Introducing the Fling – An Innovative Serious Game to Train Behavioral Control in Adolescents: Protocol of a Randomized Controlled Trial

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Abstract. Behavioral control weaknesses are a strong predictor of problematic behaviors in adolescents, such as heavy alcohol use. Heavy alcohol use at this young age can lead to health and school-related problems and is a severe societal problem. Strengthening of cognitive control mechanisms through computerized training has been shown to have positive effects on behavior, but is often perceived as a tedious exercise. Applying novel serious gaming techniques to evidence-based training paradigms may offer a solution to this motivational problem. This paper describes the design and analysis plan that will be used to evaluate an innovative Serious Game called The Fling, aimed specifically at increasing cognitive control over impulses in adolescents. The game will be evaluated in a randomized controlled trial (RCT) among adolescents between 15–18 years in mainstream and special education.

Keywords: Serious games · Cognitive training · Adolescents · Motivation · Inhibition

1 Introduction

Heavy alcohol use among adolescents is a severe societal problem that can lead to health problems and academic underperformance, as well as addictive behaviors later in life [1]. Weaknesses in behavioral control (e.g., the ability to plan behavior, inhibit inappropriate responses, and consider alternative response options) are a strong predictor of alcohol use [2–5]. Experimenting with risky behaviors such as alcohol use is a relatively normative development often associated with the onset of puberty. Some adolescents, however, have difficulties to withstand the feelings of temptation and craving, associated with some of these behaviors (e.g. alcohol, smoking, drug use [6]),

resulting in a shift from relatively innocent experimental behavior to more uncontrolled and compulsive behavior. Weaknesses in behavioral control increase the chance that adolescents will develop an uncontrolled and problematic drinking style.

Recently, several effective, evidence-based cognitive training paradigms have been developed that can increase behavioral control [e.g., 7, 8], and thus help adolescents to control their drinking behavior. By applying these training paradigms, we may be able to withhold adolescents from developing an unhealthy drinking pattern. An important aspect of these cognitive training paradigms is that they are often seen as long and boring [9]. Many interventions aimed at reducing adolescents' alcohol use focus on changing the outcome behavior and not so much on motivating participants to complete the training. Moreover, risk groups that could benefit the most from interventions aimed at controlling drinking behavior, are often groups that have difficulties with concentration and attention [2]. This characteristic increases the likelihood of inefficient training in this particular group. It is therefore of vital importance to develop a training that matches the needs and motivates participants in the best way. This is where the use of serious gaming techniques may offer a solution. Serious games have been shown capable to increase participants' motivation to complete training [e.g., 10]. They provide a safe training environment, tailored to adolescents' individual level of development, against a competitive and arousing game background, which connects well to the perceptions of adolescents [11].

In line with recent developments in the application of serious games to induce behavioral change [12, 13], we have adapted one of these training paradigms by integrating it in a serious game, called *The Fling*. Two mechanisms are targeted using evidence based training principles [e.g., 7, 14–16]: delay of gratification (withstanding immediate rewards in favor of bigger long term rewards) and response inhibition (the ability to suppress or delay automatic responses or impulses that might be inappropriate or irrelevant in a given context).

There are two similar paradigms that are most frequently used for training response inhibition: the go/no-go (GNG) and the stop-signal (SST) paradigm [17]. Both can be used to train response inhibition by consistently pairing certain stimuli with a go-response and others with a no-go or stopping response. The difference between a no-go-cue and a stop-cue is subtle. Both cues indicate that a response should be withheld, but a no-go cue represents the instruction to withhold a response immediately when it is presented, whereas a stop-cue first appears as a go-cue, and then turns into a stop-cue after a brief interval (e.g., 300 ms). The latter thus makes it more difficult to withhold a response as a motor response to the initial go-cue may already be underway. As such, the SST paradigm is believed to target executive processes at the motor level [18].

Another aspect relevant to inhibition is the differentiation between automatic response inhibition and controlled response inhibition [17]. Controlled response inhibition is a top-down process that can be used to actively inhibit a response, whereas automatic response inhibition is a bottom-up process that can develop when a certain stimulus is consistently paired with a no-go or stopping response [19]. Repeated exercise with such stimulus-cue combinations can strengthen the ability to develop automatic inhibition [19]. For example, Houben and colleagues [7] used a GNG training that consistently paired alcohol-related cues with a no-go response to strengthen the ability to inhibit responses to alcohol-related stimuli in heavy drinking college students. A more

indirect strategy can be to strengthen controlled response inhibition in a more general context. For example, Dovis and colleagues [20] successfully improved controlled response inhibition in children with ADHD through a gamified training inhibition training based on the SST paradigm.

