# Measuring the Alcohol-Approach Bias with the Breindebaas Application: An Examination of its Psychometric Qualities

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Bachelor Thesis

December 14th, 2021

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**Abstract**

**Introduction.** Excessive alcohol consumption can lead to negative consequences regarding health, social, and economic aspects. Dual-process models suggest that imbalances between the implicit and reflective pathways lead to alcohol-approach biases. Cognitive bias modifications (CBM) such as the alcohol approach-avoidance task (AAT) aim to reverse this bias and reduce the patient's alcohol consumption. The Breindebaas application offers a mobile version of the measurement AAT and training CBM. This study focuses on examining the measurement AAT's psychometric properties.

**Methods.** This study applied a mixed cross-sectional and a pre- and post-test single group design. The sample (N=19) was conveniently recruited via the researcher's private and social media networks. Participants received an invitation followed by a link to a questionnaire measuring their demographic characteristics, alcohol consumption, perceived stress, and motivation. Afterward, they completed two measurements, one training, and another measurement session with the app over three consecutive days. Main analyses of the study include a test-retest, split-half reliability test, and a pre- and post-test after a training CBM session. Predictors of alcohol approach bias such as baseline alcohol consumption, perceived stress, and motivation will be investigated to confirm external validity.

**Results.** Whereas test-retest reliability was poor ($r$ = .09, $p$ = .34), internal consistency was good ($r$ = .93). A marginal positive effect of one CBM session on the alcohol-approach bias was found ($t$ = 2.00, $p$ = .06). Cross-sectional correlational analyses between alcohol consumption measures and the alcohol-approach bias were not significant ($r$ = -.20, $p$ = .4; $r$ = -.39, $p$ = .1). Moderation effects of perceived stress and motivation on the alcohol approach bias were not significant.

**Discussion.** The external reliability of the measurement AAT seems poor whereas its internal reliability is good. The measurement AATs sensitivity to change appears promising but its external validity is overall poor. Limitations revolve around the app's technical issues, the study design, the size and nature of the sample, and the calculation of the alcohol-approach bias score. Future studies might investigate the correlation of bias scores with post-alcohol consumption and social or physical contexts as well as adding features such as response force and virtual reality. Further research about the Breindebaas application's psychometric properties is encouraged to enable more sustained claims about its reliability and validity for measuring the alcohol-approach bias.

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## Introduction

Alcohol is a drug, a toxicant, a depressant, a psychoactive substance that produces tolerance and physical dependence. In many countries, alcohol is the second most abused substance (Pinel & Barnes, 2017; Word Health Organization, 2018). The fifth version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) includes three conditions related to alcoholism which are alcohol dependence, alcohol abuse, and alcohol use disorder (AUD). In general, excessive drinking is defined as consuming more than 15 drinks a week as a male and more than seven as a female which are often consumed in binges (Centers for Disease Control and Prevention, n.d.). The negative consequences of excessive alcohol consumption are threefold. First, there are health aspects like brain damage, liver cirrhosis, digestive- and cardiovascular system impairments. Moreover, it increases the risk of heart attacks, many forms of cancers, communicable diseases as well as injuries and accidents on the roads, at home, or the workplace (Pinel & Barnes, 2017; Word Health Organization, 2018). Overall, alcohol consumption contributes to 3 million deaths each year globally (5% of all deaths worldwide) and is responsible for 5.1% of the global burden of disease. Furthermore, it is the main cause of untimely mortality and inability among the 15- to 49-year-olds, representing 10% of all deaths in this age group (Word Health Organization, 2018). Besides that, alcohol consumption can also have effects on a person's mental health and lead to aggression problems or suicidal tendencies (Klingemann & Gmel, 2001). Second, there are social aspects like vandalism and struggles at work or with friends and family members (Anderson & Baumberg, 2006; Klingemann & Gmel, 2001; Word Health Organization, 2014). Finally, there are the economic aspects, for example, costs due to excessive alcohol consumption amount to 2.5 billion euros each year within the Netherlands and 249 billion dollars within the US (Elflein, 2020; Wit, 2016). Therefore, excessive alcohol consumption constitutes a severe social problem that requires appropriate solutions.

### Dual-Process Models

Fortunately, there are several treatment options for excessive drinking like cognitive behavioural therapy, motivational interviewing, and self-help groups. While these interventions have been proven to be effective, their long-term impact remains either modest or non-existent (Magill & Ray, 2009; Mueller et al., 2007; Riper et al., 2014; Vasilaki et al., 2006). A similarity of those kinds

of behavioural interventions is that they focus mainly on regulating conscious cognitive mechanisms. However, most of the adverse consequences of alcohol consumption are considered common knowledge, and yet many people tend to drink disproportionate amounts of alcohol (Wiers & Stacy, 2006). Thus, approaching solely the conscious and controlled cognitive mechanisms of alcohol addicts seems not enough to achieve prolonged changes.

Another factor that plays a role in excessive drinking might be of a more implicit and unconscious nature. Dual-process models propose that two neurological pathways determine how an individual will respond to addiction-related stimuli (Strack & Deutsch, 2004; Wiers et al., 2010[a]). The former is referred to as the impulsive or associative pathway and is characterised by affectivity, impulsivity, and associativity since it evaluates stimuli on their emotional or motivational impact. It is concerned with the craving, the wanting, and needing in an addiction wherefore it acts rapid and automatic so that the individual might not be aware of its influence. The latter is referred to as the reflective pathway which is concerned with higher-order evaluative processes such as emotion regulation and decision-making. Because it works with conscious and controlled processes it is more slowly and thus the individual is more aware of its impact (Carbia et al., 2018; Moss & Albery, 2009). According to the dual-process model, the reflective and impulsive pathways operate in parallel, however, the impulsive one is thought to be the default mode of information processing because this pathway does not require much effort regarding an individual's cognition. The reflective pathway, on the opposite, involves heightened cognitive effort, attention, and motivation (Strack & Deutsch, 2004). The resulting imbalances between the neurological pathways can lead to the development and maintenance of addictive behaviour (Wiers et al., 2007).

**Cognitive Biases and their Modification**

When the impulsive pathway overrules the reflective pathway, one can also speak of a cognitive bias which is defined as a "systematic selectivity in information processing that operates to favour one type of information over another" (MacLeod & Mathews, 2012). Consequently, alcohol approach bias refers to the phenomenon when action tendencies are automatically activated to approach alcohol instead of avoiding it due to substance-related cues in the environment (Wiers, 2010[a]). Wiers et al. (2010[b]) proved that the alcohol approach bias correlates with an increase in

alcohol consumption and Noel et al. (2006) even showed that the size of the bias is associated with the seriousness of the drinking problem. Because such biases are formed through associative learning and operant conditioning, they remain outside of one's consciousness and are thus difficult to address in treatments like motivational interviewing (Boffo et al., 2015).

Recently, cognitive bias modification (CBM) programs have been developed to alter such unconscious cognitive mechanisms like the alcohol approach bias. CBM can be described as a "direct manipulation of a target cognitive bias, by extended exposure to task contingencies that favour predetermined patterns of processing selectivity" (MacLeod & Mathews, 2012). One such CBM technique is the alcohol approach-avoidance task (AAT) which is conducted on a computer. During this task, participants are confronted with pictures (stimuli) of alcoholic or non-alcoholic beverages on a screen. The task of the respondent constitutes of pulling pictures of non-alcoholic beverages towards oneself and pushing pictures of alcoholic drinks away with a joystick or keyboard. The zooming function has proven to be particularly important as it generates the impression of the beverage moving either toward or away from the respondent (Klein, Becker, Rinck, 2011). The difference in response latency (i.e. reaction time) between pushing (avoiding) and pulling (approaching) in response to pictures constitutes the approach bias. When this score is positive, the respondent suffers from an alcohol approach bias (Wiers et al., 2010[b]). Until now, the AAT was found to predict hazardous drinking and weekly alcohol consumption accurately and reliably (Kersbergen et al., 2015; Sobell & Sobell, 1995). Consequently, the AAT presents itself as a reliable measurement tool to assess an individual's alcohol approach bias.

