A Mobile Version of Cognitive Bias Modification as Alcohol Avoidance Training: measuring its psychometric qualities

Milan Quinten Verhoeven (s1806890)

University of Twente, Faculty of Behavioural, Management and Social Sciences, Department of Psychology, Positive Psychology and Technology, Enschede, the Netherlands

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First supervisor: Dr. Marcel Pieterse

Second supervisor: Dr. Thomas Rompay

External supervisor: Drs. Melissa Laurens

External organization: Tactus Addiction Treatment

Abstract

Background: Excessive alcohol consumption has great effects on mortality rates, social costs and economic costs. Dual-process models offer an explanation for voluntarily structurally high alcohol consumption, which subsequently form a possible target for therapy. Cognitive Bias Modification (CBM) aims to change the alcohol-approach bias in heavy drinking individuals, and, thereby, reduce their alcohol consumption. The *Breindebaas* application is one of the first mobile versions of CBM which makes this form of therapy easier to access. The current study focuses on the psychometric properties of the *Breindebaas* application within the scope of a self-selected non-clinical sample.

Methods: Participants (n = 19), whom consisted mostly out of students, were asked to complete a survey and work with the *Breindebaas* application for four days. The initial survey included demographic questions, and measurement scales for alcohol consumption, conscientiousness, and for motivation. Next, the participants were instructed to complete a measurement session on the first two days, complete a training session and a measurement session on the third day, and complete another measurement session on the eight day. The current study aims to identify predictors and moderators that explain the differences in the alcohol-approach bias score (AABS).

Results: The current study does not find significant results for the test-retest reliability feature of the *Breindebaas* application. Additionally, the correlational analyses between alcohol consumption measures and the alcohol-approach bias was found to be insignificant. The reduction in AABSs after CBM was also found to be insignificant. The current study did find the AABSs to increase back to baseline after a 5-day period after training. The moderation effects of motivation and conscientiousness were found to be insignificant.

Conclusion: The mobile version *Breindebaas* was tested for its psychometric qualities in a non-clinical setting by a selection of students. The current study does not find significant associations for most of the hypotheses. An explanation for this, that is in line with former studies on mobile CBM, is that the sample consists mostly out of students. Findings are different compared to an actual clinical setting. Investment, motivation and alcohol dependency cannot be imitated by the current study.

Introduction

Excessive alcohol consumption

Excessive alcohol consumption is one of the most common health problems globally. It is responsible for an estimated 3 million deaths a year, which makes the effects on mortality greater than the effects of tuberculosis, diabetes, and HIV/AIDS (WHO, 2018). Additionally, 4.6% of the global disability-adjusted life-years can be attributed to alcohol consumption, making its effects on the public's health detrimental (Rehm *et al.*, 2009). Excessive alcohol use also accounts for social and economic costs. The net costs of alcohol were estimated to be around 2.5 billion euro's in 2013 by the Dutch National Institute for Public Health and the Environment (de Wit *et al.*, 2016). These costs include the social impacts that are expressed in monetary terms. Excessive alcohol consumption is defined by a weekly consumption of more than 21 units of alcohol by males and more than 14 units of alcohol by females. This was accountable for 8.5% of people aged 18 or higher of the Dutch population back in 2019 (Volksgezondheidenzorg, 2021). In case of alcohol consumption, repeated intake can lead to alcohol use disorders (AUD), as described by the DSM-V criteria (American Psychiatric Association, 2013). Evidently, the need for counteractive measures against excessive alcohol consumption is high.

Due to the effects on the public's health, the social effects, and the economic costs, a diversity of treatment plans have been composed. The Dutch National Institute for Public Health and the Environment refer to a website named 'minderdrinken' containing a program for adults who want to reduce their alcohol consumption, or stop entirely (Rijksoverheid, 2021). The general practitioner, local GGD, or psychologist are also mentioned as help in treatment towards alcohol addiction. Moreover, alcohol addiction treatment organizations have been developed with the aim of reducing alcohol addiction in a variety of ways. One of which is Tactus Verslavingszorg, which aims to reduce alcohol addiction by use of interventions, consultation, and crisis admissions (Tactus, 2021). Within this organization, interventions are developed that are tailored to the preferences of the client. The main aim of these interventions is to reduce alcohol consumption.

Dual-process models

A structurally high alcohol consumption can be explained by dual-process models of alcohol

addiction. Traditionally, the dual-process models describe two ways of thinking – namely, an 'impulsive' and 'reflective' pathway (Strack & Deutsch, 2004; Wiers *et al.,* 2010[a]). The impulsive pathway refers to an individual's approach oriented system in which action tendencies towards alcohol have become relatively automatic (Carbia, Corral, Doallo & Caamaño-Isorna, 2018; Wiers *et al.*, 2007). This pathway is linked to associative and motivational orientations (Strack & Deutsch, 2004). The other pathway – the reflective pathway – consciously evaluates the decision to make (Moss & Albery, 2009; Wiers *et al.,* 2010[a]). The reflective pathway would take into the account the advantages and disadvantages in order to adjust the behaviour. Carbia, *et al.* (2018) state that executive functions like working memory and cognitive flexibility are associated with the reflective pathway. In case of increasing alcohol intake, this form of self-regulation has become under-activated, whereas the impulsive pathway has become over-activated (Lannoy, Billieux & Maurage, 2014; Moss & Albery, 2009). This imbalance triggers early alcohol abuse, since appetitive motivation to consume alcohol outweigh the knowledge about the negative consequences of excessive alcohol consumption (Field, Schoenmakers & Wiers, 2008; Wiers *et al.*, 2007).

The automatic action tendencies towards alcohol are related to the context of the impulsive pathway of the dual-process model. This can be contextualized as the 'alcohol-approach bias' (Palfai & Ostafin, 2003; Wiers *et al.*, 2010[a]). Cognitive biases, like the alcohol-approach bias, are based on associative learning processes (Boffo, Pronk, Wiers & Mannarini, 2015). These are cognitive processes that have been formed to be involuntary and difficult to control. Other examples of cognitive biases in relation to alcohol are selective attention and memory bias in favour of alcohol related stimuli (Wiers, Gladwin, Hofmann, Salemink & Ridderinkhof, 2013). In case of a cognitive bias towards alcohol, the cues related to alcohol are automatically processed quicker than other cues in the environment (MacLeod & Mathews, 2012). Former research concludes that the alcohol-approach bias is linked to an increased alcohol consumption (Wiers *et al.*, 2007; Wiers *et al.*, 2010[a]).

Cognitive Bias Modification

Cognitive biases form an interesting target for treatment procedures to reduce alcohol consumption. Automatic processes that influence alcohol addiction can be manipulated by use of Cognitive Bias

Modification (CBM). One way to use this approach is to use computerized tasks to manipulate cognitive biases, like the Approach Avoidance Task (AAT) (Eberl *et al.*, 2013; Wiers *et al.*, 2011). The AAT measures reaction times (RTs) to visual stimuli in order to calculate biases within the impulsive action tendencies. The AAT was originally designed for anxiety disorders, yet was found to also be applicable for alcohol approach biases (Rinck & Becker, 2007; Wiers, Rinck, Dictus & van den Wildenberg, 2009). Wiers *et al.* (2010[b]) conducted an experiment with an adapted version of AAT – that is, the Alcohol Approach Avoidance Task (A-AAT). Images containing alcoholic or non-alcoholic beverages were presented on a screen. Approaching an image was simulated by pulling a joystick towards themselves, whereas avoidance was simulated by pushing the joystick away from themselves. Differences in RTs in the behaviours in response to the presented stimuli were then used to calculate an indication of the strength of the automatically activated action tendencies. The behavioural cues that have been added form the embodiment of the cognitive processes (Neumann & Strack, 2000; Wiers *et al.*, 2011). Palfai (2006) found that men drank more beer in a taste test when action primed to lift a glass as compared to men whom were action primed to lean towards a glass. Researchers have argued that associations and movements are crucial ingredients for A-AAT to be effective. The original CBM methods, such as the A-AAT, make use of the behavioural cues in computerized form.

The A-AAT was found to accurately predict alcohol consumption via the alcohol-approach bias (Eberl *et al.*, 2013; Wiers *et al.*, 2010[b]; Wiers *et al.*, 2011). Therefore, the first studies using A-AAT investigated if the alcohol-approach bias actually correlated with drinking behaviour. These promising results have made the bias an interesting target to modify. In order to modify the alcohol-approach bias, an alcohol avoidance training was adapted from the original A-AAT (Wiers *et al.*, 2010[b]). The Approach Avoidance Task-Training (AAT-T) provided promising results for retraining the alcohol approach bias. Other studies have also found a beneficial effect of AAT-T for appetitive cues on consumption, relapse rates, and self-reported measures of behaviour (Kakoschke, Kemps, Tiggemann, 2017).

Breindebaas

New technologies have opened up possibilities to tailor the AAT and the AAT-T to more personal settings. Originally, CBM Alcohol Avoidance Training was offered via a computer in clinical settings. However, an application on a mobile device might make CBM easier to access and reduce dropout rates that were high in computerized training interventions (Wiers *et al.*, 2015). Laurens *et al.* (2020) introduced a mobile translation of the CBM Alcohol Avoidance Training called *Breindebaas*, as developed by Tactus Verslavingszorg (Tactus Verslavingszorg, n.D.). The application mimics AAT-T function from the computerized version by having the participant swipe alcoholic beverages away from oneself, whilst swiping non-alcoholic beverages towards oneself. A feasibility study conducted by Laurens *et al.* (2020) tested the *Breindebaas* application in its usability and its effect on alcohol consumption and found positive results. A reduction of eight standard glasses of alcohol a week was found when participants used the application for three consecutive weeks, with a subsequent reduction of approximately six units at three months for follow-up responders. Alcohol-consumption remained reduced four months after the training sessions. However, whether the *Breindebaas* application actually modifies the alcohol-approach bias has not been investigated. In former CBM studies that offered CBM computerized and online, the findings were largely found to be non-significant (Macleod & Clarke, 2015). A hypothesised explanation for this is the lack of embodied cognition as explained by Palfai (2006). Whether this is also the case in alcohol tailored CBM remains to be investigated by use of the *Breindebaas* application. In order to do so, the alcohol-approach bias should be investigated before and after using the AAT-T function of the application. Then, the causality towards the reduction in alcohol consumption can be explored.

In the updated version of the *Breindebaas* application, the AAT got included as a measurement function for the alcohol approach bias. This feature of the application provides the user with 60 images of alcoholic and non-alcoholic drinks. The images have to be swiped either towards or away from the user, which simulates an approach or avoid movement. Importantly, the images turn smaller when they are swiped away, whilst turning bigger when swiped towards the participant. This 'zooming function' generates the sensation of approaching and avoiding movements. This body-reference interpretation is added in order to disambiguate the association between the swiping

movement and the sensation of the drink coming closer or further away from the body (Rinck & Becker, 2007). The intention of this feature is to mimic the visual impression of either 'taking' a drink or 'refusing' it. The user is asked to swipe alcoholic drinks away from oneself and non-alcoholic drinks towards oneself for the first 30 images. This is in congruence with avoiding alcoholic beverages. Then, immediately after, the user is required to reverse his swiping pattern so that the alcoholic drinks are swiped towards the user. This is in congruence with approaching alcoholic beverages. Both the avoidance task and the approach task can be used to calculate the individuals tendency to either one of the behaviours in response to alcohol. The relative score between the two is used to measure the Alcohol Approach Bias Score (AABS). This new feature of the application provides the possibility to measure the change in approach bias over time, and whether this mediates the positive effect of the AAT-T on alcohol consumption (Sharbanee *et al.*, 2014).