Dovis and colleagues [20] also suggest that for the purpose of training controlled response inhibition, the GNG may be less appropriate compared to the SST. The way the GNG task is designed makes that it interacts with other processes, such as selective attention, and has a relatively low load on inhibition [21]. Verbruggen and colleagues [19] also showed that a controlled response inhibition training at the motor level with the SST paradigm can translate specifically to a decrease in risky behavior (assessed with a monetary gambling task). The SST paradigm may thus show better transfer of cognitive control improvements to other cognitive domains [19, 22] whereas the go/no-go paradigm appears to be more suitable to train domain specific behavioral control (e.g., [7]). Therefore, the training task used as a basis for The Fling is based on the SST paradigm.

The aim of the current study is to see whether a general controlled response inhibition training can help adolescents to gain more control over their risk behavior. The cognitions involved in behavioral control are still maturing during mid and late adolescence [23, 24], making this period particularly suitable for training. In the current article we will describe the design process and elaborate on our plans to evaluate The Fling in an upcoming randomized controlled trial (RCT) among regularly developing adolescents between 15–18 years in a mainstream education setting.

2   Methods

2.1   The Fling: Concept and Development

The target population for The Fling consists of typically developing adolescents between 15–18 years of both sexes. As such, the game elements used were aimed specifically at adolescents in that age group. In The Fling, the player is presented with a brief introduction to a lighthearted 'boy-meets girl' love story. After the brief cut-scene, the first of five training levels can be started. During each training level a song is played, presenting a musical rhythmic pattern that coincides with the presentation of the go- and stop-cues. Besides fitting the atmosphere of the game, the music is also intended to make the tendency to respond to the cues more potent: after several go-cues are presented to the rhythm of the song, when a stop-cue appears to the rhythm, the impulse to keep tapping the response key may be higher, thus creating a stronger response conflict, which may lead to a stronger training effect [25, 26]. Figure 1 depicts The Fling during training. The camera flies along a ribbon through a colorful scene that connects to an overarching story arc. Along the way, and on the rhythm of the accompanying music, the cues show up in a neutral color (grey), turning either green (signaling a go-cue) or green followed by red (signaling a stop-cue) at 1000 ms in front of the camera. The cues are placed randomly on one of three lanes on the ribbon. In the first levels the three lanes all correspond to one response key on the keyboard (the [SPACEBAR]). Later in the game, two additional response keys become active, where each key represents a different lane (the [Q], [SPACEBAR], and [P] keys, respectively).

Fig. 1. The stop-signal paradigm incorporated into the fling game, used in the active and placebo game training conditions. Green cues signal go-responses and green cues that have turned red signal stop-responses. The scene depicts a lighthearted boy-meets-girl scene while the ribbon flows through the tree. The horizontal white line signals the optimal reaction time. (Color figure online)

To keep participants challenged throughout the game, the speed with which the cues approach varies slightly over the course of each level, based on performance, as well as the time it takes for the stop-cue to turn red. Additionally, from level 4 onwards, blue cues sometimes appear in place of green cues signaling that the player should keep the correct button pressed for 500 ms, giving an extra bonus score. This cue serves no purpose beyond other go-cues, other than adding diversity to the game. To motivate the player to also respond quickly, but not too fast, the number of points awarded for each correct go-response increases the closer the cue moves to the camera. This 'optimal reaction time' is also visualized through a horizontal bar overlaying the ribbon, as well as the cue itself becoming brighter. If the response was correct, this is signaled by an increase of points. When an incorrect response is given (either the wrong or no key on a go-cue, or any key on a stop-cue), the screen briefly gives a little shake (emulating the force feedback feature found in many console games). In both cases a text message also appears, indicating whether the response was correct or incorrect, too late or too fast. Doing well on the training also affects the background of the level during play, e.g., the first level (depicted in Fig. 1) features a lighthearted boy-meets-girl scene while the ribbon flows through the tree. Doing well makes the tree change color to reveal fresh green leaves and flowers, whereas incorrect responses turn the tree into a darker, autumn-like color. After finishing each level, another brief cut-scene is shown that shows how the love story progresses, usually in a slightly comical way (e.g., after singing his song underneath the tree, the boy is devastated to see the girl he's trying to impress still leaves him there - upon which a meteor falls down from above and destroys the entire scene, comically reflecting the boy's feelings).