Wiers et al. (2010[b]) developed an AAT-Training (AAT-T) which is based on the AAT but instead of measuring a person's alcohol approach bias, it aims to alter this bias and unconsciously teach users to avoid alcohol instead of approaching it. In their study, this was done by manipulating the percentage of pictures of alcoholic or non-alcoholic drinks, which were to be pushed or pulled. Thus, during the AAT-T most or all (depending on the percentage) alcoholic stimuli had to be avoided to train the unconscious of the individuals to avoid alcohol instead of approaching it. So far, multiple studies in the clinical setting have shown that the AAT-T was able to reliably modify the automatic processes governing alcohol approach biases of problem drinkers (Gladwin et al., 2017; Grafton et al.

2017; Wiers et al., 2010[b]; Wiers et al., 2011) which has been proven to lead to enduring reductions in relapse as well (Eberl et al., 2013; Wiers et al., 2011). To conclude, the AAT-T seems to be an effective intervention to train the individual to learn to avoid alcohol-related stimuli in the environment.

**A new intervention: The Breindebaas Application**

With advancing technology, it seems logical to make CBM programs available online on smartphones and tablets since those are the technologies that are being used more frequently by the younger generations (Deloitte, 2018). On the one hand, 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). On the other hand, the efficacy of CBM in clinical settings might be reduced since the physical act of avoidance and approach behaviour that was mimicked by pushing and pulling a joystick are no longer part of the mobile version. In 2016, an application was developed by the Dutch organization Tactus Holding B. V. which represents a mobile version of the AAT. The Breindebaas app (Figure 1), where Breindebaas stands for 'being the boss of your brain', slightly altered the original version of the AAT as the original keyboard operated push and pull responses are replaced by touchscreen operated swipe movements (Laurens et al., 2020; Tactus, n.d.). The app contains two features, the former is the alcohol approach bias measurement (AABM, similar to AAT) and the latter is the alcohol approach bias training (AABT, similar to AAT-T). Within both features, 60 stimuli from the same picture set as the original version are presented of which half are pictures of alcoholic beverages and the other half are pictures of non-alcoholic beverages. During the AABT all 60 pictures have to be swiped congruently (i.e. alcoholic stimuli pushed away and non-alcoholic stimuli pulled towards). Whereas during the AABM only 30 pictures must be swiped congruently, and the other 30 pictures must be swiped incongruently (i.e. alcoholic stimuli pulled towards and non-alcoholic stimuli pushed away). When the stimuli are swiped congruently the alcohol is avoided and when the stimuli are swiped incongruently the alcohol is approached.

Based on criticism and feedback the developers received, a second version of the Breindebaas app was developed where users can choose between a standardized and personalized AABM option. The standardized option contains all pictures from the Amsterdam Beverage Picture Set and in the

personalized option users can choose at least half of the stimuli themselves (Laurens et al., 2020; Pronk et al., 2015). According to the incentive-sensitisation theory of addiction, a personalized AABM might be considered superior (Robinson & Berridge, 2008). This theory states that cognitive biases rely to a major part on the unique association individuals developed between specific stimuli from their environment and their following rewarding experience. Because the content of the self-chosen images is more relevant to the individual, it can be assumed that the personalized AABM is more accurate in identifying an alcohol-approach bias (Brouwer, 2017).

Until now the features of the Breindebaas App were tested, and the results provide valuable additional insights. Concerning the AABT, mixed results have been obtained. For example, Roeleveld (2017) examined the effect of the AABT on alcohol-dependent patients and found no significant effects whereas the studies of Somsen (2017) and Nijen Es (2017) suggest that this feature of the app led to a reduction of alcohol consumption up to four months follow-up which could not be proven since they were not controlled for third variables. Laurens et al. (2020) analysed the data of Somsen (2017) and Nijen Es (2017) again and confirmed the significant reduction of alcohol consumption up to three months after receiving two training sessions over three weeks. Furthermore, around half of the post-test respondents reported having gained more control over their drinking behaviour. Nevertheless, it was not investigated whether this reduction was due to a change in the alcohol approach bias. Regarding the AABM, Brouwer (2019) and Balci (2019) tested the standardized and personalized options and found no correlation between the two and no added value by the customized version. However, the results might be due to several limitations like small sample sizes, flaws in the application as well as the feeling of respondents of not having personalized their set of stimuli.

CBM programs like the Breindebaas app with its mobile version of the AAT are still in their infancy, wherefore it is crucial to further examine its psychometric properties. On the one hand, to evaluate the effectiveness of mobile CBM programs a reliable and valid measurement is necessary to assess the changes on the bias level (Kakoschke et al., 2017). When the AABM is found to be reliable and valid, the statements that can be made about the effectiveness of the AABT become more assured. On the other hand, to be able to test the sensitivity to change of a bias measure, also known as internal validity, an effective intervention that manipulates the bias is required. Therefore, this paper will

examine the reliability of the personalized AABM feature within the Breindebaas app with a test-retest and a split-half reliability test. More specifically, the test-retest reliability is the degree to which the AABM scores remain unchanged when measuring the alcohol approach bias on two separate occasions shortly after another. High reliability would indicate that the AABM measures a person's alcohol approach bias accurately. The split-half reliability test examines the internal consistency reliability of the scores for the different stimuli during an AABM session. It involves splitting one AABM session into equal halves and correlating the participant's scores on the two halves of the test. Moreover, a pre and post-test after an A-AAT session will be conducted to measure the AABM's sensitivity to change (Slack & Draugalis, 2001).

**Figure 1.**

*Pictures of the Breindebaas app.*

*Note.* Screenshots of the Breindebaas app. Reprinted from "Alcohol avoidance training as a mobile app for problem drinkers: longitudinal feasibility study", by Laurens, M. C., Pieterse, M. E., Brusse-Keizer, M., Salemink, E., Allouch, S. B., Bohlmeijer, E. T., and Postel, M. G., 2020, *JMIR mHealth and uHealth, 8,* p. 3. Copyright 2020 by Laurens et al.

**Predictors and Moderators**

To further strengthen claims about the ABBM's external validity this study will also explore associations with variables that based on theory and/or empirical evidence can be expected to correlate with a person's alcohol approach bias.

### *Alcohol Consumption*

One of the most basic tenets of the Breindebaas app is that a person's alcohol approach bias correlates positively with the amount of alcohol they are drinking as was already established in similar studies with similar inventions (Kersbergen et al., 2015). Like a learning process, people who turn to alcohol might strengthen their automatic pathway and develop an alcohol approach bias wherefore they cannot seem to stop drinking (Copersino, 2017). According to the dual-process model, this is because for a person with a higher unconscious bias to approach alcohol it will be harder to avoid alcohol. Therefore, a person who has a higher baseline AABM score can also be expected to drink a higher amount of alcohol.

### *Perceived Stress*

Perceived stress (PS) can be defined as "the feelings or thoughts that an individual has about how much stress they are under at a given point in time or over a given time period" (Phillips, 2013). It gauges how an individual feels about the general tensity of their life and their capacity to deal with such pressure. People may endure comparative pessimistic life occasions but evaluate the effect or seriousness of these to various degrees because of elements like personality, coping resources, and support. Along these lines, PS mirrors the interaction between an individual and their environment (Phillips, 2013). Higher levels of PS have been found to correlate with an increased desire for alcohol as well as heightened alcohol consumption in numerous studies (Carney et al., 2000; Cole et al., 1990; Yoon et al., 2016). According to the dual-process model, when cognitive resources are limited, the associative pathway will determine an individual's consciousness and behaviour (Strack & Deutsch, 2004). Cognitive resources can be restricted when a person experiences competing demands, distractions, and/or time pressure (Beevers, 2005). To conclude, when a person perceives higher levels of stress, their cognitive resources are low which makes it more likely that their automatic pathway will dominate their behaviour which in turn might result in a higher baseline alcohol intake.

In addition, PS can function as a moderator within two other relations. First, it can be argued that the positive correlation between a person's AABM scores and their self-reported drinking levels is stronger for people with higher PS. It might be that people who perceive a high amount of stress turn towards alcohol as a coping mechanism due to the dominant automatic pathway which might

then lead to an alcohol approach bias. Second, the dual pathway model also gives ground to assume that individuals with higher PS are more sensitive to a CBM effect on their AABM scores. The automatic pathway can be hypothesized to dominate the reflective pathway in individuals with higher PS, wherefore an attempt to alter the former might be more effective for those people.