The CBM method that is AAT-T aims to modify cognitive biases. It has been concluded that CBM often leads to a decrease in the approach-bias after treatment in a clinical setting (Gladwin, Wiers & Wiers, 2017; Grafton *et al.*, 2017). Additionally, Wiers, Rinck, Kordts, Houben and Strack (2010[b]) had conducted a proof-of-concept study which concluded that the approach and avoidance bias could be manipulated by training. A randomized clinical trial was conducted by use of a approach-bias retraining, a placebo-training, and no training. The group retraining the approach-bias showed a stronger reduction in AABSs as compared to the placebo-training group, and the no training group. The AAT-T was proven to be a reliable task for modifying the alcohol-approach bias of its participants. Since the reduction in alcohol consumption has already been found for the *Breindebaas* application, it can be hypothesised that this was caused by the similar reduction in the cognitive bias after treatment in a clinical setting. A correlation between drinking behaviour at baseline and the alcohol-approach bias at baseline would prove *Breindebaas* to address the same phenomenon as the original AAT-T. The reduction in alcohol consumption in clinical studies might be caused by a change in the alcohol-approach bias after CBM. Automated and online interventions have, thus far, been very promising for treating problem drinking (Riper, 2014). However, the efficacy of the CBM as seen in clinical settings might be reduced since the physical act of avoidance and approach behaviour that were mimicked by pushing and pulling a joystick are no longer part of the mobile version. Yet, the

identical reduction in alcohol consumption after CBM for both the clinical setting and the *Breindebaas* application might suggest that the same underlying principle is active.

Insight into the psychometric qualities of the *Breindebaas* application might help conclude that the *Breindebaas* application actually modifies the alcohol approach bias of its participants. For this, both the validity and reliability of the CBM features of the application need to be investigated. Firstly, to test the reliability of this mobile version of A-AAT, a test-retest measure needs to be taken. A high test-retest reliability would suggest that the alcohol-approach bias at baseline is measured accurately. The effectiveness of the training feature can be analysed by showing a significant reduction in AABS after training. Secondly, in order to test the validity of this mobile version, additional constructs will need to be measured that can theoretically explain the AABSs at baseline and after training. Therefore, correlations between predictors of the alcohol-approach bias at baseline might validate that the AABSs actually refer to the alcohol-approach bias.

Moreover, the effects of training have been found to endure over time. Wiers *et al.* (2011) found that trained patients were less likely to have relapsed one year after the AAT program as compared to patients that had no training. This effect on relapse rates was later replicated and was found to be caused by a change in approach-bias (Eberl *et al.*, 2013). There appears to be a mechanism at hand which suggests that the effects of CBM are endured over time. Whether the hypothetical effects of CBM in case of the *Breindebaas* application also remain present over time is still to be investigated. In case of the replication study conducted by Eberl *et al.* (2003), participants were treated for a period of three months. The relapse rates were measured at a one-year follow-up. Based on this ratio of 1:4, the current study measures the alcohol-approach bias after a period of 4 days after the CBM has been completed to see if the effects of CBM endure.

Alcohol related predictors

The updated *Breindebaas* application provides the opportunity to measure the AABS before and after training. Evidently, predictors for an effective training can be taken into account. A systematic review conducted by Adamson, Douglas Sellman and Frampton (2009) concluded that dependence severity, consumption level, and motivation were the most consistent predictors of a positive treatment outcome

in 'normal' clinical settings. Dependence severity and consumption level can be measured by use of the Alcohol Use Disorders Test (AUDIT) (Babor *et al.*, 2001). In case of CBM, some similar predictors as in the 'normal' clinical setting have been found. Laurens *et al.* (2020) found that high levels of baseline craving and a high AUDIT score showed a significant effect to reduce alcohol consumption. Dependence severity has been closely associated with high levels of alcohol consumption and a strong approach bias (Dwivedi, Chatterje & Singh, 2017; Eberl *et al.*, 2013). It appears to be that patients with a strong approach bias – and thus, a strong dependence severity and high consumption levels – are most likely to benefit from the CBM training.

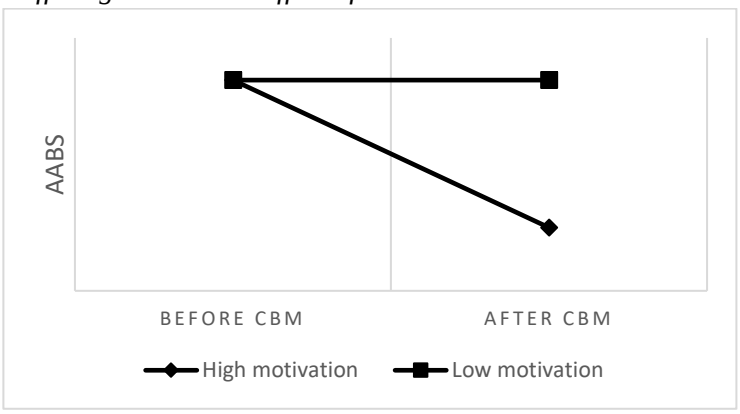
Moderation effects of motivation

As explained by the dual-process model of alcohol addiction, appetitive motivation in alcohol-approach associations are formed by the impulsive pathway which causes the action tendencies towards alcohol to have become relatively automatic (Wiers *et al.*, 2007). In turn, this can be linked to dependence severity which has been noted to predict an effective treatment outcome of CBM. Appetitive motivation is, thereby, closely linked to the alcohol-approach bias.

Motivation also plays an important role in the reflective pathway as explained in the dual-process model of alcohol addiction. Note that this form of motivation is different from appetitive motivation. The amount of alcohol consumed and the subsequent alcohol-related problems are a common contributor to higher levels of reflective motivation to change the addictive behaviour (Shealy, Murphy, Borsari & Correira, 2007). Gladwin, Wiers & Wiers (2017) state that adequate motivation-to-change by use of the reflective pathway is necessary for CBM to be effective. CBM has been found to be less effective when it was provided online for nonclinical volunteers (Wiers *et al.* 2018). As has been stated, the reflective pathway is hypoactive for individuals that have a strong alcohol-approach bias. It can be hypothesised that motivation-to-change counteracts this hypoactivity of the reflective pathway. Therefore, higher levels of reflective motivation to reduce alcohol consumption are expected to predict the effectivity of the training feature of the *Breindebaas* application. The buffering moderation role of motivation that is expected can be seen in Figure 1.

Figure 1

Buffering moderation effect of motivation



Conscientiousness

The Alcohol-approach bias is expected to be reduced after training with the *Breindebaas* application. However, in order to test the validity of the alcohol-approach bias measurement of the app, a construct that is linked to the alcohol-approach bias needs to be applied. One optional personality trait that could be applied is 'conscientiousness'. The personality trait of conscientiousness is defined as 'the general tendency to be organized, disciplined, and work hard' (Friedman, Kern, Hampson & Duckworth, 2014; Roberts, Walton & Bogg, 2005). Thus far, a highly consistent correlation between conscientiousness and substance-use behaviours has been demonstrated. As a matter of fact, a meta-analysis of 194 studies found that conscientiousness negatively correlates with drug use, including excessive alcohol consumption (Bogg & Roberts, 2004). In other words, people high in conscientiousness are less likely to develop AUD.

It can be hypothesised that individuals high in conscientiousness have a lower alcohol-approach bias on average. It has been found that conscientiousness negatively correlates with impulsivity, and positively with self-control (Mao *et al.*, 2018). Taken into account the dual-process theory of alcohol addiction, the above mentioned correlations might support the hypothesis. It has been stated that the impulsive pathway has become over-activated which leads to automatic action tendencies to approach alcohol. This over-activation of the impulsive pathway might be less applicable to individuals high in conscientiousness as indicated by the negative correlation between impulsivity and conscientiousness. Moreover, the dual-process model of alcohol addiction suggests an under-

active reflective pathway. People high in conscientiousness portray high levels of self-regulation which would suggest that their personality trait protects them from gaining an under-active reflective pathway (Lenzenweger, 2005).

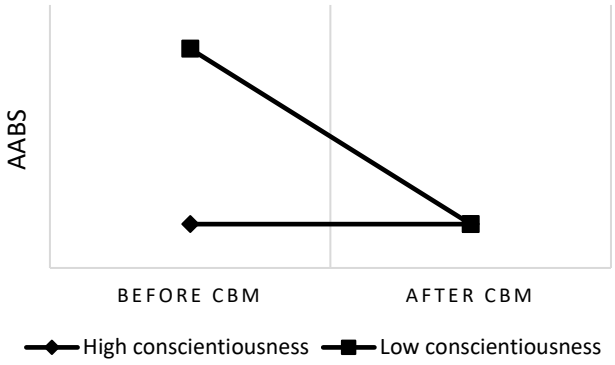
In combination, both pathways of the dual-process model of alcohol addiction are supportive of the argument that highly conscientious individuals would be driven by the alcohol-approach bias less. Direct literature on the association between conscientiousness and the alcohol-approach bias cannot be found. However, conscientiousness has been reviewed in relation to alcohol consumption. A meta-analysis conducted by Hakuninen *et al.* (2015) examined personality traits in combination with alcohol consumption among 72,949 adults and found that people with moderate alcohol consumption who were low in conscientiousness had an increased risk to develop heavy alcohol consumption over time. The current study would hypothesise that this finding is related to peoples propensity to be driven by the alcohol-approach bias as an early stage to develop an AUD. The drive for people to drink excessively is expected to come forth out of the alcohol-approach bias for which individuals whom are low in conscientiousness fall more easily victim to.

The above mentioned theory might give an indication on how conscientiousness might predict the alcohol-approach bias at baseline. This way, conscientiousness might also offer insight into the moderation of the AABS. People low in conscientiousness are more likely to have an alcohol-approach bias at baseline as explained by the dual-process model of alcohol addiction. A study conducted by Eberl *et al.* (2013) showed that a high alcohol-approach bias at baseline was a good predictor for its own decrease after CBM. This would mean that people low in conscientiousness are more likely to benefit from CBM in reducing their alcohol-approach bias.

The effect of CBM on the alcohol approach bias might differ for people low in conscientiousness compared to people high in conscientiousness. People high in conscientiousness are expected to have a lower alcohol-approach bias at baseline on average. This would subsequently mean that CBM would have less effect for these individuals. This hypothetical buffering moderation effect of conscientiousness is shown in Figure 2.