The game is currently designed to be played twice over four play sessions: once in story mode and another time where one can skip the cut-scenes and focus on getting high scores. Specifically, during the first session, the first two levels can be played; during the second session, levels 3, 4 and 5 are played, and the special blue go-cue is introduced. In the third session, levels 1 through 3 are played again, but this time the difficulty is increased a bit by introducing the additional response keys. During the fourth session, levels 4 and 5 are played again, as well as a new sixth level, which is an 'endless' level, allowing players to keep going until they want to quit, or until the time limit is reached. This free play time will be used as a behavioral measure of motivation to play the game.

2.2   Study Design and Procedure

The study will include three experimental groups (N = 150): *The Fling* with active training elements (the Game-training condition); *The Fling* without training elements as a control measure for the training aspect (the Placebo condition, using only go-cues) and a standard non-game control training to evaluate the added value of the game elements (the Non-Game training condition). The training will be divided over four ten-minute sessions spread over four weeks. Immediately before the first training session a baseline assessment will take place for 20 min. Following the last training, another assessment will take place for 20 min. All training sessions will take place at schools and are performed under the guidance of trained research assistants. The training and assessments are individually completed on notebooks and each participant has a headphone. A brief (one minute) three-month follow-up assessment will be presented through email. Passive informed consent will be obtained from the adolescents' parents through letters sent by the schools two weeks before the first session. The adolescents will be informed that participation in the study is entirely voluntary and that no information will be shared with their school. Before they start, the adolescents will also give active consent to their participation in the study. They can earn a ten Euro gift voucher to be used in a large online store, when they complete the entire training and follow-up assessment. The Ethical Review Board of Utrecht University has approved the study, protocol number #FETC16-064, and the study has been registered at The Netherlands National Trial Register (registry number forthcoming).

The effectiveness of *The Fling* will be evaluated based on its ability to increase behavioral control and subsequently reduce of adolescents' drinking behavior, as well as being fun to play, as measured by self-reported questionnaires and actual play time. It is expected that participants in the Game- and Non-game training conditions will show an increase in behavioral control, and in effect a reduction in alcohol drinking, over time, whereas participants in the Placebo condition do not. The Placebo and the Game training are expected to be more fun to do than the Non-game training.

2.3   Sample

For this study we will target students in mainstream education, specifically in the vocational tracks as these children tend to show most attention and concentration related problems [27] and for that reason may benefit most from the motivating game elements.

Because of these problems, these are also children that typically are at risk of developing heavy alcohol drinking habits [2, 27]. The children will be 15–18 years old and we aim towards an equal distribution between boys and girls. Power analyses based on effect sizes found by Prins and colleagues [13] suggest a sample size of $N = 51$ students per condition. Since we have clear expectations about the directions of the effects, analyzing our data using inequality constrains [28] will allow us to include fewer participants (<30% in our study), meaning roughly 40 participants for each condition (see Table 1 in [29]), while maintaining power and effect size. Expecting at least some level of drop-out in the study, the aim is to include up to 50 participants per condition.

2.4   Materials

Questionnaires. At baseline, demographic information (e.g., age, sex, level of education) will be assessed, as well as month and year prevalence of alcohol use, and frequency of smoking behavior and cannabis use (conf. [30, 31]). Both before and after training, the recent level of alcohol use will be assessed using a quantity by frequency measure (i.e., drinking days during the week and weekend multiplied by average drinks on a drinking day in the weekend and/or during the week). As a measure of inhibitory control, the 13-item Brief Self-Report Scale (BSCS) [32] will be conducted both before and after the training. After training, we will inquire about experience with computer games in general and evaluate the (game or non-game) training with a number of questions specifically developed for this project.

Assessment Tasks. To ascertain the effect of the training on cognitive control, two measures will be used. First, a Stop-Signal Task [SST; 18] will be used to measure inhibitory control before and after training (and an extra assessment after two training sessions). In this task, participants are instructed to respond as quickly and accurately as possible to the direction (left or right) of a green arrow. However, when the green arrow turns red (a stop signal), they are instructed to withhold their response. A Stop-Signal Reaction Time (SSRT) can be calculated from this task, indicating the adolescent's ability to inhibit certain responses. As delay of gratification also relates to working memory [33] and is an important aspect of behavioral control (cf. [3]), a computerized version of the Self-Ordered Pointing Task (SOPT; [34]) will be used to assess working memory capacity (WMC). The SOPT presents participants with a grid of pictures of concrete or abstract objects with the instruction to click on each picture only once. After each click, the pictures are shuffled and presented again, until the number of responses matches the number of pictures presented in the grid. The task starts with a practice block of 4 pictures, followed by several test blocks with increasing numbers of pictures. The total number of unique pictures selected can be used as a measure of WMC.