### *Motivation to Change one's Behaviour*

In alcoholism treatment, the motivation to change one's behaviour can influence a person to "seek, complete, and comply with treatment as well as make successful long-term changes in their drinking" (DiClemente et al., 1999). According to the dual-process model, when the motivation to change is high the reflective pathway will be dominant which might be able to counteract the desires and urges of the automatic one and result in less alcohol intake (Strack & Deutsch, 2004). Besides, for CBM to be effective an adequate motivation by use of the reflective pathway is necessary (Gladwin et al., 2017). Consequently, it can be proposed that highly motivated people already tried to lower their level of alcohol consumption with the help of their reflective pathway wherefore a correlation between the motivation to change and less baseline alcohol consumption might exist. In addition, motivation to change can function as a moderator so that for highly motivated people, the CBM effect from the AABT session on their AABM scores can be expected to be lower because the attempt to alter their automatic pathway might not be as effective anymore since their reflective pathway is already the dominant one.

## This Study

As elaborated above, the Breindebaas app with its mobile AAT presents a promising additional treatment option for people who struggle with drinking disproportionate amounts of alcohol. However, until now its reliability and validity have not been investigated enough wherefore, the current study aims to further elaborate on its psychometric functions and qualities. Regarding the reliability of the AABM feature of the Breindebaas app, the following research questions will be answered: *(1) How high is the test-retest reliability between the AABM scores from the first and second point of measurement?* and *(2) Is the internal consistency of the Breindebaas app measured with the split-half reliability test adequate?* Concerning the internal validity of the AABT feature of the Breindebaas app, the following research question will be answered: (3) *Does the post-test AABM*

*score decrease significantly compared to the pre-test AABM score after receiving one session of AABT?* Considering the external validity of the Breindebaas app in association with alcohol consumption, PS, and MOT, the following research questions will be answered: (4) *Is there a significant positive correlation between the baseline AABM score, the baseline Alcohol TLFB, and the monthly binge-drinking frequency?* and (5.1) *Is the correlation between a participant's baseline AABM score and their self-reported level of alcohol consumption stronger for those with higher PS scores?* and (5.2) *Are participants with high PS scores more sensitive to a CBM effect on their AABM scores?* and (6) *Are participants with a higher motivation to change their drinking behaviour less sensitive to a CBM effect on their AABM scores?*

## Methods

### Design

This study applied a mixed cross-sectional and a pre- and post-test single group design. It was approved by the Ethical Committee of the University of Twente on the 16th of April 2021 under registration number 190383. During the period from the 01st of June 2021 to the 10th of June 2021, data was collected. Due to problems with the new update of the Breindebaas application, the initial data from the first collection of April 2021 could not be downloaded wherefore some conveniently selected participants were asked to take part in the data collection a second time. The information gathered by the Qualtrics survey of the initial data collection was kept and combined into one dataset with the information gathered by the second data collection from the Breindebaas app.

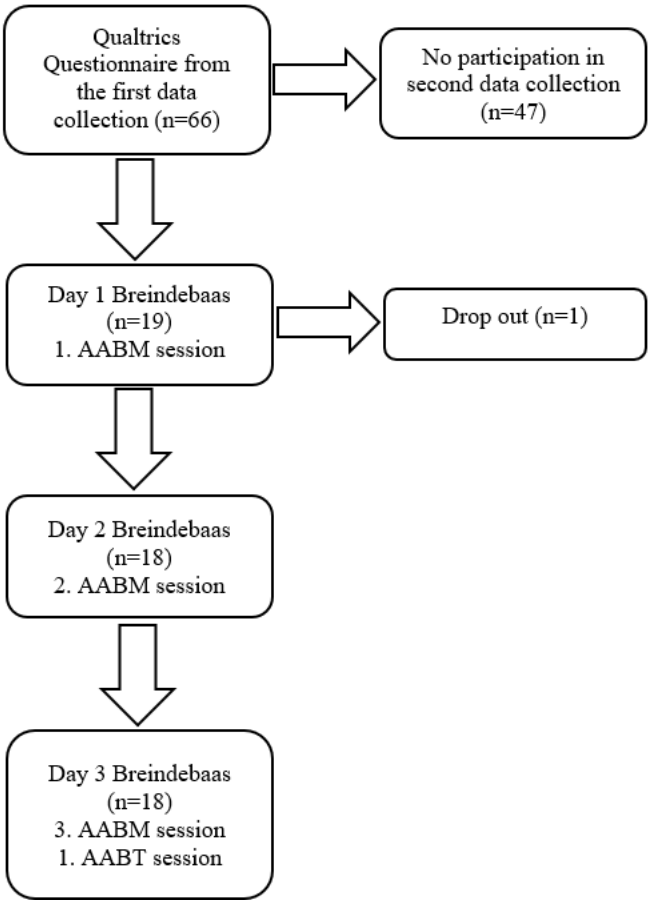
### Participants

Figure 2 shows the participant flow of the study. From the 66 people who filled in the Qualtrics Questionnaire during the first data collection, 25 were asked to test out the Breindebaas application a second time and eventually the final sample consisted of 19 participants, 13 of these were male and six females. The age range of the participants was between 18 and 58 years of age, with a mean age of 28.4 years (SD = 14.6). For the second data collection, all participants have been conveniently recruited via the researchers' private and social media (e.g. Instagram, Facebook, etc.) networks. Interested participants received an invitation message with more detailed information about the study (Appendix A). To be allowed to participate, the respondents needed to be willing to

download the Breindebaas app for which they required an android phone, be 18 years or older, and have sufficient English skills.

**Figure 2**

*Participant flowchart.*




## Measures and Materials

### *Qualtrics Questionnaire*

Every participant had to fill in an online questionnaire that was created in Qualtrics which is a cloud-based platform for creating and distributing web-based surveys (https://qualtrics.com; Appendix B). The questionnaire was conducted in English and took approximately 15 minutes.

**Demographic Characteristics.** Participants were asked to indicate their gender, age, and current primary occupation. Regarding gender, respondents had the options of ‘male’, ‘female’, and ‘other’. Concerning age, respondents could type in theirs in rational numbers. Pertaining to primary

occupation, respondents had the answer options ‘pupil/student’, ‘paid work’, ‘in search of employment’, and ‘other’ which they were asked to specify further in a textbox.

**Perceived Stress Scale.** The Perceived Stress Scale (PSS) is a ten-item self-report questionnaire on a five-point Likert scale that assesses the perceived stress of the respondents (Cohen, 1994). The internal consistency and the test-retest reliability of the PSS are both sufficient (> .70; Lee, 2012). 645 respondents between 18 to 29 years from the U.S make up the norm group which is comparable to the sample of this study wherefore its psychometrics can be generalized to this sample (Cohen, 1994).

**Motivation to change one’s drinking behaviour.** The motivation of the respondents to change their alcohol consumption was assessed with the statement “I intend to reduce my alcohol consumption compared to my current level.” Respondents had five answer options ranging from “Yes, certainly’’, “Yes, probably”, and “I don’t know” to “No probably not’’ and “No, certainly not”. This item was developed based on Fishbein and Ajzen’s (1975) construct behavioural intention which can be defined as “the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior” (Warshaw & Davis, 1984).

**Alcohol Timeline Follow-Back.** The Alcohol Timeline Follow-Back (Alcohol TLFB) is a self-report questionnaire that was developed by Sobell and Sobell (1995) and is used to measure the amount of alcohol individuals consumed in the past week. Hence, respondents were asked to indicate how many standard units of alcohol they consumed each day in the last week. A standard unit was defined in the questionnaire as a “unit of measurement used throughout Europe in order to be able to use the term 'glass' as an indication of the amount of pure alcohol (10-12 gr) despite the different alcohol content of different drinks” (Korte et al., 2012). The questionnaire has adequate psychometric properties as it displayed high test-retest reliability among low, medium, and high problem drinkers sampled from the general population (Sobell & Sobell, 1992). What is more, the Alcohol TLFB score has been found to significantly correlate with the total number of drinks consumed by participants even when divided by the total amount of drinking and abstinence days. Thus, this measurement tool can reliably collect retrospective estimates of data about an individual’s daily alcohol consumption (Sobell et al., 1996).

**Monthly Binge Drinking Frequency.** Because over 90% of excessive drinkers binge (Centers for Disease Control and Prevention, n.d.), participants were asked to specify how many times they drank six or more standard units of alcohol in a single occasion over the past four weeks. This was assessed with a closed question with eight answer options ranging from "I never drank six or more units in the past 4 weeks" over "1-6 times in the past 4 weeks" to "more than 6 times in the past 4 weeks." According to the World Health Organization (2018), binge drinking consists of consuming minimally 60 grams of pure alcohol on one occasion. As a standard unit of alcohol contains 10 grams of pure alcohol in the Netherlands (Mongan & Long, 2015), the minimum number of six standard units of alcohol was derived at.