Figure 2

Buffering moderation effect of conscientiousness



People who score low on the conscientiousness subscale (the BFI-C) are expected to benefit more from CBM (John & Srivastava, 1999).

Current study

The effect of CBM on the alcohol approach bias and drinking behaviour has been investigated with patients in clinical settings. CBM was found to have a decrease in cognitive bias, and an additional decrease in the amount of alcohol consumed after training (Sharbanee *et al.*, 2014; Gladwin, Wiers & Wiers, 2017; Grafton *et al.*, 2017). The current study focuses on the psychometric properties of AAT and AAT-T in the *Breindebaas* application, its association with drinking behaviour at baseline, and how conscientiousness moderates the effect of training on the alcohol-approach bias.

Two measurement scales will be applied the answer the study questions. Firstly, the Alcohol TLFB will be used to assess alcohol consumption over a period of time (Sobell & Sobell, 1995). Secondly, conscientiousness will be measured by use of the Big Five Inventory – Conscientiousness subscale (BFI-C) (John & Srivastava, 1999). By help of these measurements, the following research questions will be answered:

(1) *'Does the test-retest reliability test provide significant results for the AABSs at baseline?'*. One of the psychometric properties that will be investigated is the test-retest reliability of the measurement feature of the *Breindebaas* application. The first two measurements in this study will be analysed in their consistency.

(2) *'Is there a significant effect of CBM on the AABSs?'.* A change in AABSs after CBM would

suggest an effect of the training feature of the *Breindebaas* application to have occurred. Positive results of modifying the alcohol-approach bias by use of an alcohol avoidance training have been found (Wiers *et al.*, 2010[b]). The current study investigates whether a similar positive effect can be found for mobile derivatives, such as the *Breindebaas* application.

(3) *'Does the effect of CBM on AABS change after a 5 day period?'*. If a significant effect of the training feature on the AABSs has been found, the lasting effect of the training feature can be measured. The rapidness of this decrease after 5 days of training will be analysed to give an indication for the endurance of the effects of the alcohol-avoidance training.

(4) *'Is there a significant positive correlation between the AABS at baseline, and the Alcohol TLFB at baseline and monthly binge-drinking frequency?* As has been stated, a high alcohol-approach bias at baseline is positively correlated with alcohol consumption. Whether this is the case for the measurement feature of the *Breindebaas* application is yet to be investigated. The current study investigates the correlation between drinking behaviour at baseline to the alcohol-approach bias at baseline.

(5) 'Is there a significant negative correlation between the AABS at baseline, and the BFI-C?'. Theoretically, people low in conscientiousness who have a moderate alcohol consumption are more likely to develop an AUD. It has been hypothesised that this causation is expected to be driven by the alcohol-approach bias. Whether the two are related, remains to be investigated. The BFI-C is expected to correlate negatively with the AABS at baseline.

(6) *'Do people low in conscientiousness show a stronger response to CBM on the AABSs?'.* If conscientiousness has a buffering moderation effect on the AABSs after CBM, highly conscientious individuals would show a significantly weaker reduction in AABS than individuals who have a low BFI-C score. The buffering moderation effect is, thereby, expected to become active for people low in conscientiousness.

(7) *'Do people with motivation to change their drinking behaviour show a stronger response to CBM on the AABSs?'* In order to find a significant effect of CBM on the AABSs an adequate motivation-to-change is necessary (Gladwin, Wiers & Wiers, 2017). This hypothesis is in line with the

dual-process models, as motivation-to-change is expected to counteract the hypoactivity of the reflective pathway.

Methods

Design

The current study consists out of three parts. In the first part a cross-sectional design was deployed which consisted of a questionnaire designed by the use of *Qualtrics*. The second part used an interrupted time series design in which participants had to download the *Breindebaas* application and complete the measurement feature of the CBM twice. Thereafter, participants were asked to complete the training feature of the CBM with a consecutive completion of the measurement again. The last part of the study complimented the interrupted time series design of the study, which was held after one week with a subsequent completion of the measurement feature of the *Breindebaas* application.

Due to inconveniences with the *Breindebaas* application, the initial data collection could not be downloaded. Participants were, therefore, asked to participate a second time. The information gathered from the survey was kept from the initial data collection. Subsequently, the information gathered by the second data collection from the *Breindebaas* application was combined to the survey dataset.

Participants

Participants were requited by use of self-selection and the SONA test subject pool. The self-selection procedure made use of convenience sampling by use of personal networks, and social media networks (e.g. Facebook). The inclusion criteria that had to be met was that participants: 1) had to be at least eighteen years old at the start of the data collection; 2) had to have access to an Android phone (e.g. Samsung, or LG); 3) had the ability to read English; 4) had signed the informed consent. After the collection of data, the IDs of the participants were made anonymous.

Intervention

Breindebaas. *Breindebaas* is an application that has been developed by the Dutch company Tactus Verslavingszorg (2021). The University of Amsterdam, University of Twente, and the Saxion

University of Applied Sciences cooperated in the development of the application (Laurens *et al.*, 2020). The current 2.0.3 version was launched in June 2021 with the aim to 1) measure the alcohol-approach bias of its users; 2) reduce the alcohol-approach bias by use of a training feature.

In the training feature of the application, users were asked to swipe a total of 100 pictures. 50 of these pictures were pictures of alcoholic beverages which had to be swiped away from the user, representing an avoidance movement. The other 50 of the pictures were pictures of non-alcoholic beverages which had to be swiped towards the user, representing an approach movement. In the measurement feature of the application, participants were asked to swipe a total of 60 pictures. 30 of these pictures were pictures of alcoholic beverages with another 30 pictures being pictures of non-alcoholic beverages. The participants were instructed to swipe alcohol away from them for the first 30 pictures. For the remaining 30 pictures, the pairing of the image category and the swipe direction got reversed. This means that the last 30 pictures had the instruction of swiping alcoholic pictures towards themselves. In both features of the *Breindebaas* application, participants were instructed to respond as quickly as possible and without mistakes in order to get the best score. In the end, a total AABS was calculated based on the RTs of the participants. This score was also shown on their screen.

Before users of the application can start with the training and measurement sessions, they had to select images of alcoholic and non-alcoholic beverages of their preference. For both categories of images, 10 to 20 images had to be selected. Based on the incentive-sensitisation theory of addiction, the alcohol-approach bias may be more accurately identified when images are personalised and, thus, more relevant to the user (Robinson & Berridge, 2008). Therefore, the personalised feature will also be used in the current study. The personal selection of the images had to be selected prior to the first measurement, and would be used for all training sessions and measurement sessions for within-subject consistency.

As of current, the new 2.0.3 version is only downloadable on Android devices. This study will use both of the features of the application in order to test for the validity and reliability of the *Breindebaas* application.

Procedure

Participation was voluntary and participants were free to dropout at any time during the study. Additionally, participants were informed about the minimization of risks, and the confidentiality of the answers given to the study, which had been treated anonymously. The study was approved by the Ethical Committee of the Faculty BMS of the University of Twente under the ethics board number 190373 in April of 2021.

Participants received a questionnaire that was designed by the use of *Qualtrics*. Participants were informed about the set up and aim of the study and were informed that they had to be at least 18 years of age, and have the ability to access an Android device. Subsequently, the participants were informed that participation was completely voluntary and that no risks were involved in participating. In order to continue with the study, participants had to agree with an informed consent and verify that they were at least 18 years old. Participants who could not confirm that they were at least 18 years old were thanked for their interest in the study and were unable to continue. Participants that were able to continue were asked to provide an ID which they would also use to identify themselves on the *Breindebaas* application. These IDs started with 'BT2021' and ended with their date of birth. After this, participants were able to complete the questionnaire.

At the end of the questionnaire, participants were thanked and redirected to the manual containing information on how to use the *Breindebaas* application (See Appendix 1). Before performing sessions on the application, participants were asked to select images of alcoholic beverages and non-alcoholic beverages that would be used in both the training and measurement sessions. The participants were instructed to select 10 images of their preference within both categories. After this, the participants were asked to work with the application for 3 consecutive days and a 4th day 5 days later. On day 1 and 2, participants had to complete a measurement session. On day 3, participants had to complete a training session with a subsequent measurement session right after. Then, on the 8th day of the study, participants had to complete a measurement session again. After the 8th day, the participants were thanked for their participation and excused.

Measures

Demographics. The online questionnaire requested the participants to provide their gender, age, and occupation. The *Breindebaas* application included a short signing up procedure in which participants were asked to provide a few baseline characteristics. These included a username, password, email address, gender, and date of birth.

Alcohol Approach Bias Score (AABS). AABSs were calculated by the *Breindebaas* application itself. The scoring algorithm was provided by Greenwald, Banaji, and Nosek (2003) and provides a measure for the strength of implicit association tests. In case of the *Breindebaas* application, the implicit association test measures one's alcohol-approach bias. The AABS was calculated by use of the reaction times of the swiping movement. Firstly, extreme outliers and extreme error rates got dropped from the data. This means that only the reaction times (RTs) between 200 and 2000 milliseconds got included into the dataset. Secondly, the correct mean RTs and standard deviations (SD) of all responses got computed. Thirdly, the incorrect RT responses got replaced by the mean RT of correct responses plus a penalty of twice the SD of correct responses. After this, the mean RTs of all responses within each response category got computed, as well as the inclusive SD, irrespective of the avoidance and approach behaviours. The categories are as follows: the avoid alcohol response (RT(alc/push)), the approach alcohol response (RT(alc/pull)), the avoid non-alcohol response (RT(non/push)), and the approach non-alcohol (RT(non/pull)). The SDs for both the alcohol and nonalcohol images were computed as well. This enabled the possibility to calculate the AABSs.

The AABSs were calculated by use of a D-score (Greenwald, Banaji, Nosek, 2003). The D-score standardizes the differences in responses by dividing the differences in RTs by the personalized SDs. Firstly, the D-score of alcoholic beverages (Alcohol D) and the D-score of non-alcoholic beverages (Non-alcohol D) were independently calculated. These D-scores represent the implicit association as assessed by the AAT. This according to the following formulas:

Alcohol D = [RT(alc/push) – RT(alc/pull)] / SD(alc), and

Non-alcohol D = [RT(non/push) – RT(non/pull)] / SD(non)

The overall AABS can be calculated by calculating the relative D-score between the two D-scores above (Greenwald, Banaji, Nosek, 2003). This was calculated as follows:

AABS = Alcohol D – Non-alcohol D

The AABSs vary between -2 and 2. A positive score resembles an alcohol-approach bias whereas a negative score resembles an alcohol-avoidance bias.

Big Five Inventory – Conscientiousness subscale (BFI-C). The Big Five Inventory (BFI) is known to be a questionnaire measuring 5 clusters of personality traits – that is, conscientiousness, neuroticism, openness, extraversion, and agreeableness (John & Srivastava, 1999). These personality traits come forth out of the Big Five Factors of Personality (Goldberg, 1993). For the current study, the Big Five Inventory – Conscientiousness subscale will be used, which are the sub questions designed to measure self-perceived conscientiousness. The complete BFI measurement scale contains 44 questions based on a five-point likert scale. Of these, 9 questions concern the personality trait of conscientiousness. This scale is labelled as follows:

1 = disagree; 2 = slightly disagree; 3 = neutral; 4 = slightly agree; 5 = agree.