Training Tasks. The training tasks used in this study, including The Fling, are based on the stop-signal paradigm. Participants are presented with a minimum of 200–300 training trials per level, depending on the duration of the song. 75% of the trials are go-trials and 25% stop trials. In contrast, while being visually and procedurally similar to the Game condition, the Placebo condition will feature only go-signals. This essentially makes the

PG-training somewhat easier and, most importantly, not focused on inhibition. Finally, the Non-Game condition will be a stop-signal training more closely matched to the original paradigm, without music or game elements. The amount of training is matched in terms of training time, rather than number of trials, but should be roughly equal between conditions. Figure 2 shows a trial in the Non-Game version of the training.
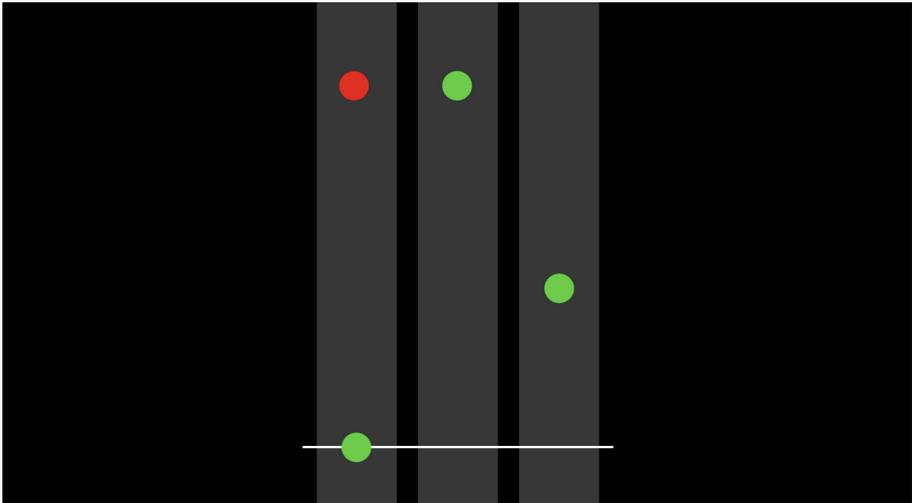

Fig. 2. The stop-signal paradigm as used in the active non-game training condition. Green cues signal go-responses and green cues that have turned red signal stop-responses. (Color figure online)

3   Conclusions and Future Work

The study described in this paper aims to evaluate a new cognitive training game called *The Fling*. The Fling aims to offer adolescents a motivating environment to increase their levels of cognitive control, without stigmatizing messages about the negative effects of alcohol use. Effectivity of the game in terms of motivation and cognitive improvement will be evaluated in the upcoming study.

While serious games have certainly gained in popularity over the last few years, it remains important to include a firm scientific basis in the design process. One way to safeguard this is to describe the development process of serious games as well as the theoretical basis which is the guiding principle of the serious game. We hope that this paper may give insight into some of the challenges and opportunities serious game development has to offer, specifically when it involves cognitive training.

In addition to the study described in this paper we plan to continue development of *The Fling* into a mobile app to test it among a broader audience with fewer limits on play time. That way we can ascertain the possibly beneficial effects of prolonged training, but also determine if fatigue may start to play a role. A central question in serious game development is for how long games can manage to raise levels of

motivation beyond that observed in regular training. Indeed, a recent study [35] showed that when participants' motivation to play drops after some time, it may even go below that found in a non-gamified counterpart, which can potentially have negative effects. As such, extensive evaluation of any serious game is to be advised, preferably using a randomized-controlled study design. Finally, it should be noted that, in theory, using games to prevent problematic alcohol use could lead to problems related to addictive gaming in some participants. Although the current, small number of supervised training sessions with game elements seems very unlikely to be sufficient to elicit, or even trigger, addictive gaming behavior, we have included several measures of the amount of gaming activity.

The current study emphasizes the importance of presenting interventions in a form that adolescents can relate to, without losing scientific integrity [12]. Serious games may be uniquely suitable to bridge the gap between an evidence-based training paradigm and an attractive, motivating training environment.

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