### *Breindebaas Application*

The Breindebaas app was developed by the Dutch organization Tactus B. V. in 2016 and includes a measurement and a training feature (Laurens et al, 2020). The new 2.0.3 version of the application that was launched in the spring of 2021 is currently only available on Android devices.

## Procedure

After people responded with interest to the invitation message (Appendix A), they were provided with a link for the Qualtrics questionnaire. The questionnaire started with an informed consent that those who wanted to participate had to agree to before they could continue. It contained information about the general procedure and aim of the study as well as the inclusion criteria. Moreover, it stated the participant's rights to withdraw at any time, not to answer questions, and to confidentiality. Besides, data management issues concerning privacy and storage were explained as it was stated that all data will be stored in a password-protected electronic format on a GDPR approved server and that each questionnaire will be anonymized.

Thereafter, participants received a manual with detailed descriptions and screenshots about the Breindebaas app (Appendix C). First, they were asked to download the Breindebaas app in the Google Play Store. After that, they had to start the app where they filled in as a username the same pseudonymized participant ID they created within the survey beforehand. Then they had to apply the right settings which means that they were asked to use the personalized version of the app and turn off any prescribed order of training and measurement sessions. Before they could start with any sessions

the participants had to select at least ten but maximal twenty pictures of alcoholic and non-alcoholic drinks. Afterward, participants were asked to complete one measurement session on day one, another measurement session on day two, and a training session followed by another measurement session on day three. To remind the participants to complete the measurement sessions those that filled in their e-mail address in the survey received reminder emails (Appendix D). Finally, the participants were thanked for their participation in this study.

**Data Analysis**

The data analysis was done with the 25th version of the statistical software package 'IBM SPSS Statistics'. It was possible to link the data of the online questionnaire to the data from the Breindebaas application with the pseudonymized participant ID the respondents generated.

***Preliminary Analyses***

**AABM scores.** For every measurement session a participant completed, an AABM score was calculated that reflects the strength of the alcohol approach bias the individual possesses. The calculation of this score is based on the D-score formula by Greenwald et al. (2003). Here, the mean and standard deviation of the reaction times (RTs) of the alcohol stimuli in both the approach and avoidance parts were calculated for everyone. Note that of the total 60 stimuli the first ten for each condition (i.e. swiped congruently and incongruently) are for practice and therefore only 40 RTs are included in the calculation. Hereby, RTs of less than 200 or more than 2000 milliseconds were excluded. Besides, all incorrect RTs were replaced with the mean RTs of all responses to which a penalty of twice the SD from correct responses was added. Thereafter, the mean RT of the approach part is divided by the pooled standard deviation (Non-alcohol D = [RT(non/push) – RT(non/pull)] / SD(non)) and the same is done for the mean RT of the avoidance part (Alcohol D = [RT(alc/push) – RT(alc/pull)] / SD(alc)). Finally, the resulting sum from the avoidance part is being subtracted from the approach part (AABM score = Alcohol D – Non-alcohol D; Cohen, 1988; Nosek et al., 2014). A D-score can range from -2 to +2 and the higher the number the stronger the alcohol approach bias of the individual and vice versa.

**Descriptive Statistics.** Descriptive statistics were performed on the demographic characteristics of the questionnaire. A normality check was done with the Shapiro-Wilk Test due to

the rather small sample. Further, descriptive statistics were performed on the D-scores. Finally, a bivariate analysis in the form of a correlation matrix was performed. A significant positive correlation between PS and the average AABM score was expected so that more PS correlates with a stronger alcohol approach bias. Besides, a significant negative correlation between MOT and the Alcohol TLFB was expected so that more MOT correlates with a lower level of alcohol consumption. Note that the nature of the recruitment made it necessary to be alerted towards specified groups since most participants were students wherefore this subgroup was analysed on specific hypotheses to detect measurement invariances.

***Further Analyses for each Research Question***

**(1) Test-Retest.** To answer the first research question, a test-retest in the form of a univariate correlation analysis between the AABM scores from the baseline and second point of measurement was conducted. The more similar the AABM scores from the baseline and second measurement sessions, the higher is the test-retest reliability of the AABM feature. To calculate this, the intraclass correlation coefficient (ICC) and more specifically, a two-way mixed-effects model with an absolute agreement definition, was determined (Koo & Li, 2016). According to Koo and Li (2016), ICC values less than 0.5 signify poor reliability, values between 0.5 and 0.75 signify moderate reliability, values between 0.75 and 0.9 signify good reliability, and values greater than 0.90 signify excellent reliability.

**(2) Split-Half Reliability Test.** To answer the second research question, a split-half reliability test was carried out. For this analysis, the 40 RTs from each participant of the baseline AABM session were put into a wide format. Hereby, it was noticed that the distribution of the four possible categories (approach/avoid alcoholic/non-alcoholic beverages) was not equal among participants. Consequently, there were some missing values wherefore the mean RTs for each of the four categories was determined and filled in instead. Thus, there were not only the original 40 but 54 items in total after inserting the category-specific average for the missing values. Next, two halves of each 27 RTs were generated by dividing odd and even numbers. Afterward, the split-half reliability analysis was run in SPSS which resulted in a Spearman-Brown coefficient. If this coefficient is more than .80 then the internal consistency of the AABM feature of the Breindebaas app can be termed acceptable (Scale statistics, n.d.).

**(3) AABM's Sensitivity to Change.** To answer the third research question, a paired sample t-test was performed after the dataset was tested for normality. This analysis was performed between the AABM scores before the training session (i.e. pre-scores) and the AABM scores after the training session (i.e. post-scores). More specifically, for the AABM scores from the first and second points of measurement before the training, the average from the test-retest reliability was used to make up the average baseline AABM score. The null hypothesis was that there is no significant difference between both measurements (i.e. training has no effect) whereas the alternative hypothesis read that there is a significant decrease (i.e. training has an effect). This was determined using the p-value and to minimise the possibility of a Type I Error, an alpha of 0.05 was used to evaluate the significance of the results. Afterward, the average baseline AABM (pre-score) as well as the post-AABM score were checked for normality with the Shapiro-Wilk test. Next, the occupational subgroups were also tested for normality with the Shapiro-Wilk Test.

**(4) Measures of Alcohol Consumption.** To answer the fourth research question, a bivariate correlation analysis between the Alcohol TLFB scores, the monthly binge-drinking frequency, and the baseline AABM scores was conducted. In this case, a significant positive correlation was anticipated, in other words, consuming more alcohol correlates with a higher alcohol approach bias.

**(5.1) & (5.2) Perceived Stress.** To start with, the total scores of the PS scale were calculated by using the sum total and taking the reversed items (4, 5, 7, 8) into account. To answer the first part of the fifth research question, a simple moderator analysis was performed using PROCESS a versatile modelling tool developed by Hayes (Hayes, 2012). In this case, the dependent or outcome variable was the Alcohol TLFB score, the independent or predictor variable was the baseline AABM score, and the moderator variable was the PS score. To answer the second part of the fifth research question, participants were divided into high and low PS groups through a median split. The median split score was calculated to be around 19 so that seven participants were grouped as perceiving a 'high' amount of stress, and the other 12 as perceiving a 'low' amount of stress. Then, a linear mixed model with the number of measurement as the first factor and the dummy variable for PS was applied to detect any differences between the groups. All factors were treated as fixed effects so that the dependent

variable, namely the AABM score, was calculated for all factors. Using MANOVA, the significance of the measures was calculated.

**(6) Motivation to change one's drinking behaviour.** To answer the sixth research question, participants were divided into high and low motivational groups through a median split. The median split score was calculated to be around four so that seven participants were grouped as having 'high' motivation, and the other 12 as having 'low' motivation. Then a linear mixed model with the number of measurement as the first factor and the dummy variable for MOT was applied to detect any differences between the groups. All factors were treated as fixed effects so that the dependent variable, namely the AABM score, was calculated for all factors. Using MANOVA, the significance of the measures was calculated.