Some of these items have a scoring that needs to be reversed. The sample of the current study was divided into high-scoring, middle-scoring, and low-scoring subgroups by use of a median split. The high scoring group would indicate a high level of self-perceived conscientiousness. John and Srivastava (1999) found a reliability of .82 and a standardized validity of .92 of the BFI-C subscale.

Alcohol Timeline Followback (Alcohol TLFB). Sobell and Sobell (1995) developed an instrument to measure drinking behaviour. The Alcohol TLFB makes use of a questionnaire which asks participants to estimate their daily alcohol consumption over a longer period (Sobell & Sobell, 1992). These periods can range from 1 week to 24 months prior to filling out the questionnaire. In the current study, the drinking behaviour of the 7 days prior to the start of the questionnaire has been investigated. Additionally, the participant was asked to give an estimate on how many times in the last 4 weeks 6 or more standard units of alcohol had been consumed. This is referred to as the monthly binge-drinking frequency (Piano, Mazzuco, Minkyung kang, & Phillips, 2017). Binge-drinking is defined as consuming 6 standard units of alcohol on one occasion (Mongan & Long, 2015).

The Alcohol TLFB has been analysed in its psychometric properties. Sobell, Brown, Leo and Sobell (1996) found that the Alcohol TLFB, when administered over the telephone or via computer, obtained reliable drinking data. The drinking variables showed a significant correlation for up to 90

days prior to the test of which the Pearson correlation coefficient ranged from .83 to .95.

Data analysis

Statistical Package for the Social Science (SPSS) IBM Statistics version 25.0 was used to process the collected data by *Qualtrics* and the *Breindebaas* application. The two data collections were combined by use of the identical IDs in both systems. The descriptive characteristics were analysed. For the variable 'age' the mean and standard deviation were calculated, and the 'gender' and 'profession' variables were analysed for their distribution. Moreover, all continuous variables were checked for normality by use of the Shapiro-Wilk Test, since the sample was relatively small. Hypotheses were examined for significance with $p < .05$ being statistically significant. Moreover, the dataset could contain multiple specified groups, since the recruitment of participants was mostly aimed at students. For that matter, the subgroup of students was also analysed on all hypotheses in order to account for measurement invariance. The factorial invariance were only be mentioned in the results if significant results had been found for the factorial invariance of students.

The first hypothesis was tested by use of a test-retest reliability measure of the first two AABSs before CBM. For this, a reliability analysis was conducted for which the correlation and intraclass correlation coefficient (ICC) between the first AABS and the second AABS were calculated. The ICC was selected for the test-retest reliability measure, since repeated measures cannot be perceived as randomized samples (Koo & Li, 2016). Also, the agreement function of the ICC was of importance for testing the test-retest reliability of the measurement feature, since the *Breindebaas* application was the rater for both measures. Therefore, the 2-way mixed-effects model (model 3) was used with the agreement function – that is, ICC(3,1). ICC values between 0.5 and 0.75 indicate a moderate reliability, whereas ICC values higher than 0.75 indicate a good reliability (Koo & Li, 2016). Moreover, a scatterplot was composed to visually provide the differences between the linear regression of the dataset and the expectation of the hypothesis.

The second and third hypotheses were answered by use of a linear model containing the three time points in which the AABSs were measured. The first time point is the average of the 2 AABSs of the test-retest reliability, which is the AABS at baseline. The second time point is the AABS after

CBM, and the third time point is the AABS after the 5 days follow-up. These three related observations were investigated on whether the mean scores changed. A significant reduction in the AABSs after training would indicate that the training feature of the application actually modifies the AABSs. A significant increase of the AABSs after the 5 days follow-up would indicate that the modification of AABSs is not permanent. This was analysed by use of the mean, standard deviations and their post-hoc differences.

Fourthly, it has been hypothesised that the alcohol-approach bias is correlated to alcohol consumption, which will be analysed by use of a multivariate correlation analysis between all three variables – that is, the AABS at baseline, the Alcohol TLFB, and the monthly binge-drinking frequency.

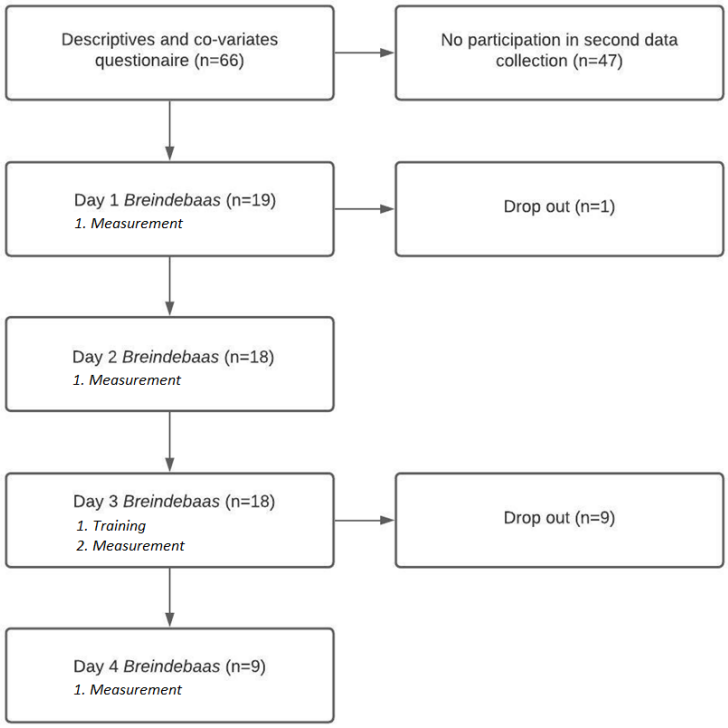
The fifth hypothesis was answered by use of a bivariate correlation analysis between the BFI-C scores and the AABS at baseline. The means and standard deviations were calculated, as well as the correlations between the variables. Subsequently, the sixth and seventh hypotheses were analysed by use of a linear mixed model analysis in order to test for differences between two subject groups – that is, people high in conscientiousness and people low in conscientiousness for the sixth hypothesis. The same accounts for the seventh hypothesis, were participants were grouped into ‘high’ and ‘low’ motivational groups. These groups were composed by use of a median split. The first factor used for this analysis was the number of the measurement, followed by the factor of the dummy variable for conscientiousness, or motivation. All factors were taken into account as fixed effects. This way, the dependent variable, the AABS, was calculated for all factors. Significance of the measures were calculated by use of a MANOVA.

Results

Figure 3 shows a participants flowchart for each day the participants were asked to participate. Of the 66 participants that completed the *Qualtrics* survey, 25 were asked to work with the *Breindebaas* application a second time of which 19 agreed to participate. The current study attempts to reject the null-hypotheses by use of an alpha level of .05 for all statistical tests.

Figure 3

Participants flowchart.



Participants' characteristics

Only the data from participants who agreed to partake in the second data collection were analysed. Of these 19 participants 68.4% were males, and 31.6% were females. Their mean age was 28.4 (SD = 14.6), ranging from 18 to 58 years old. The participants varied in their nationality. The sample consisted mostly out of pupils or students (73.7%). A total of 9 participants (47.4%) completed the follow-up experiment containing the extra measurement after 5 days. Of these full completers 77.8% were male and 22.2% were female. Their mean age was 24.9 (SD = 10.0). Table 1 shows the participants characteristics, as well as the baseline categories.

Table 1. Participant characteristics at baseline (n=19)

Variable	N	%
Age (years), mean (SD)	28.4 (14.6)	
Gender		
Male	13	68.4%
Female	6	31.6%
Occupation		
Pupil or student	14	73.7%
Paid work	4	21.1%
In search of employment	0	
Housewife	1	5.3%
Total Alcohol TLFB, mean (SD)	20.0 (23.8)	
Pupil or student	25.9 (25.0)	
Other	3.6 (6.5)	
Monthly binge-drinking frequency, mean (SD)	3.7 (3.1)	
Pupil or student	4.9 (2.8)	
Other	.4 (.9)	
BFI-C score[1]		
High (>32)	11	57.9%
Low	8	42.1%
Motivation[2]		
High (>4)	7	36.8%
Low	12	63.2%

[1] The scores were calculated from a 5-point Likert-scale containing 9 items. The categorization of high and low conscientious people was made by use of a median split

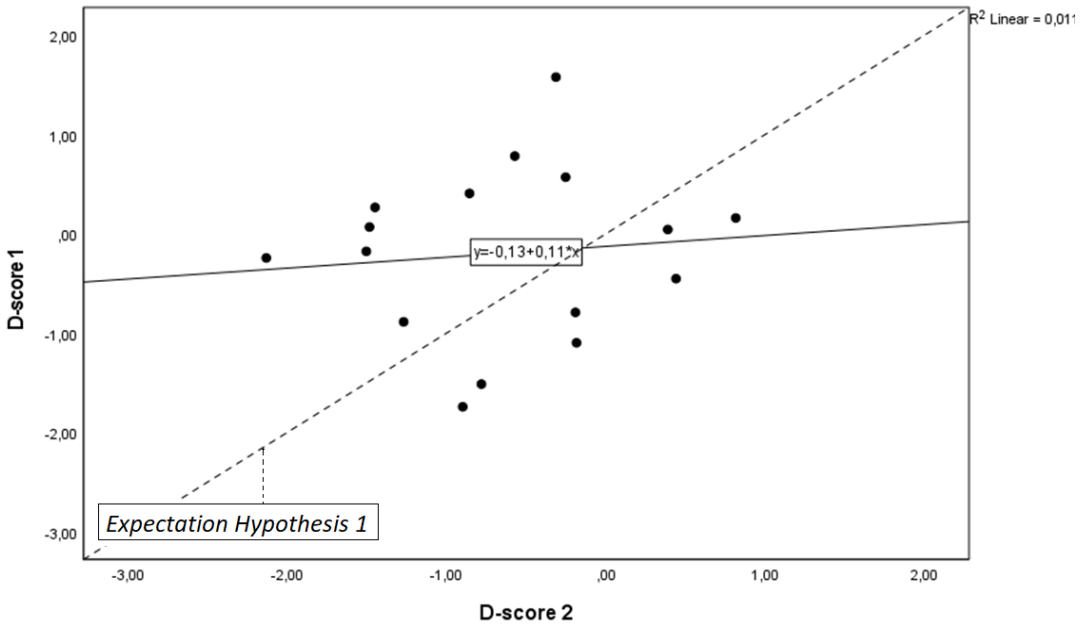
[2] The scores were calculated by use of a 5-point Likert-scale. The categorization of high and low motivation was made by use of a median split.

