognitive training can be a promising basis for the development of serious games, the specifics of the disorder, the target population, and the training paradigm are very important for the efficacy of the training.

Another important aspect that can influence the efficacy of cognitive training is the participant's motivation, which is where serious game techniques may play a pivotal role (Gladwin et al. 2011).

14.3 Motivations

Similar to physical training exercises, most cognitive training paradigms rely on a substantial number of repeated actions over multiple sessions to reach a training effect. To sustain performance during these training sessions, it is necessary to reach and maintain a state of motivation high enough to continue training. But prior to the actual training, adolescents first need to be motivated to consider participating in a training. That is, they need to have a basic *motivation to change* their problematic behavior (Boffo et al. 2015). Although the negative effects of adolescents' problematic behavior are often obvious to those around them, adolescents themselves sometimes lack the realization that they even have a problem. For example, many adolescents don't think of their heavy alcohol use as problematic or harmful (Johnston et al. 2012). This is not strange when we look at the developmental function that many risk behaviors, such as alcohol use, can fulfill. Adolescents often engage in risky behaviors to attain or increase peer status or to receive positive evaluation of peers (Crone and Dahl 2012; Sommerville 2013; Steinberg 2007). Peers and their perspectives become increasingly important in adolescence, and adolescents' behavioral decisions are often taken while conforming to peer norms and peer cultures (Baumeister 1990; Forbes and Dahl 2010), making it harder to provoke behavioral change. For that reason, it is important that intervention strategies are developed in line with the perceptions of adolescents, and they can only be effective when aspects such as motivation and attention are taken into account. In contrast, most CBM studies feature adult patient samples, where most participants have a long history of substance use problems and are thus more motivated to change their behavior. As such, there are important motivational differences between adolescents and adults that have to be taken into account when designing a motivating intervention, such as a serious game training. When this *motivation to change* is low, it may be best to combine cognitive training with other types of intervention (Wiers et al. 2013), such as motivational interviewing (Miller and Rollnick 2002) or (cognitive) behavioral therapy. But even when participants are somewhat motivated to make a behavioral change, they often find cognitive training paradigms to be long and boring and have a hard time believing that a simple computer task can help them to, e.g., control their substance use (Beard et al. 2012). As such, they may still need to be motivated to complete the full training. Applying serious gaming techniques to evidence-based training paradigms may help adolescents to increase their *motivation to train*. Specifically, serious games as an intervention strategy for adolescents have the ability to anticipate on two important cognitive developments that characterize adolescence: (1) development of behavioral control and (2) increased sensitivity for reward. Adolescents are (hyper)sensitive for reward, but at the same time have

difficulties in controlling their behavior as behavioral control continues to develop into late adolescence (18–20 years; Blakemore and Choudhurry 2006; Luna et al. 2004). Not yet fully developed behavioral control skills increase the chance that insufficient attention is giving to the task, specifically when the task is long and boring, subsequently resulting in incomplete or inefficient training. Adolescents with externalizing behavioral problems such as ADHD and CD are particularly at risk because of their deficits with behavioral and motivational control functions (Dovis et al. 2013; Krueger et al. 1996). Exactly this group of youngsters is at the greatest risk for developing addictive behaviors (Peeters et al. 2015) and therefore could benefit most from an efficient intervention strategy. As such, serious games can significantly advance the field of interventions for adolescents in general and particularly for adolescents with externalizing behavioral problems. Compared to traditional intervention approaches, serious games can be better equipped to grasp attention and increase adolescents' motivation to complete the training (Dovis et al. 2013). Moreover, the competitive and arousing character of games can better connect to the perceptions of adolescents (Granic et al. 2014), status increase and competition are two often observed reasons of why adolescents engage in risk-taking behavior (de Boer et al. 2016; Sommerville 2013), and these factors could act as important reinforcers when efficiently processed in a serious game. The gameplay and the competitive character of serious games may increase the rewarding and motivating capacity of the intervention; however, notion should be taken in how rewarding elements are incorporated (Dovis et al. 2013; Boendermaker et al. 2015b).

14.4 Serious Games and Cognitive Training

As we have seen in Sect. 14.2 of this chapter, it is important to consider the delicate nature of evidence-based cognitive training paradigms in order to be able to use them as a basis for serious games. Most paradigms are structured as repeated stimulus-response exercises and tend to be very sensitive to slight structural changes (e.g., changing the display duration of a cue from 500 to 2000 milliseconds may give very different results; Field et al. 2013). As such, there is always a risk involved in adding game elements to such paradigms, as these may render the task less effective. Boendermaker et al. (2015b) propose a model that features several techniques for turning cognitive training tasks into serious games.