## Results

### Descriptive Statistics

First, descriptive statistics of the demographic characteristics were performed that are summarised in Table 1. The mean age of all 19 participants was 28.4 ranging from 18 to 58 years (SD=14.6). What stands out is that the sample has more males (68.4%) than females (31.6%). As expected, most of the participants were students (73.7%) who displayed higher values for the Alcohol TLFB (25.9 as opposed to 3.6) as well as the monthly binge-drinking frequency (4.9 as opposed to 4.). Additionally, more participants perceived a low amount of stress (63.2%) and were not motivated to change their drinking behaviour (63.2%).

Moreover, descriptive statistics of the AABM scores for each session were calculated that are summarised below in Table 2. Remarkable is that the mean decreases from one AABM session to another (1. -.14, 2. -.64, 3. -.82). Along with that, the minimum (1. -.17, 2. -.21, 3. -.23) and especially the maximum values (1. 1.58, 2. .81, 3. .47) are decreasing as well.

Table 3 displays the correlation matrix with the Pearson's correlation between the relevant variables of this study. A person's PS and baseline AABM score do not correlate significantly, $r(17) = .08$, $p = .73$ just as a person's MOT and their Alcohol TLFB scores do not correlate significantly, $r(17) = .10$, $p = .66$. However, participant's age and occupation both negatively correlate with the monthly binge drinking score in a significant way ($r(17) = -.62$, $p = .01$; $r(17) = -.63$, $p = .01$).

Furthermore, a person's MOT and PS score correlate negatively in a significant manner, $r(17) = -.52$, $p = .02$. Another significant positive correlation is that between a person's age and occupation, $r(17) = .87$, $p = .01$.

**Table 1.** Demographic characteristics of the participants (n=19).

| **Variable** | **N** | **%** |
|---|---|---|
| **Age (years), mean (SD)** | 28.4 (14.6) | 100% |
| **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 | 00.0% |
| Housewife | 1 | 05.3% |
| **Total Alcohol TLFB, mean (SD)[a]** | 20.0 (23.8) | |
| Pupil or student | 25.9 (25.0) | |
| Other | 3.6 (6.5) | |
| **Monthly binge-drinking frequency, mean (SD)[b]** | 3.7 (3.1) | |
| Pupil or student | 4.9 (2.8) | |
| Other | .4 (.9) | |
| **Perceived Stress, mean (SD)[c]** | 18.9 (2.9) | |
| High (>19) | 7 | 36.8% |
| Low | 12 | 63.2% |
| **Motivation, mean (SD)[d]** | 3.8 (1.2) | |
| High (>4) | 7 | 36.8% |
| Low | 12 | 63.2% |

[a] How many standard units a participant drank during the last seven days.

[b] How many times a participant drank more than six standard units on one occasion during the past four weeks.

[c] Measured with ten items on a five-point Likert scale.

[d] Measured with one item on a five-point Likert scale.

**Table 2.** Descriptive Statistics of the AABM scores from all participants (n=19) for each session.

| | **1. Baseline AABM** | **2. Pre-AABM** | **3. Post-AABM** |
|---|---|---|---|
| **Mean** | -.14 | -.64 | -.82 |
| **SD** | .83 | .77 | .68 |
| **Minimum** | -.17 | -.21 | -.23 |
| **Maximum** | 1.58 | .81 | .47 |

**Table 3.** Pearson correlations of all relevant variables (n = 19).

| **Variable** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** | **7.** | **8.** | **9.** |
|---|---|---|---|---|---|---|---|---|---|
| **1. Average AABM score** | 1.00 | | | | | | | | |
| **2. Post-AABM score** | .08 | 1.00 | | | | | | | |
| **3. Alcohol TLFB[a]** | -.21 | -.10 | 1.00 | | | | | | |
| **4. Binge Frequency[b]** | -.39 | -.12 | .74** | 1.00 | | | | | |
| **5. PS[c]** | .08 | -.21 | .21 | .03 | 1.00 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **6. Age** | .19 | -.31 | -.44 | -.62** | -.06 | 1.00 | | | |
| **7. Gender**[d] | .54* | .22 | -.40 | -.41 | -.31 | .14 | 1.00 | | |
| **8. Occupation**[e] | .44 | -.24 | -.42 | -.63** | -.04 | .87** | .41 | 1.00 | |
| **9. MOT**[f] | -.17 | .33 | .10 | .18 | -.52* | -.28 | .14 | -.33 | 1.00 |

[a] How many standard units a participant drank during the last seven days.

[b] How many times a participant drank more than six standard units on one occasion during the past four weeks.

[c] Measured with ten items on a five-point Likert scale.

[d] 1 = Male, 2 = Female, 3 = Other.

[e] 1 = Pupil or student, 4 = Paid work, 5 = In search of employment, 6 = Other (Please specify).

[f] Measured with one item on a five-point Likert scale.

*$p$ < .05 level (2-tailed); **$p$ < .01 level (2-tailed).

**Further analyses for each research question**

***(1) Test-Retest***

First, a test-retest in the form of a univariate correlation analysis between the AABM scores from the baseline and second point of measurement was conducted. An insignificant ICC (3,1) of absolute agreement of .093 was found with a 95% confidence interval from -.313 to .503 ($F$(17) = 1.228, $p$ = .338).

***(2) Split-Half Reliability Test***

Second, a split-half reliability test was performed. The Spearman-Brown coefficient for equal length pointed towards good internal consistency with a value of .93.

***(3) AABM's Sensitivity to Change***

Third, a paired sample t-test was conducted which revealed that the average baseline AABM score (pre-score) had a mean of -.42 (SD = .59) and the post score had a mean of -.82 (SD = .68). However, no significant difference between the pre- and post-AABM scores was found, $t(17) = 2.00$, $p = .062$. Nevertheless, a *p*-value of .062 can be seen as a marginally positive effect, suggesting an expected improvement in AABM toward avoiding alcohol (95% CI [-.02, .83]) after a single CBM session. The Shapiro-Wilk test revealed that the average baseline and post score, were normally distributed ($W(19) = .97$, $p = .66$; $W(18) = .98$, $p = .88$). However, participant 11 was displayed as an outlier for the post-score. Furthermore, the measurement invariance analysis showed non-significant results since the occupational subgroups were found to be normally distributed for all measurements according to the Shapiro-Wilk Test ($W(14) = .98$, $p = .97$; $W(14) = .97$, $p = .83$).

***(4) Measures of Alcohol Consumption***

Fourth, a bivariate correlation analysis was conducted between the baseline AABM score, Alcohol TLFB score, and the monthly binge-drinking frequency; the results are listed in Table 4. A significant positive correlation between the Alcohol TLFB and the monthly binge-drinking frequency was found, $r(17) = .74$, $p = .01$. The Alcohol TLFB and the monthly binge-drinking frequency, in turn, correlate slightly negatively with the baseline AABM score, however both correlations are not significant ($r(17) = -.20$ $p = .4$; $r(17) = -.39$, $p = .1$).

**Table 4.** Pearson correlations of the Alcohol TLFB, the monthly binge-drinking frequency, and the average baseline AABM score (n = 19).

| **Variables** | **1.** | **2.** | **3.** |
|---|---|---|---|
| 1. Baseline AABM | 1 | | |
| 2. Alcohol TLFB | -.20 | 1 | |
| 3. Monthly binge-drinking frequency | -.39 | .74* | 1 |

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

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

***(5.1) & (5.2) Perceived Stress***

Overall, the PS scores varied across the sample between 14 and 23 with a mean of 18.9 (SD = 2.9). The Shapiro-Wilk test showed that the PS scores were normally distributed without outliers ($W(19) = .93$, $p = .20$). For the first part of the fifth research question, the PROCESS analysis revealed that the overall model can explain up to 24% of the variance but was found to be not significant, $F(3, 15) = 1.56$, $p = .23$, $R^2 = .24$. Both predictors, namely the baseline AABM score ($b = 44.83$, $t(15) = .95$, $p = .77$), and the PS score ($b = 1.56$, $t(15) = .85$, $p = .36$) as well as the interaction between the both were not significant, $b = -2.84$, $t(15) = -1.17$, $p = .26$.