Test-retest reliability of the cognitive bias measure

An intraclass correlation coefficient (ICC) was calculated for the D-scores of measurement 1 and 2. The type of ICC was a Two Way Mixed format in absolute agreement. A single measures ICC score of .093 was found with a 95% confidence interval from -.313 to .503 ($F(17) = 1.228$, $p = .338$). The reliability of the measurement feature of the *Breindebaas* application appears to be low and insignificant. This concludes that the first two measurements do not correlate significantly, as also can be seen in the scatterplot in Figure 4. The spread of the scatter plot appears to be wide, which explains the low ICC score. The low ICC suggests that the A-AAT feature of the *Breindebaas* application is not a reliable measurement for the alcohol-approach bias. Therefore, the first hypothesis can be refuted.

Figure 4

Scatterplot of first two measurements prior to training.



An average score of the first two measurements prior to training was made. The average score, the first score after training, and the score after the 5 day follow-up were checked for normality. Since the study contains a small sample size, the Shapiro-Wilk Test was used. All of the above mentioned D-scores were normally distributed according to the Shapiro-Wilk Test (D = .97, p = .66; D = .98, p = .89; D = .93, p = .49). However, the measurement right after training had one outlier, namely participant 11. Next, for the analyses that focus on the factorial invariance that might be caused by the specified group of students, the normality was also tested. The D-scores were normally distributed for all measurements according to the Shapiro-Wilk Test (D = .98, p = .97; D = .97, p = .83; D = .88, p = .20). The subgroup dataset did not contain any outliers. This sample, containing students, had a single measures ICC score of .093 which was found with a 95% confidence interval from -.511 to .535 (F(13) = 1.047, p = .468). The measurement invariance test could, thereby, not find a higher test-retest reliability.

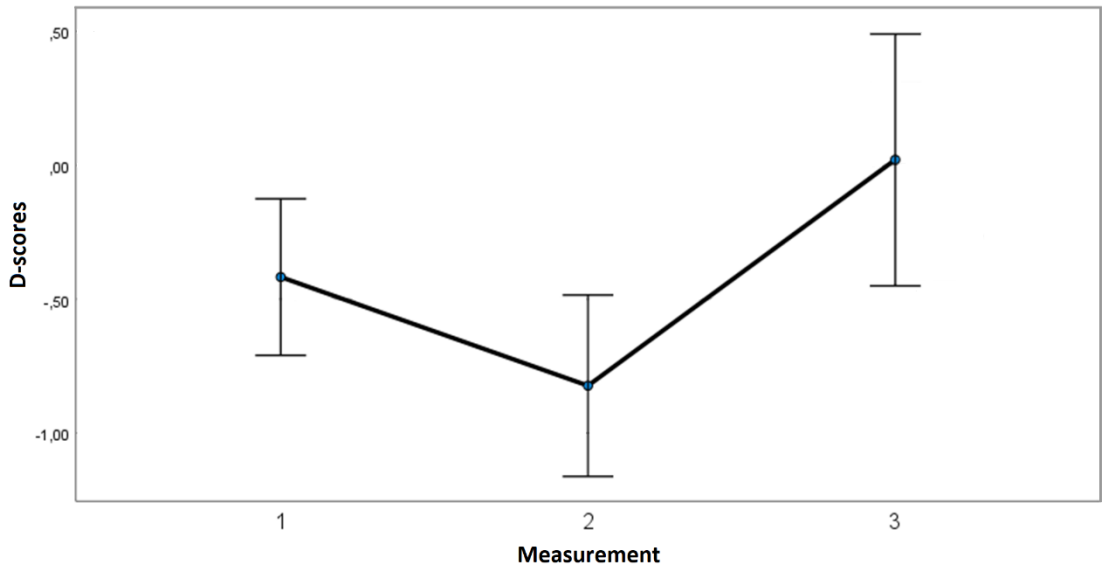
Overall alcohol-approach bias scores per session

The three time points in which the alcohol-approach bias was measured were analysed. For the first time point, the first 2 measurements prior to training were combined to get an average score. The

average score had a mean of -.42 (SD = .59). Subsequently, the A-AAT session after training had a mean score of -.82 (SD = .68). The repeated measures ANOVA found no significant differences within-subjects between the first two measurement points, $F(1,17) = 3.991$, $p = .062$. Therefore, the second hypothesis cannot be accepted. Subsequently, the third measurement was added to the general linear model. For this, only 9 participants were used whom had completed the study in full. The mean score of the last measurement after a 5 day follow-up was .02 (SD = .62). The repeated measures ANOVA found a significant differences within-subjects between the measurement right after training and the measurement at the 5 day follow-up, $F(1,8) = 16.855$, $p < .01$. Therefore, the third hypothesis can be accepted, and the AABSs increase after a period of no training. The mean scores and error bars of all measurements can be seen in Figure 5. Note that the graph contains two repeated measures ANOVA, namely of n = 18 from measurement 1 to measurement 2, and n = 9 from measurement 2 to measurement 3.

Figure 5

General linear model containing the three measurement points (prior to training, after training, and after the 5 day follow-up) with error bars.



Note. Error bars show a 95% confidence interval

Note. Mean scores are calculated by use of different n-values. Measurement 1 and 2 have n = 18, whereas measurement 3 has n = 9

The measurement invariance analysis showed non-significant results for the first two measurements as well. However, the subgroup of students also showed a significant increase in AABSs after the 5 day period without working with the application. The within-subjects effects were significant and, therefore, the third hypothesis can also be accepted for this subgroup ($F(1,7) = 2.905$, $p < .01$).

Alcohol related measures

The alcohol-related measures were first analysed for their descriptive statistics. The mean scores for the Alcohol TLFB was 20.0 (SD = 23.8), whereas the mean score for the monthly binge-drinking frequency was 3.7 (SD = 3.1). Noticeably, there is a clear distinction between two groups within the sample. The sample consists mostly out of pupils or students whom have a mean score of 25.9 (SD = 25.0) on the Alcohol TLFB, and a mean score of 4.9 (SD = 2.8) on the monthly binge-drinking frequency. These scores are considerably higher than that of the other occupations within the sample, whom have a mean score of 3.6 (SD = 6.5) on the Alcohol TLFB, and a mean score of .4 (SD = .9) on the monthly binge-drinking frequency.

Next, a multivariate correlation analysis was conducted to find predicting effects of the Alcohol TLFB, and of the monthly binge-drinking frequency on the alcohol-approach bias at baseline. These correlations can be found in Table 3.

Table 3. Pearson correlations of the Alcohol TLFB, the monthly binge-drinking frequency, and the D-score of the AABS at baseline (n = 19)

Variables	**1**	**2**	**3**
1. AABS at baseline	1		
2. Alcohol TLFB	-.20	1	
3. Monthly binge-drinking frequency	-.39	.74*	1

Note. *p < .05 level (2-tailed)

Note. The mean score of the AABS at baseline is slightly different from prior tests, namely -.35 (SD = .64), since for this analysis the data of a 19th participant is used.

The positive correlation between the Alcohol TLFB and the monthly binge-drinking frequency of .74 was proven to be significant (p = .00). This supports that the drinking behaviour in forms of binge-drinking and recent alcohol consumption are related. These alcohol related correlations were found to be slightly negative compared to the AABS at baseline. However, both correlations to the AABS at baseline were insignificant. The correlation with the Alcohol TLFB has a significance of p = .4, and

the correlation with the monthly binge-drinking frequency has a significance of p = .1. Conclusively, the fourth hypothesis cannot be accepted. Similarly, the only significant association that had been found for the subgroup of students was the correlation of .66 between the monthly binge-drinking frequency and the Alcohol TLFB (p = .01).

Conscientiousness as moderator of CBM

The total scores of the BFI-C subscale were calculated by using the sum total and taking the reversed items into account. The BFI-C subscale scores varied between 23 and 37 with a mean score of 31.5 (SD = 4.00). The Shapiro-Wilk Test showed that the BFI-C scores were normally distributed without outliers (D = .95, p = .44). Initially, the correlational analysis between the BFI-c and the AABS at baseline showed a correlation of -.14 which was proven to be insignificant (p = .57). In order to analyse the differences between peoples level of conscientiousness and the AABS at baseline further, the BFI-C subscale was used to label the participants into categories of high and low conscientiousness by use of a median split. Additionally, the differences in Alcohol TLFB and monthly binge-drinking frequency were tested for these categories, as can be seen in Table 4. The differences were tested for significance by use of a multivariate ANOVA.

Table 4. Descriptives at baseline for high conscientiousness and low conscientiousness.

	High BFI-C (n=11)		**Low BFI-C (n=8)**	
	M	**SD**	**M**	**SD**
Age	33.6	17.5	21.25	2.31
Gender (% male)	63.6%		75%	
Alcohol TLFB	16.36	17.71	25.07	30.86
Binge-drinking frequency	3.45	3.45	4.00	2.83
AABS at baseline	-.40	.61	-.28	.72

There appear to be some indications for differences between the two categories. For instance, people high in conscientiousness appear to have a lower alcohol-approach bias, as well as a lower alcohol consumption at baseline. The multivariate ANOVA showed that the differences between all values were insignificant, including the AABS at baseline for people high in conscientiousness and people low in conscientiousness ($F(1,17) = .155$, $p = .699$). Therefore, the fifth hypothesis cannot be accepted.

Next, in order to analyse the hypothesised moderation effect of conscientiousness, a linear mixed model analysis was conducted within-subject. The between-subject factor existed of two

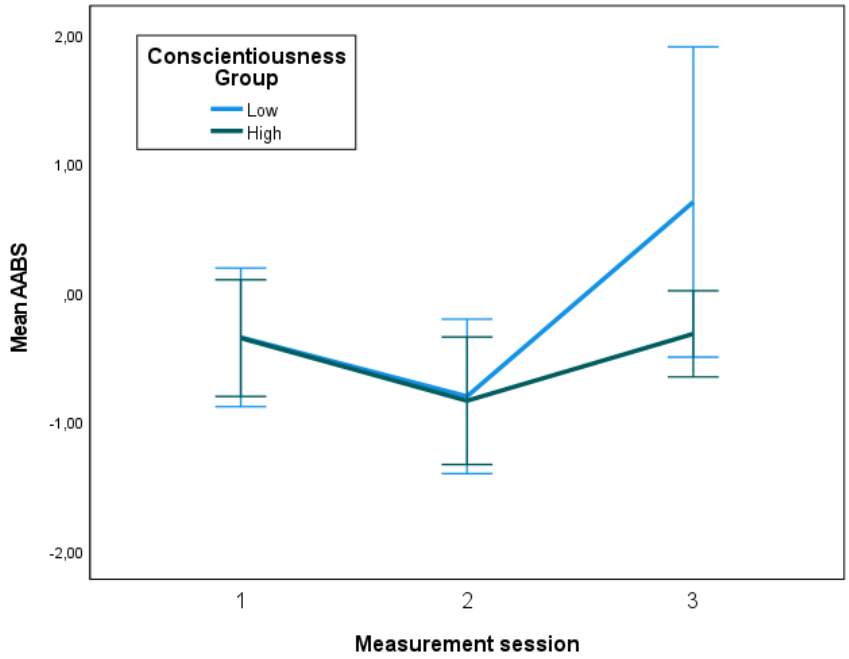
categories of conscientiousness. The categorization was made by use of a median split at a score of 32. This means that there are 11 participants within the 'high' conscientiousness group, and 8 participants within the 'low' conscientiousness group. Table 5 shows the mean scores and standard deviations for each measurement session between both groups. These mean scores are visualised in Figure 6.