The model distinguishes between several steps on a dimension going from purely serious (i.e., the original, evidence-based paradigm) to purely game (e.g., the use of a commercial game for serious purposes; see Fig. 14.1). Many studies already report including some sort of reward system (Step 1), such as a prize, money, or course credits, for participation (Anguera et al. 2012; Jaeggi et al. 2011) or specifically based on task performance (e.g., points for speed and accuracy; van Deursen et al. 2013). Although this is probably the easiest step to include, it has been suggested that using such extrinsic rewards can also hinder performance (Jaeggi et al. 2014) by undermining intrinsic motivation (Deci et al. 1999).

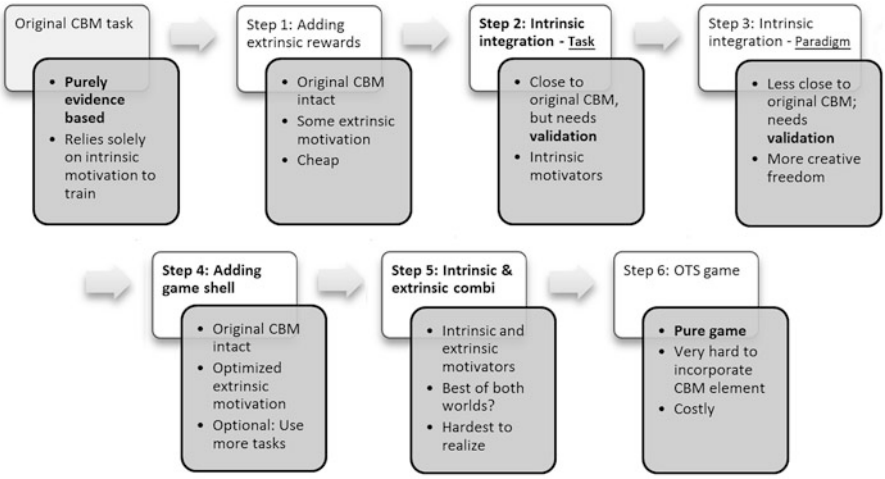

Fig. 14.1 Gamification model. Six gamification steps from evidence-based paradigm (CBM) to commercial "off-the-shelf" (OTS) games (Adapted from Boendermaker et al. (2015b). Copyright 2016 by Elsevier Ltd. Reprinted with permission)

The next two steps involve making more elaborate changes to the original training task, increasing the motivation to train through the use of intrinsic motivators, such as game elements, making it more fun to perform the task itself. As such, the motivating elements are fully integrated into the training paradigm. For example, the Cheese Ninja Game on Facebook (Boendermaker et al. 2015a) is based on the go/no-go paradigm used by Schoenmakers et al. (2010), aimed at retraining alcohol-related memory bias. In this game, the user controls a mouse character running through a tunnel, grabbing pieces of cheese and avoiding cats. These playful cues are selectively paired with pictures of alcohol- and nonalcohol-containing beverages in the background in order to retrain the alcohol bias. First, results among heavy-drinking students indicated that adding (social) game elements increased their motivation to train, compared to a regular go/no-go training. Gamito et al. (2014) used a set of similarly gamified mobile trainings of attention, working memory, and logical reasoning to train cognition in clinical alcoholic patients. Although they found an overall increase of cognitive abilities for both the game and nongame training groups, the game training group showed a more pronounced improvement in frontal lobe functions from baseline to follow-up, suggesting that the addition of mobile game elements to existing training paradigms may result in even better training effects. Dennis and O'Toole (2014) developed a mobile game based on the dot-probe paradigm (originally developed by MacLeod et al. 1986) to retrain attentional bias in highly trait-anxious young adults. In their game, participants were presented with cartoon characters showing angry or neutral/mildly positive facial expressions, their reaction to which was rewarded with jewels based on speed and accuracy. A single session of this training managed to reduce subjective

anxiety and observed stress reactivity. In contrast, the Shots Game (Boendermaker et al. 2016), which incorporates the same dot-probe paradigm, aimed at retraining alcohol attentional bias, produced less positive results. This game, which features an animated slot machine with an elaborate reward system, did not reduce alcohol attentional bias, whereas the nongame dot-probe training did. Moreover, motivation to train decreased over time in both the game and the nongame conditions, suggesting that the added game elements were not enough to counteract the tiresome nature of the training.

Taken together, these games all introduce a richer context for the points earned, while remaining as close as possible to the original, evidence-based training task. Nevertheless, it appears that not all game elements are beneficial to the training efficacy, and despite the changes being minimal, there is still a relatively high risk involved of losing some of the key elements of the paradigm in the process of creating the game, potentially making the training less effective. Therefore, these games should always be revalidated by comparing them to the original training task.

An alternative can be to add game elements *around* the original training task, like a shell, while leaving the task itself relatively unchanged (Step 4 in the model). Although this approach minimizes the chance of rendering the training less effective, it also leaves the relatively boring task intact, motivating the user primarily by rewarding good task performance, *after* that performance. As such, a possible drawback to this approach is that the motivating part remains separated from the training task. Such motivators are sometimes called extrinsic and are viewed as inferior to intrinsic motivators (Deci et al. 1999). An advantage of this game type is that it allows for the incorporation of several different training tasks in one serious game. For example, in the CityBuilder game (Boendermaker et al. 2013), players can train different cognitive aspects, such as working memory and inhibition, as well as more CBM-related processes such as attention and approach bias. The original training task is presented on top of the game, as shown in the right pane of Fig. 14.2.