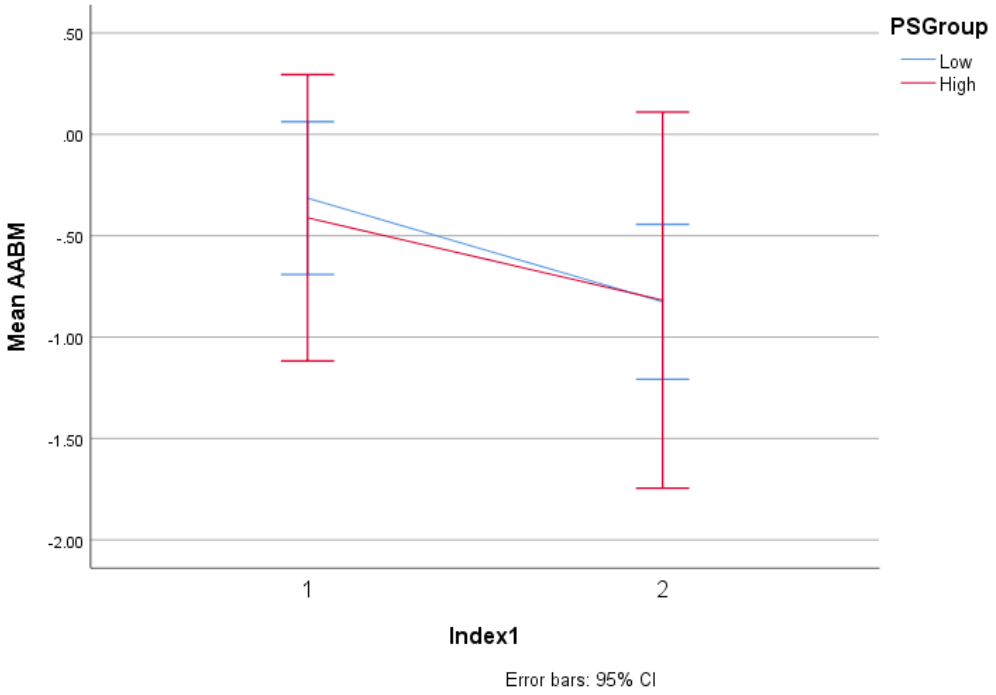
For the second part of the fifth research question, the mean and standard deviations for each average baseline AABM and post-AABM session according to the two PS groups are given in Table 5. The linear mixed model showed that PS has no statistically significant effect neither on the average AABM score ($F(1, 16) = 1.11$, $p = .98$) nor on the post-AABM score ($F(1, 16) = .00$, $p = .31$). Although the numbers in table 5 indicate that people with a high amount of PS reacted more strongly towards the AABT, the linear mixed model does not confirm this. The change in AABM scores from pre to post did not differ between high and low PS individuals, $F(2, 15) = .527$, $p = .60$; Wilk's $\Lambda = .93$. This result is also well visualized by the Graph below in Figure 3: although the baseline AABMs before the training might differ, after the training they are nearly identical.

**Table 5.** Means (M) and standard deviations (SD) of baseline AABMs, separated by 'High' (n=7) and 'Low' (n=12) perceived stress (PS) groups.

| | **Before training** | | **After training** | |
|---|---|---|---|---|
| | **M** | **SD** | **M** | **SD** |
| High PS | -.41 | .76 | -.82 | .88 |
| Low PS | -.31 | .59 | -.83 | .60 |

**Figure 3**

*A linear mixed model containing two AABMs (before and after training) with error bars. The lines are separated by a 'high' and a 'low' perceived stress (PS) group.*




*Note.* The mean AABM scores (y-axis) before and after training (x-axis) are displayed for the 'high' and 'low' perceived stress groups (PSGroup). Error bars show a 95% confidence interval.

***(6) Motivation to change one's drinking behaviour***

Overall, the MOT scores varied across the sample between 1 and 5 with a mean of 3.58 (SD = 1.26). The Shapiro-Wilk test showed that the MOT scores were not normally distributed ($W(19) = .87$, $p = .01$) wherefore caution must be given during the interpretation of the following results. For the sixth research question, the mean and standard deviations for the average baseline AABM as well as post-AABM session according to the two motivation groups are given in Table 6 and the graph from the linear mixed model is presented in Figure 4. According to the linear mixed model, MOT has no statistically significant effect neither on the average AABM score ($F(1, 16) = .22$, $p = .64$) nor on the post-AABM score ($F(1, 16) = .62$, $p = .44$). Although the graph indicates that people with high motivation show a stronger reduction in AABMs of the post score than people with low motivation, the linear mixed model analysis does not corroborate this. The change in AABM scores from pre to post did not differ between high and low MOT individuals, $F(2, 15) = .44$, $p = .65$; Wilk's $\Lambda = .94$.

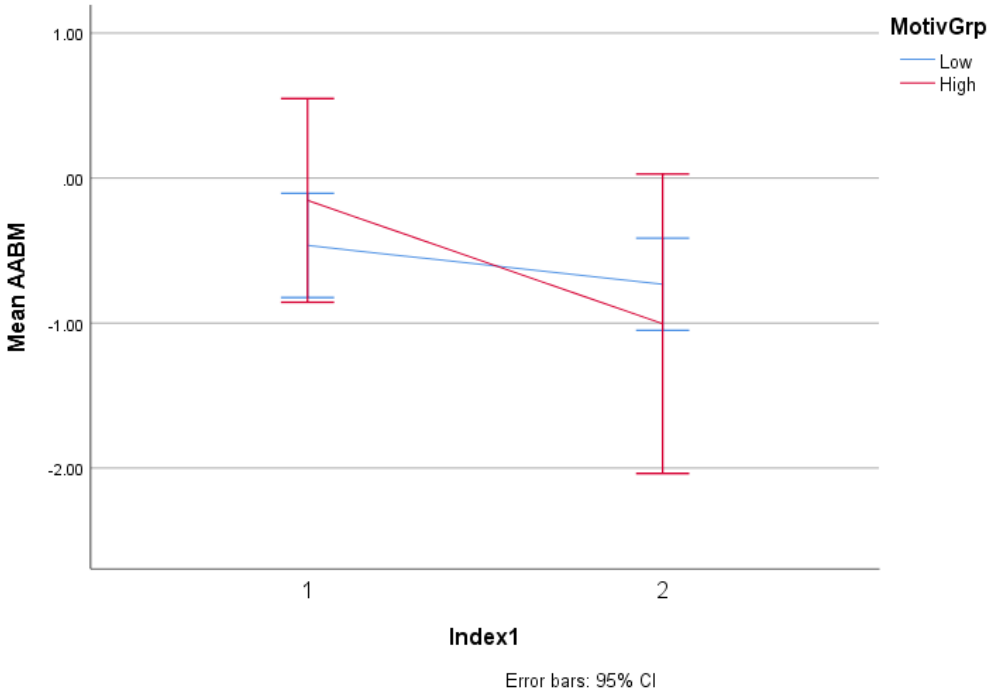
**Table 6.** Means (M) and standard deviations (SD) of AABMs, separated by 'High' (n=7) and 'Low'

(n=12) motivation groups.

| | Before training | | After training | |
|---|---|---|---|---|
| | **M** | **SD** | **M** | **SD** |
| High motivation | -.15 | .80 | -1.00 | .98 |
| Low motivation | -.46 | .57 | -.73 | .50 |

**Figure 4**

*A linear mixed model containing the two AABMs (before and after training) with error bars. The lines are separated by a 'high' and a 'low' motivation group.*




*Note.* The mean AABM scores (y-axis) before and after training (x-axis) are displayed for the 'high' and 'low' motivation groups (MotivGrp). Error bars show a 95% confidence interval.

## Discussion

This study aimed to investigate the psychometric properties of the Breindebaas application which makes use of a mobile version of the alcohol approach-avoidance task (AAT) to measure the alcohol approach bias. During the personalized alcohol approach bias measurement (AABM), 30

pictures must be swiped congruently, and the other 30 pictures must be swiped incongruently (i.e. alcoholic stimuli pulled towards and non-alcoholic stimuli pushed away). A mixed cross-sectional and a pre- and post-test single group design were applied which yielded ambiguous results. Whereas the test-retest displays poor external reliability of the AABM, the split-half-reliability test suggests good internal reliability. On the one hand, the AABMS sensitivity to change looks promising but on the other, hand its external validity appears poor.