Table 5. Means and standard deviations for AABSs, separated by 'High' (n=11) and 'Low' (n=8) conscientious groups.

	Before training		**After training**		**After 5 days follow-up**	
	M	**SD**	**M**	**SD**	**M**	**SD**
High BFI-C	-.35	.67	-.84	.69	-.32	.32
Low BFI-C	-.35	.64	-.80	.72	.70	.48

Figure 6

Linear mixed model containing the three AABSs (prior to training, after training, and after the 5 day follow-up) with error bars. The lines are separated by a 'high' BFI-C group and a 'low' BFI-C group.



Note. Error bars show a 95% confidence interval

Quantitatively, the differences between groups 'high' in conscientiousness, and people 'low' in conscientiousness appear to be insignificant. Overall, the mean scores change similarly up to the last measurement session. There, it appears that people low in conscientiousness increase in AABS more rapidly. These changes compared to people high in conscientiousness remains to be insignificant, though ($F(1,7) = 2.538$, $p = .155$). Qualitatively, however, both groups appear to have a similar

decrease in AABS after training, which starts to increase after the period of 5 days without training. The moderation effects caused by conscientiousness appear to be insignificant. Therefore, the sixth hypothesis is refuted.

Motivation

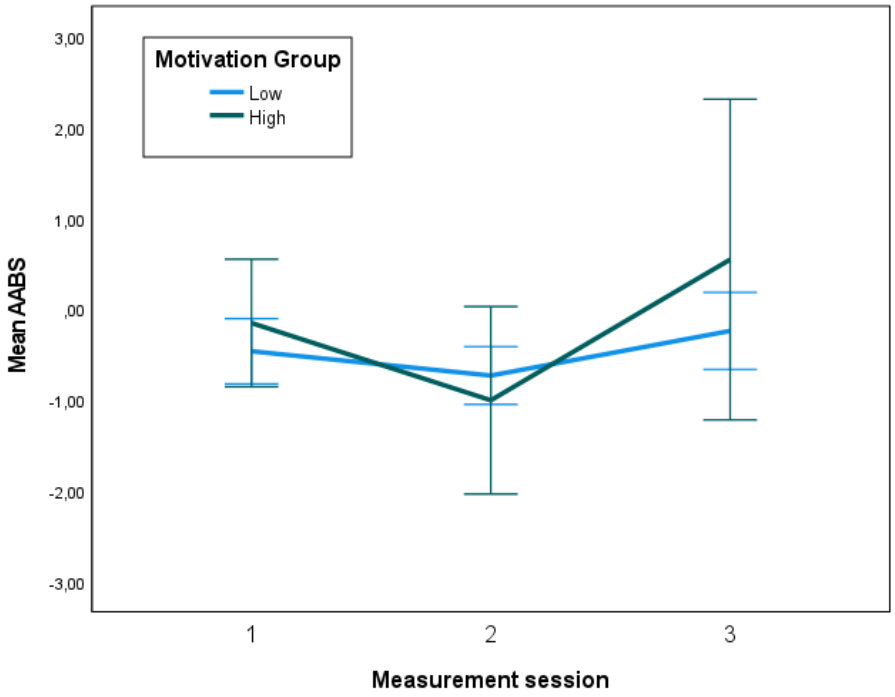
The hypothesised moderation effects were tested by use of a linear mixed model with a within-subjects change in AABSs over time. Peoples motivation to change was measured by use of a 5-Likert scale. These scores were analysed for their median in order to split the data into groups of people 'high', and 'low' motivation to change their drinking behaviour. The median split score was calculated to be around 4, with 7 participants within the 'high' motivation group, and 12 participants within the 'low' motivation group. The mean and standard deviations for each measurement are given in Table 6. The moderation effects can be qualitatively analysed in Figure 7.

Table 6. Means and standard deviations for AABSs, separated by 'High' (n=7) and 'Low' (n=12) motivation groups.

	Before training		**After training**		**After 5 days follow-up**	
	M	**SD**	**M**	**SD**	**M**	**SD**
High motivation	-.15	.80	-1.00	.98	.54	.71
Low motivation	-.46	.57	-.73	.50	-.24	.40

Figure 7

Linear mixed model containing the three AABSs (prior to training, after training, and after the 5 day follow-up) with error bars. The lines are separated by a 'high' motivation group and a 'low' motivation group.



Note. Error bars show a 95% confidence interval

Quantitatively, the differences in measurement scores appear to be insignificant. People high in motivation to change their drinking behaviour do not differ significantly from people with a low motivation to change ($F(1,16) = .224$, $p = .643$), which refutes the seventh hypothesis. Figure 7 does seem to indicate that there might be a difference after the 5-day follow up, but these differences are also insignificant ($F(1,7) = 4.731$, $p = .066$). The latter is not surprising, as the full linear mixed model was insignificant. Qualitatively, however, the results indicate that people with a relatively high motivation to change their alcohol consumption show a slightly stronger reduction in AABSs at the measurement after training than people with a low motivation to change, as can be seen in Figure 7. Additionally, these reductions are lost after a 5 day break from training. Moreover, the scores even seem to be higher than the initial AABSs prior to training. On the other hand, people with a low motivation to change their drinking behaviour appear to be less responsive to the effects of CBM.

Discussion

The current study focusses on the psychometric qualities of the CBM function in the *Breindebaas* application. The reliability and validity of the measurement function of the application have been tested. Furthermore, the relationships between drinking behaviour and the alcohol-approach bias at baseline have been tested, as well as the hypothesised moderation effects of conscientiousness and motivation on the effects of CBM. The current study attempts to do this by use of a longitudinal study in which the participants had to fill in a survey after which they had to work with the *Breindebaas* application for 3 consecutive days with an addition of a 5 day follow-up measurement. Overall, none of the hypotheses are found to be statistically significant but one. The hypothesised increase in AABSs after 5 days without training was found to be significant by the current study. Nevertheless, a qualitative interpretation of some of the results suggest indications that are in line with the hypotheses. Therefore, interpretations of these results will also be qualitatively interpretated in order to give indications that are suitable for further research.

Study questions

Firstly, the current study focusses on the test-retest reliability of the measurement function of the *Breindebaas* application. The current study found the test-retest reliability to be very low which indicates that the measurement feature of the *Breindebaas* application is not reliable to measure the alcohol-approach bias. The application is one of the first mobile versions of the AAT-T for alcohol as converted from the AAT-T composed by Wiers *et al.* (2010[b]). Earlier research on the *Breindebaas* application took interest into the validity of the application (Balci, 2019; Brouwer, 2019). The current study is the first to examine the test-retest reliability of the measurement feature of the *Breindebaas* application. In order for the AAT-T for alcohol to be as effective when provided as a mobile version, the test-retest reliability should be ‘moderate’ to ‘high’. The original reliability that was found for the computerized AAT-T for alcohol could not be recomposed in the mobile version. This low ICC could not be explained by heterogeneity in the sample, as no indications were found for measurement invariance due to factors that apply for specified groups. In case of the current study, this was analysed for the group of ‘students’ whom showed a test-retest reliability that was substantially low as well.

This suggests that the measurement is not interpretated differently by the 'students' as compared to the sample as a whole. The finding of a low test-retest reliability could be explained by the number of reaction times obtained from the data. The *Breindebaas* version 2.0.3 provides the participant with 60 images during the measurement. Of these, the first 10 for the avoidance behaviour and the first 10 of the approach behaviour are excluded from the data which resulted in a number of 40 RTs in the dataset. Other mobile AAT-Ts are designed by use of 80 RTs (Zech, Rotteveel, van Dijk & van Dillen, 2020). The *Breindebaas* application was also supposed to have 80 RTs obtained from 100 images that should have been presented to the user. It is assumed that, since half of the RTs were obtained, the final D-scores would be less representative for the AABSs. The current study provides a hypothesis that if the number of RTs increases, the D-scores will become more accurate. Another possible explanation for the low test-retest reliability is that the original AAT-T is not mimicked adequately. The current mobile AAT-T makes use of swipe movements that should mimic the 'approach' and 'avoidance' behaviours. However, the swiping derivative might not be enough to represent these behavioural cues. Therefore, the mobile version could be better understood as an Implicit Association Test (IAT) (Lindgren *et al.*, (2013). The latter explanation would mean that the D-scores for alcohol and the D-scores for non-alcohol are not representative for their association to the type of drink which might subsequently mean that the relative D-score is less reliable.

The current study does not find significant differences between the AABSs at baseline and the AABSs after training. Noticeably, the overall mean AABSs at baseline was slightly negative (-.42) and got reduced even more after training (-.82). The fact that these findings were found to be insignificant was not expected. Yet, it can be explained by former studies on CBM. MacLeod and Clarke (2015) found that beneficial effects of CBM were largely reduced when applied as a mobile AAT-T. In their evaluation, these findings were attributed to the easiness of distraction. Other possible explanations could be that the behavioural cues are mimicked inadequately, or the investment of the participant in completing the task is reduced due to the easiness of participating. Participants were able to complete a measurement or training task relatively rapidly, which means that their mental investment on completing the task at hand has a shorter endurance and less physical embodiment. Even though, quantitatively, the results cannot be interpreted to be significantly different, the

indications for a reduction in AABSs seem to be present. A bigger sample size and an increase in obtained RTs might prove the training to be significantly effective. These presumptions can be made by use of a qualitative interpretation of the results. The latter interpretation does seem to indicate a reduction in AABSs after CBM.

The only statistical evidence that the current study finds is for the lasting effects of CBM. The AABSs significantly increased after the 5 day follow-up measurement. This is in line with the replication study conducted by Eberl *et al.* (2013) in which relapse rates were measured at a one-year follow up. In their study, it is mentioned that there is a sensitivity for relapse after a period of no training, which also resulted in an increase in the alcohol-approach bias. However, an unexpected finding in the current study is that the increase in AABSs exceeds the initial AABSs at baseline. Yet, this increase is not significant as compared to the AABS at baseline. Identically, it was found in the study by Eberl *et al.* (2013) that the alcohol-approach bias did not exceed the baseline score after a period without CBM as well. It should be mentioned that the 5 day follow-up measurement contained a small sample size of nine participants which is why the generalizability may be low. The observed reduction that was found after the training session is nullified after a period of inactivity with the *Breindebaas* application. This finding is in line with the observations from a former study by Wiers, Boffo and Field (2018). In their findings, drinking behaviour of students was affected by CBM in a lab study, but only when the alcohol-approach bias was changed. Additionally, these results were found to be short-lived and clinically irrelevant. Wiers, Boffo and Field (2018) suggest that the effect of CBM is different for students as compared to an actual clinical setting. The current study has a sample consisting mostly out of students and suggest results that are in line with these earlier findings. CBM as related to alcohol dependence and craving might become useful in identifying potential targets. Alcohol dependence and craving are substantially applicable to the clinical setting. These two variables would be less representative in a sample consisting mostly out of students. Possibly, these two factors are crucial for beneficial effects. Furthermore, drinking behaviour during the 5-days before the follow-up measurement might affect the alcohol-approach bias in a reversive way as compared to CBM. This might be explanatory for counteractive effects in heavy drinking individuals in general.