By performing well on the training (i.e., based on speed and accuracy), they receive points that can be spent buying a variety of objects to build a custom city, after the training block is over. Going one step further, combining these two

Fig. 14.2 Shell game "CityBuilder." Game screen on the left, embedded training task overlaying the game screen on the right (Adapted from Boendermaker et al. 2013. Copyright 2016 by the authors. Reprinted with permission)

approaches may result in the most optimal balance between training efficacy and motivational elements. For example, Braingame Brian (Prins et al. 2013) is a game training aimed at improving different cognitive control processes, such as working memory and inhibition. It has managed to extensively integrate several original training tasks into a game shell while remaining very close to the original paradigms. Verbeken et al. (2013) and van der Oord et al. (2012) have used Braingame Brian and reported positive training effects in obese children and children with ADHD, respectively. Another example of this game type is Watermons (Dörrenbächer et al. 2014). The Watermons game adapts a task-switching training, based on the alternating-runs paradigm from Karbach and Kray (2009), into an elaborate game world filled with engaging story lines to motivate participants. First, results showed increased training effects compared to a regular nongame version of the training in terms of reaction times and switch costs, as well as a higher motivation to train (Dörrenbächer et al. 2014). The final step toward gamification concerns the use of a commercial, off-the-shelf (OTS) game to measure improvements on cognition, such as visual short-term memory and selective attention (Boot et al. 2008). Although this strategy could arguably have the highest motivational value, most commercial games were not developed with nonentertainment purposes in mind and as such are often filled with visual and auditory distractors. Moreover, many cognitive training paradigms, especially CBM related, include disorder-specific stimuli, which may be hard to incorporate into an existing commercial game. As such, although there have been reports of cognitive benefits of commercial gaming (for a review, see Granic et al. 2014), they seem less well suited for targeted cognitive training games.

14.5 Recommendations for Future Research and Development

Serious games can be a promising new way to reach at-risk youth, through prevention as well as intervention, and cognitive training can be a firm scientific basis for the design of those serious games. As this field is relatively young, more research is needed to determine for whom these cognitive training programs work best and which game elements should be used or avoided. For example, the different game types described have thus far not been compared directly to see which one works best. Similarly, certain game elements, such as loud sound effects, flashing visual distractors, and real-time scoring, can also distract the participant during their performance and lead to reduced task performance (e.g., Katz et al. 2014). This underscores the importance of validation of the new gamified measure, with regard to the degree to which the game elements add to the cognitive load during task performance. Other interesting questions concern, e.g., whether the combination of explicit and implicit motivational techniques, targeting motivation to change, e.g., through motivational interviewing or cognitive behavioral therapy, as well as motivation to train through the use of game elements that work best. Perhaps

a serious game can be designed that incorporates elements of implicit cognitive training as well as more explicit cognitive behavioral therapeutic elements. And if game elements can improve cognitive training efficacy, can they also improve the quality of cognitive assessment data (Hawkins et al. 2013)?

While many of these questions are currently being studied (e.g., Lumsden et al. 2016), several critical notions also apply. For example, as a typical cognitive (re)training program can take up to 600–2000 trials over multiple sessions (e.g., van Deursen et al. 2013), serious games that incorporate such large numbers of trials will need to keep participants' motivation high over a longer period of time in order for them to be able to sustain a sufficient level of performance. Interestingly, the use of game elements may therefore also introduce a new risk: when the training is presented as a game, participants' expectations of the level of fun during training will be raised, as the word "game" undoubtedly creates certain expectations based on previous experience (Boendermaker et al. 2015b). As such, they now expect to be entertained. If this does not happen, however, their disappointment may also be greater than when they did not have these expectations in the first place (as is presumably the case when participating in a regular, nongame training intervention). Because of this, it is important to use the word "game" with caution when presenting a serious game to participants. It would also be interesting to study participant expectations about the (gamified) training and their effects on motivation and treatment outcome. A related problem that may affect research outcomes is that after participating in a game training, the sudden lack of motivating elements in the post-training assessment measures could demotivate participants to do well, potentially canceling out any training effects.

Despite the evidence that game elements can increase participants' motivation for doing cognitive training, the level of fun may never reach that of commercial games. However, the question is, can or should we expect them to be? Buday et al. (2012) suggest that a direct comparison with commercial games should perhaps be avoided altogether. Given that even expensive commercial games sometimes fail to keep critical players interested for long, there is indeed a challenge for typically low-budget serious games to keep motivation reasonably high while keeping expectations relatively low. As such, serious game research, as well as training outcomes, could benefit from keeping expectations modest.

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