**Reliability Research Questions (1 & 2)**

The first research question asked about the test-retest reliability between the AABM scores from the first and second measurement sessions assessed over two consecutive days. The test-retest reliability was very low (ICC > .10) which means that both AABM sessions do not correlate significantly, consequently the AABM does not seem to be an internally reliable measurement for the alcohol approach bias. It seems unlikely that these results were caused by a heterogeneous sample because no measurement invariances for the specified group of students were found. While this study has been the first to investigate the internal reliability of the AABM feature of the Breindebaas app, this result might be due to the little number of reaction times (RTs) as the original computerized alcohol approach-avoidance task training (AAT-T) by Wiers et al. (2010[b]) but also other mobile versions of the AAT (Zech et al., 2020) use substantially more RTs. It can be speculated that the more RTs, the more representable the AABM scores, and consequently the more reliable the AABM feature. This could be further investigated by calculating inclusive standard deviations (SDs) that assess how much subjects vary in their RTs across a full AABM session. Afterward, the inclusive SDs from this study could be compared with those of other similar studies to verify whether the number of RTs has indeed the speculated impact. The second question tested the internal consistency of the Breindebaas app measured with the split-half reliability for adequacy. The statistical analysis revealed a good Spearman-Brown coefficient meaning that one half of the AABM session correlates with the other half wherefore the AABM appears to have good internal consistency. However, caution must be paid because due to the unequal divisions of stimuli per category the missing values were replaced by category-specific mean RTs which artificially increased the overall number of RTs.

Notably, the two research questions investigating the reliability of the AABM feature yielded two different results: whereas the test-retest reliability is poor, the internal consistency is good. It is important to acknowledge that the test-retest aims attention at the external reliability namely the extent to which the AABM feature varies from one time point and participant to another whereas the split-half reliability test focuses on the internal reliability of the AABM feature namely the extent to which it is a consistent measure within itself. Thus, although both tests examine the reliability of the AABM feature, they still centre on two different aspects of reliability. Similar results have been found in a study by Reinecke et al. (2010), where the test-retest reliability of the AAT was also found to be low, but its internal consistency was good. Nevertheless, they argue that "measuring RTs reliable at millisecond level is very difficult" (Reinecke et al., 2010), wherefore this weakness of the test-retest reliability needs to be considered when making inferences or comparisons. Comparable results have been found in other studies assessing the external and internal reliability of the AAT (Piercy et al., 2021; Zech et al., 2020). To conclude, the individual tests and their results need to be put into perspective, thus the test-retest of a mobile AAT cannot be expected to be as high as the split-half reliability test. Furthermore, Reinecke et al. (2010) suggest keeping the tested AABM sessions as similar as possible to achieve higher test-retest results which was due to the unequally divided alcoholic and non-alcoholic stimuli within and among the two AABM sessions not given.

Based on the incentive-sensitization theory of addiction, it was hypothesized that the personalised AABM feature of the Breindebaas app would be more accurate than the standardized AABM feature. Although no comparison between the customized and standardized AABM feature was done in this study, the research previously done in this field might give additional insights. For example, Brouwer and Balci (both 2019) tested the standardized and personalized options and found no correlation between the two and no added value by the customized version. Therefore, it can be speculated that the two features work via two different mechanisms hence, the two versions might lead to different results. But this argumentation asks for more research especially since the respondents of Brouwers and Balci's study (both 2019) had the feeling that they did not truly personalize their set of stimuli.

**Validity Research Questions (3, 4, 5.1, 5.2 & 6)**

None of the following four research questions concerning the predictors or moderators of the AABM score showed significant results which means that the external validity of the personalized AABM feature of the Breindebaas application might be considered low. First, each research question will be discussed separately with specific explanations for the results and afterward, further explanations will be listed that possibly apply to multiple or all the validity research questions.

The third research question investigated whether the post-test AABM score decreased significantly compared to the pre-test AABM score after receiving one session of AABT. A marginal positive statistical effect was found as the mean AABM score after the AABT session decreased compared to the mean AABM score before the AABT session which means that the AABM feature is sensitive enough to change to detect such. However, caution must be paid not only because the AABM has been found unreliable in this study but also because no control group was used wherefore this effect cannot be verified. Nevertheless, the direction in which this effect goes is in line with previous research showing that the original computerized AAT-T was able to modify the automatic processes governing alcohol-approach bias of problem drinkers (Gladwin et al., 2017; Grafton et al. 2017; Wiers et al., 2010[b]; Wiers et al., 2011). An explanation for the mere marginal results might be due to the single AABT session because in the studies where significant CBM effects have been found, the numbers of AAT-T sessions varied between one, four, and eight (Eberl et al., 2013; Ghaffari-Touran et al., 2021; Wiers et al., 2010[b]; Wiers et al., 2011).

The fourth research question examined whether there is a significant positive correlation between the baseline AABM score, the baseline Alcohol TLFB, and the monthly binge-drinking frequency. No significant positive correlation between the AABM score and the two alcohol consumption measurements could be found which implies that whether a person drinks more or less does not mean they have a stronger or weaker alcohol approach bias. During the time of the first data collection (April 2021), the worldwide Corona pandemic was still present wherefore strict governmental regulations controlled a huge part of people's social life. Consequently, participants might have consumed less alcohol than usual because there were not as many parties and social gatherings as there normally would be (Trimbos instituut, n.d.). It might be that this particularly

impacted this sample because arguably most students drink socially within associations or with flatmates etc. whereas alcohol-dependent adults are likelier to drink alone at home.

The first part of the fifth research question dealt with the possibility that the correlation between a participant's baseline AABM score, and their self-reported level of alcohol consumption might be stronger for those with high perceived stress (PS). Nevertheless, the statistical analysis could not confirm this wherefore it could not be proven that the amount of PS moderates the relationship between a participant's baseline AABM score and their self-reported level of alcohol consumption. It was hypothesized that people with high PS turn towards alcohol as a coping mechanism due to the dominant automatic pathway which might lead to an alcohol approach bias. The second part of the fifth research question focused on the likelihood that participants with high PS are more sensitive to a CBM effect on their AABM scores. Again, the statistical analysis cannot corroborate this since the change in AABM scores from pre to post did not differ between high and low PS individuals. It was hypothesized that the automatic pathway dominates the reflective one in individuals with higher PS, wherefore an attempt to alter the former might be more effective for those people.

The sixth research question aimed attention at the chance that participants with high motivation to change their drinking behaviour (MOT) are less sensitive to a CBM effect on their AABM scores. Generally, caution must be paid because the Shapiro-Wilk test showed that the MOT item is not normally distributed. Anew, the statistical analysis cannot attest to this, as the change in AABM scores from pre to post did not differ between high and low MOT individuals. It was hypothesized that the attempt to alter high MOT participants' automatic pathway might not be as effective because their reflective pathway is already the dominant one. It might be that they are motivated to drink less but still drink much because they are not able to control their cravings. It could be that despite the motivation to act otherwise their automatic pathway still overrules their reflective one, for example, the automatic pathway acts rapidly on the cravings not leaving room for conscious decision-making (Strack & Deutsch, 2004).

Generally, due to having asked participants to take part twice, the second series of pre-tests are no longer true pre-tests, and it cannot be ruled out that this single AABT session might still influence the AABM scores. As mentioned above, it is not clear yet how many sessions are necessary

to establish a CBM effect but in some studies, significant changes have been found after a single AAT-T session (Eberl et al., 2013; Wiers et al., 2010[b]). Furthermore, the AABM sessions were not assessed in a controlled laboratory environment which results in less control for confounding variables. Because it is not the aim of the developers of the app that it is only used in laboratories it might prove valuable to ask for other critically and possibly confounding variables some ideas for that are mentioned below under further research. Moreover, the sample was small and especially not clinical. However, the motivation of people with serious clinical drinking problems might have a different scope and Gladwin et al. (2017) even state that motivation is necessary for significant CBM effects. In this sample, most participants were not motivated to change their drinking behaviour which might have distorted some results. Besides, non-clinical participants might use different coping mechanisms such as physical exercise or talking with friends rather than turning to alcohol, when they perceive much stress. What is more, the change from computerized AAT to mobile AAT might have a higher impact than previously anticipated. For example, MacLeod and Clarke (2015) found that the beneficial effects of CBM were largely reduced when applied as a mobile AAT-T. This might be due to the missing physical act of avoidance and approach behaviour that is mimicked by pushing and pulling a joystick within the computerized version. According to Klein et al., (2011), the zooming function has proven to be an important factor and it might be that on smartphones with much smaller displays the effect of zooming is less noticeable. Finally, previous studies that investigated similar research questions and found significant correlations used different calculations for the AABM score. For example, instead of using the relative D-score, it could prove valuable to only use the alcohol D-score because there might be some interdependency between the D-score for alcoholic drinks and the D-score for non-alcoholic drinks. Another option is to base the AABM score calculations on raw RTs to avoid the correction of outliers. Raw RTs are the mean differences between the alcohol approach and the alcohol avoidance parts. This calculation might have led to significant positive correlations between the relevant feature version of the AAT and the participant's alcohol consumption and the alcohol use disorder identification test (AUDIT) in a study by Kersbergen et al. (2015). Yet another option could be to log transform the weekly alcohol consumption to decrease skewness. In a study by

Field et al. (2008), this might have been the reason for a significant positive correlation between participants' weekly alcohol consumption and the AUDIT with the bias score.