Unexpected results were found in the correlational analyses for alcohol related variables. The

only significant correlation that has been found is the correlation between the Alcohol TLFB and the monthly binge-drinking frequency. This confirms the validity of both self-reported alcohol consumption measures as presented by Sobell and Sobell (1992). Drinking behaviour in recent periods is, thereby, found to be related to overall drinking on longer periods. However, none of the other correlations – that were slightly negative – were found to be significant. A marginal effect of $p = .1$ was found for the correlation between the AABSs and the monthly binge-drinking frequency. It has been hypothesised that a strong alcohol-approach bias would be positively correlated with high levels of drinking behaviour. The slightly negative correlation is, therefore, unexpected. Since a marginal effect of $p = .1$ has been found, the correlation between both variables might not have been found due to the low test-retest reliability of the AABSs.

One of the participants provided information for a small case study concerning this unexpected phenomenon. The participant was provided with his requested personal results, which showed a strong alcohol-avoidance bias. The participant mentioned that he/she used to have an AUD for which he/she had taken measures. These measures have caused the participant to feel more able to be in control of his/her drinking behaviour. This single case observation provides insight into how the correlation between the alcohol-approach bias and alcohol consumption might be different per individual, based on personal history. Like mentioned priorly, phenomena like alcohol dependency and craving might be crucial for a beneficial effect of CBM. A personal history in reducing the alcohol-approach bias might work in a similar way. Possibly, this might be studied by use of a longer study to find out how consistent the alcohol-approach bias is for individuals whom consume alcohol on a frequent basis, and are noticeably driven by their alcohol-approach bias.

The BFI-C scale was firstly used to find correlations between conscientiousness and the AABS at baseline. Subsequently, a moderation analysis was conducted and was found to be insignificant by the current study. The buffering moderation effect that was hypothesised could not be found by the current study. Since conscientiousness has been found to positively correlate with self-control, the reflective pathway of the dual-process models was expected to remain hyperactive, which would suggest people high in conscientious to be less prone to develop an alcohol-approach bias (Mao *et al.*, 2018). Nevertheless, the correlations found by the current study suggested no direct association

between both factors. A qualitative interpretation of the results suggests that individuals low in conscientiousness have a higher alcohol consumption as compared to people high in conscientiousness. Yet, the alcohol-approach bias of high conscientious people is not significantly lower. This might still suggest that people low in conscientiousness are more driven by their alcohol-approach bias. Drinking behaviour that is not stimulated by the alcohol-approach bias could not be targeted by use of AAT-T. Therefore, highly conscientious individuals are less likely to change their alcohol consumption by use of AAT-T. Despite the insignificant results, the higher alcohol-consumption for people low in conscientiousness does leave room for further research into peoples ability to be driven by or to supress the urges of the alcohol-approach bias.

It was expected that people high in conscientiousness benefit more from CBM than people low in conscientiousness. This expectation was based on the finding that people high in conscientiousness have higher levels of self-regulation, which protects them from developing an under-active reflective pathway, as well as an over-active impulsive pathway (Lenzenweger, 2005). Nevertheless, the current study found both quantitative and qualitative interpretations of the results to indicate that the effects of CBM are equal for both groups. The current study hypothesised that the higher likelihood for people low in conscientiousness to develop an AUD could be explained by their likelihood to be driven by the alcohol-approach bias (Hakuninen *et al*., 2015). Noticeably, the current study contained a sample consisting mostly out of students. This means that the effects of CBM are different as compared for people whom actually have an AUD (Wiers, Boffo, & Field, 2018). The similar reduction of both groups is, therefore, not expected to be guided by conscientiousness.

A qualitative interpretation of the moderation effect of motivation appears to confirm the hypothesis that people high in motivation to change their alcohol consumption are more responsive to CBM. It appears that for people, whom have motivation to change their maladaptive behaviour, the reflective pathway has become hyperactive (Gladwin, Wiers & Wiers, 2017). Individuals are less driven by their impulsive pathway and are, therefore, more invested in the training sessions. The current study suggests that motivation to change is, therefore, of importance to CBM. Motivation to change causes the individual to be invested in the performance. This might work similarly as the reduction in investment when the AAT-T is given in mobile form. Both reduction in investments,

serious performance might have negative effects on CBM. This means that CBM should be tailored in other ways for it to become effective for individuals whom lack this intrinsic motivation. In a recent study presented by Wiers, van Dessel and Köpetz (2020), early cognitive bias was discussed to be difficult to change. Integration of previous findings suggest that taking into account contextual antecedents, like stress or craving, would give rise to an optimalization of CBM. Conclusively, tailoring the *Breindebaas* application in such a way that contextual antecedents of the individuals in question are taken into account might prove valuable in case of a low motivation to change alcohol consumption. In the suggestion made by Wiers, van Dessel and Köpetz (2020) adaptive inferences and related behaviours should be taken into account in order to revise maladaptive behaviour. This might be an effective equivalent to motivation.

Strengths and Limitations

Important to mention are the inconsistencies that occurred during the data collection of the current study. Participants were asked to work with the *Breindebaas* application right after completing the survey. The data obtained from this initial data collection were found to be empty which resulted in a second attempt to collect the RTs from the *Breindebaas* application. The period between the initial completion of the survey and the eventual data collection of the *Breindebaas* application was approximately 4 weeks. As a result, the variables obtained from the survey are used under the assumption that these were continuous during this period. Since they are expected to be co-variates, the current study uses that same data set for the second data collection.

Most of the limitations in the current study were caused by the functioning of the *Breindebaas* application version 2.0.3. Originally, this study was set up to be conducted within one day. However, since the *Breindebaas* application provides the participant with only one measurement a day, the measurement sessions had to be completed on separate days. This change in schedule might have had an effect on the results. For instance, the reduction in AABSs after training might have been caused by recent working memory. The training feature of the application is focused on alcohol-avoidance movements which is also the task in the beginning of the subsequent measurement feature. The sudden change halfway through the measurement feature to perform an alcohol-approach movement might

cause the participant to perform worse because of a switch in continuity. This would ultimately give rise to a lower relative D-score. This could partly explain why the average AABSs at baseline have a mean below 0.

Moreover, the AABSs that were composed were proven to be unreliable. Assumably, this was partly caused by the insufficient RTs for each measurement session. A frequency analysis of the alcohol-approach movements and the alcohol-avoidance movements indicated that these requests made by the *Breindebaas* application 2.0.3 was not equally distributed. The application had a bug which caused the participant to be presented with an unequal amount of alcoholic drinks and non-alcoholic drinks. Both the reduction in RTs and the inequal amounts of the type images form a fundamental aspect for the measurement feature to give rise to inaccurate AABSs. Therefore, conclusions drawn from this study – that is both the significant and the insignificant differences – cannot be published.

The last limitation caused by the *Breindebaas* application concerns the technical difficulties. Firstly, the data of the initial data collection was not stored. This means that all participants had completed a CBM session before the second data collection started. Therefore, the AABSs at baseline had been affected already. Secondly, multiple participants notified the authors of this study about the application crashing on their mobile phones. The only way to circumvent this bug was to ask the participant to redownload the application. However, the data up to the time of the crash would have been lost. Therefore, these participants were asked to stop with the study and their data was downloaded as they were. Conclusively, the number of participants completing the eight day of the study was halved.

Next, a few limitations occurred by the study itself. Firstly, there appears to be a limitation in the sample that has been used. The inclusion criteria stated: 1) had to be at least eighteen years old at the start of the data collection; 2) had to have access to an Android phone (e.g. Samsung, or LG); 3) had the ability to read English; 4) had signed the informed consent. Ultimately, the *Breindebaas* application will be used by people whom aim to reduce their AUD. This means that there is a difference in populations out of which the sample for this study is chosen and the population that will eventually end up using the application. The current study found unexpected results concerning the

relationship of consuming behaviour and the alcohol-approach bias. Possibly, this relationship differs for people whom will use the application eventually compared to people whom have used the application during this study. In order to tailor the application for eventual use, analyses should be conducted by use of a sample that represents the right population. The current sample includes participants that vary in alcohol consumption from none to high, which might have an effect on the correlations and moderations.

Secondly, the current study itself was limited by a slight inaccuracy in the calculations of the D-score. The relative D-scores are calculated by use of a penalty score for each swiping movement that occurred in the wrong direction. These penalty scores, however, have been excluded from the calculations. Since the RTs obtained from the *Breindebaas* application were halved, penalty scores would have had a much bigger impact on the eventual AABSs. However, since the amount of RTs were found to be limited, all should be taken into account to get the most accurate measurement scores for the alcohol-approach bias. Both the reduction in RTs and the exclusion of the penalty score provide explanations for the low test-retest reliability.

Further research

The current study could not find significant differences for most of the hypotheses but one. However, qualitative interpretations seem to form a guidance for further research. Further research might find significant differences when the correct amount of RTs are used, and when the penalty scores are taken into account. These two criteria are of crucial importance for the findings to be published. This might result in a measurement feature that has an optimal agreement reliability, which would increase the within-subject accuracy. Moreover, the sample size should be increased in order for the between-subjects analyses to be more accurate. If both of these accuracies are improved, significant differences might be found.

Secondly, insight into the interdependency between the D-score for alcohol and the D-score for nonalcohol might prove to be valuable. The current study used the relative D-score and found a mean AABS that was slightly negative and was used through the whole study. Whether the relationships between variables and the relative D-score might be improved when only the D-score for

alcohol is used remains to be investigated. Further research could try to investigate the differences in associations between the variables, and the relative D-scores and the D-scores solely for alcohol.

Thirdly, the psychometric qualities of the *Breindebaas* application might be better investigated further when a sample from the appropriate population is used. The current study had a sample consisting of mostly students. Drinking behaviour of students is known to be highly above average and has been taken up into their 'culture'. This means that the alcohol consumption of students might be driven by another factor instead or besides the alcohol-approach bias. This offers a presumption that the relationship between drinking behaviour and the alcohol-approach bias is different for the current sample as compared to the population the *Breindebaas* application will be tailored to. Different moderators might be effective that are dependent on the participants. Further research might want to investigate the differences in correlational and moderation analyses between two different populations in order to eliminate measurement invariance. Evidential to this is the case study as presented above. The alcohol-approach bias might be subjective to the measures already taken by the individual.

Fourthly, a correlational analysis can be conducted between the mobile AAT-T of the *Breindebaas* application and former computer-based AAT-Ts. Such further research could validate the *Breindebaas* application to actually be measuring the alcohol-approach bias. Furthermore, finding validity by comparison to a computer-based AAT-T could give more insight into the factors on which the reliability of the measurement feature is dependent.

Lastly, the current study did not involve a post training measurement of alcohol consumption. The psychometric qualities of the *Breindebaas* application can be investigated in comparison with alcohol consumption even further. Hypothetically, the alcohol consumption should be reduced after CBM as the alcohol-approach bias is modified. Additionally to this suggested longitudinal study, a control group could be added in order to account for the effects to be caused by solely CBM. Increasing the amount of training session in between measurement sessions might, thereby, reveal more insights into the psychometric properties of the *Breindebaas* application.

Breindebaas: A Mobile CBM

In order for the mobile version of the A-AAT to be effective, it should have good psychometric properties. The original computerized CBM methods that target the alcohol-approach bias make use of physical movements and require the participant to be invested to the objective. The current mobile version lacks these two attributes. The embodied cognition is reduced, since the pulling and pushing of a joystick got replaced by swiping an image away and towards oneself. As a result of this, the avoidance and approach behaviours are mimicked less well. Therefore, the participants do not interpretate these behaviours similarly as the computerized version of A-AAT and the task at hand resembles an Implicit Association Test (IAT) more. The embodied cognition that is lost might be one of the reasons why mobile versions of CBM are less effective.

An advantageous aspect of the mobile version of CBM is the easiness to use the *Breindebaas* application. As compared to computerized lab studies, the participant is less restricted by the presence of equipment. Therefore, the participant is able to use the training feature of the *Breindebaas* application, and thus the AAT-T, more regularly. The accessibility is a big advantage of the mobile version of CBM as compared to the computerized version that can be used clinically. However, the easiness of use comes with a cost. Participants spend less time in total with the objective at hand and the presented assignment demands less mental effort. Therefore, alteration of the alcohol-approach bias might be less likely.

The *Breindebaas* application is expected to be most beneficial in altering the an implicit association between alcoholic and non-alcoholic drinks. It might be useful to combine a regular use of mobile AAT to frequent computerized CBM. This way the associations are learned on regular use, and the approach-avoidance behaviours can be mimicked by use of embodied cognition. The investment of the participant is, thereby, stimulated in combination with the accessibility of the mobile version on a daily basis.

Conclusion

The current study investigates the psychometric qualities of the *Breindebaas* application to measure and train the alcohol-approach bias. Moreover, predicting effects of alcohol related measures, and

moderation effects of motivation and conscientiousness on CBM were analysed. Significant results were found for the decay of the effects of CBM over an extended time without training after a single session. However, these results have been obtained out of a small study sample, which means that further research is needed to give an ultimate answer.

Conclusively, the *Breindebaas* application needs to undergo additional updates before usable outcomes can be identified. Most importantly, correct relative D-scores with a high test-retest reliability need to be obtained before analyses can be conducted on the effects of CBM on the alcohol-approach bias and additional variables. The current study can be qualitatively interpretated for guidance for future research. Investment and motivation of the participant is necessary for the *Breindebaas* application to be effective in changing the alcohol-approach bias. Implementing a mobile form of AAT-T might be advantageous if tailored to motivated individuals.

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Appendix

Appendix 1: Manual with instructions for the study

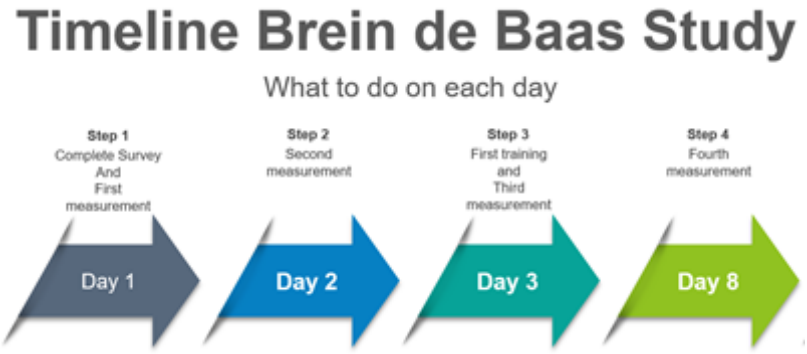
Version B (for Dutchies)

Dear …,

This is an invitation to participate in a research study about measuring one's alcohol approach bias with the Breindebaas application. This study will be conducted by students from the Faculty of Behavioural, Management and Social Sciences at the University of Twente as part of their bachelor thesis.

To participate in the study, you need to be **18 years or older**, you need to have good English proficiency, and you need to have access to an **android mobile device** with an internet connection. Furthermore, downloading the Breindebaas app is essential for participation. If you want to participate but do not have an android phone yourself the researchers Milan and Laura may be able to provide you with one so, please contact them via Mail (m.q.verhoeven@student.utwente.nl; l.vondeetzen@student.utwente.nl) for further information about this issue.

The purpose of this research is to investigate a new measurement tool with which a person's alcohol approach bias can be evaluated as well as a training feature with which said bias might be reduced. Both features are made available in the Breindebaas app where you will have to respond to pictures of alcoholic and non-alcoholic drinks.



Overall, the study will take you approximately **two hours of active work, stretched over four days with a week of rest in between the third and eight day**. On the first day, you will have to fill in a Qualtrics questionnaire that will give us insights into the variables related to the alcohol approach bias. Immediately after finishing the questionnaire, you will receive an explanation about how to download and use the app, and then you can start the first measurement session. On the second day, you will be asked to complete another measurement session. On the third day, you will be asked to complete a training sessions and another measurement session right after. Then you will be asked to rest for a week and on day eight you will be asked to complete one follow-up measurement session.

The data will be used for scholarly purposes only. Afterward, you will have the opportunity to get a debriefing of the results. After you completed the whole study, you will have the **chance to win one of the five 20-euro bol.com gift vouchers**.

Participation in this study is completely voluntary. If you decide not to participate there will not be any negative consequences. Please be aware that if you decide to participate, you may stop participating at any time and you may decide not to answer any specific question.

To the best of our knowledge, there are no risks involved in participating in this study. Your answers in this study will remain strictly confidential. We will minimize any risks by storing all the data in a

password-protected electronic format on an GDPR approved server. Furthermore, confidentiality will be secured by anonymizing each questionnaire.

Are you interested to participate in the study? First go to: (link Qualtrics questionnaire) and afterwards go to: (link manual).

Sincerely,

Milan Verhoeven & Laura von Deetzen

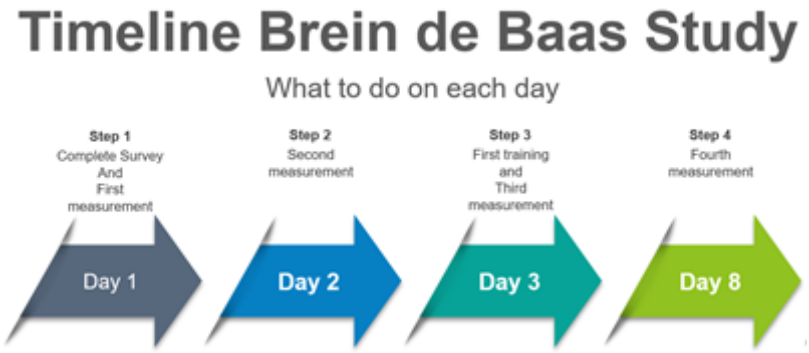
Version B (for Germans)

Dear …,

This is an invitation to participate in a research study about measuring one's alcohol approach bias with the Breindebaas application. This study will be conducted by students from the Faculty of Behavioural, Management and Social Sciences at the University of Twente as part of their bachelor thesis.

To participate in the study, you need to be **18 years or older**, you need to have good English proficiency, and you need to have access to an **android mobile device** with an internet connection. Furthermore, downloading the Breindebaas app is essential for participation. If you want to participate but do not have an android phone yourself the researchers Milan and Laura may be able to provide you with one so, please contact them via Mail (m.q.verhoeven@student.utwente.nl; l.vondeetzen@student.utwente.nl) for further information about this issue.

The purpose of this research is to investigate a new measurement tool with which a person's alcohol approach bias can be evaluated as well as a training feature with which said bias might be reduced. Both features are made available in the Breindebaas app where you will have to respond to pictures of alcoholic and non-alcoholic drinks.



Overall, the study will take you approximately **two hours of active work, stretched over four days with a week of rest in between the third and eight day**. On the first day, you will have to fill in a Qualtrics questionnaire that will give us insights into the variables related to the alcohol approach bias. Immediately after finishing the questionnaire, you will receive an explanation about how to download and use the app, and then you can start the first measurement session. On the second day, you will be asked to complete another measurement session. On the third day, you will be asked to complete a training sessions and another measurement session right after. Then you will be asked to rest for a week and on day eight you will be asked to complete one follow-up measurement session.

The data will be used for scholarly purposes only. Afterward, you will have the opportunity to get a debriefing of the results. After you completed the whole study, you will have the **chance to win one of the five 10-euro amazon gift vouchers**.

Participation in this study is completely voluntary. If you decide not to participate there will not be any negative consequences. Please be aware that if you decide to participate, you may stop participating at any time and you may decide not to answer any specific question.

To the best of our knowledge, there are no risks involved in participating in this study. Your answers in this study will remain strictly confidential. We will minimize any risks by storing all the data in a password-protected electronic format on an GDPR approved server. Furthermore, confidentiality will be secured by anonymizing each questionnaire.

Are you interested to participate in the study? First go to: (link Qualtrics questionnaire) and afterwards go to: (link manual).

Sincerely,

Milan Verhoeven & Laura von Deetzen

Appendix 2: Reminder mails to participants

Day 2

Dear …,

Yesterday you agreed to take part in our study about measuring one's alcohol approach bias with the Breindebaas application. Today is the second day of the study wherefore we would like to ask you to look into the user manual for the Breindebaas application (https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing) and to complete the steps that are mentioned there under "Day 2". There you will be asked to complete the second measurement session.

Thank you very much for keeping up with our study!

Sincerely,

Milan Verhoeven & Laura von Deetzen

Day 3

Dear …,

Two days ago, you agreed to take part in our study about measuring one's alcohol approach bias with the Breindebaas application. Today is the third day of the study wherefore we would like to ask you to look into the user manual for the Breindebaas application. **Notice that today a training session is added.** (https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing) and to complete the steps that are mentioned there under "Day 3". There you will be asked to complete one training and one measurement session right after another.

Thank you very much for keeping up with our study!

Sincerely,

Milan Verhoeven & Laura von Deetzen

Day 8

A MOBILE VERSION OF COGNITIVE BIAS MODIFICATION AS ALCOHOL AVOIDANCE TRAINING: MEASURING ITS PSYCHOMETRIC QUALITIES

Dear …,

A week ago, you agreed to take part in our study about measuring one's alcohol approach bias with the Breindebaas application. Today is the last day of the study wherefore we would like to ask you to look into the user manual for the Breindebaas application (https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing) and to complete the steps that are mentioned there under "Day 8". There you will be asked to complete one last measurement session right after another. **After this, you are eligible to win one of our gift vouchers, congratulations!**

Thank you very much for keeping up with our study!

Sincerely,

Milan Verhoeven & Laura von Deetzen