**Strengths and Limitations**

This study was one of the very first attempts to validate mobile cognitive bias measures which makes it a worthwhile addition to the previous literature on the psychometric properties of the Breindebaas application. Moreover, the detailed instructions in the invitation message, the Breindebaas manual, and the reminder emails make the steps to take not only easily understandable but also highly standardized. Moreover, because the study was online it was accessible and less demanding and/or obtrusive.

Nevertheless, the results presented here should be interpreted with caution as several limitations could hinder their inference. The first limitation concerns the difficulties experienced during the initial data collection as this data could not be downloaded. After the problems could be solved, the participants were asked to complete the sessions with the app a second time which had serious consequences for this study. For once, due to the delay, approximately four weeks lay between the completion of the questionnaire and the sessions with the Breindebaas app. The finished questionnaires from the first data collection were used to not burden the participants further but during the four weeks many changes could have occurred in the lives of the participants; especially because most scales in the questionnaire ask the respondent to focus on the last four weeks. For example, during the second data collection in June 2021, there were already some Corona regulations that got repealed by the government wherefore more social events could take place which was then not accounted for. Furthermore, the pre-tests of the second data collection are no longer true pre-tests and the single CBM session might have still affected the second measurements. In addition, only a fraction of the initial sample agreed to participate a second time which led to a much smaller sample than initially aimed at. It can be hypothesized that with a bigger sample different results could have been achieved. Besides, no control group was used to verify the effectiveness of the AABT just as the measurements were not taken in a controlled laboratory environment which are serious design flaws that should be accounted for in further research.

Other limitations concern the Breindebaas app directly as there have been multiple technical issues. To begin with, the new version of the app is currently only available for Android thus excluding potential participants who use an iPhone which might have been an additional reason for the small sample size. Furthermore, there were not as many RTs as in similar studies who had different results (e.g. Wiers et al. 2010[b]; Zech et al., 2020). Besides, the present RTs were unequally divided into the four categories (pushing/pulling alcoholic/non-alcoholic drinks) between-subjects during one measurement as well as within-subjects across measurements wherefore the assessment conditions were not the same for each participant among all trials. As a result, this might have affected the reliability as could be seen in the low test-retest results. Additionally, multiple participants reported that their app froze mid-trial or crashed down. Sometimes, these difficulties could be solved by restarting the app but at other times the app needed to be redownloaded which led to the deletion of all previously collected data from that user. Such technical problems need to be dealt with to be able to offer an app that can be inclusively used by any participants without further struggling them.

Another weak point of this study constitutes the AABM calculation which is based on the D-score formula by Greenwald et al. (2003). Normally, the scores are calculated with the use of a penalty score for each swiping movement that occurred in the wrong direction. However, it was decided to leave this step out as due to the tiny number of RTs this would have had a heavier impact on the final AABM scores than usually. Nevertheless, the penalty score increases the accuracy of the AABM scores and thus might explain the low test-retest reliability and insignificant results this paper encountered.

Finally, another limitation concerns the nature of the sample since normally the app is aimed at people with serious drinking problems, but the sample of this study was not clinical which could have affected the results. With the tailored sample some results might turn out differently because, for example, people with serious drinking issues might drink more and have different motivations to use the app than the current sample. A clinical setting might also be safer for the participants because from several statements made by participants, it seemed as if some were for the first time confronted with such an issue and might have realised that they struggled. In addition, some participants

mentioned triggering effects or appetitive cues by the alcoholic stimuli. This might create serious ethical problems in the future wherefore it should be verified whether these potential adverse effects occur often enough to be of concern.

**Suggestions for Further Research**

Further research is needed to investigate the psychometric properties of the newly developed Breindebaas application. It would be interesting to conduct an experiment that would account for the limitations of this study to examine if this would lead to more significant results regarding the app's external reliability and validity. First, the technical difficulties of the app should be accounted for so that this app is made available for iPhone users, comes without any bugs etc., and contains more RTs. In addition, future research could focus on a double-blind experiment with a control group to verify if the CBM effect from the AABT leads to bias changes. Additionally, further research should aim at a bigger ($N > 30$) and clinical sample and should include the penalty score in the AABM score calculation or even compare different AABM score calculations.

There are more specific predictors with which the app's external validity could be further investigated. Originally, it was planned to assess them within this study but because the study design had to be changed from having participants doing the whole study done on one day to doing it over three consecutive days this was not possible anymore. For once, measuring the amount of alcohol consumption at the beginning of the study and the end or during a longer study even in between might reveal valuable additional insights. This way more research questions or hypotheses can be tested in different variations for example within a longitudinal study or with a control group to clarify if the effects arise from CBM alone. Another aspect is the physical and social context but to investigate this properly the environmental context must be elaborated before every measurement session. It is long known that the environmental cues might trigger certain responses and thus it remains to be seen if that might influence the AABM scores as well. There are many more additional variables such as the participant's craving, their current mood, or the time of their last drink that could influence the AABM score wherefore an investigation of these in future studies is desirable.

With advancing technology, computerized CBM programmes such as the AAT were made available on smartphones and tablets but because technology is ever evolving there are now multiple

relatively new promising features the Breindebaas app could integrate. For instance, Zech et al. (2020) did not only measure reaction times (RT) but also response forces (RF) using motion sensors. Traditionally, RF is used to assess approach-avoidance motivation in animals, but recently it has been related to motivation strength in humans as well. In several experiments, Zech et al. (2020) discovered that RT and RF did not correlate significantly wherefore they suspected that both are driven by different processes. Furthermore, the mobile AAT reliably measured RTs and RFs in the laboratory and the field. Hence, an AAT based on RTs and RFs might be more accurate because it captures multiple aspects of the approach-avoidance behaviour.

Besides, virtual and augmented reality have become popular over the last years and a recent review by Tsamitros et al. (2021) suggests that virtual reality (VR) is a "promising tool for the assessment and treatment of craving among individuals with substance use disorders." With the inclusion of multiple sense modalities such as vision and hearing, VR creates an environment with more realistic stimuli and situations and a more authentic interaction with them wherefore it can be expected that an AAT incorporating VR might be more accurate in measuring and modifying the alcohol approach bias than the standardized or computerized version (Kim & Lee 2015; Kim & Lee, 2019). Similar to the superiority argumentation for the personalized AABM feature of the Breindebaas app, an explanation for this might be given by the incentive-sensitization theory which states that cognitive biases rely to a major part on the unique association individuals developed between specific stimuli from their environment and their following rewarding experience (Robinson & Berridge, 2008). Kim and Lee (2015 & 2019) developed a virtual AAT (VAAT) where respondents enter either a filled or empty room where several alcoholic and non-alcoholic related scenes are displayed. Right after the scenes, a colour signal appears, and users must respond by pulling or pushing a joystick and a zooming function then imitates the approach or avoidance behaviour. So far, they have tested the VAAT's measuring function suggesting that it might be more accurate in assessing the alcohol approach bias (Kim & Lee, 2015). Additionally, the VAAT's training function was also investigated and appears promising in reducing automatic action tendencies toward alcohol (Kim & Lee, 2019). Another study compared the computerized, mobile, and VR AAT directly and found that the VR delivered AAT resulted in fewer errors as well as higher engagement, flow, and

immersion ratings from users. Hence, VR appears as a promising alternative to the other AAT interfaces as it might lead to more engaged, accurate, and effective use of the AAT (Kakokschke et al. 2021).

**Conclusion**

This study aimed to investigate the psychometric properties of the Breindebaas application. Whereas the external reliability of the AABM seems poor, its internal reliability is good. Furthermore, its sensitivity to change appears marginal and its external validity overall poor. However, due to several technical difficulties, flaws in the study design, the small and non-clinical sample, as well as the flawed calculation of the AABM scores no firm conclusions can be drawn from this study. Future studies might investigate the effect of different calculations for the AABM score, the AABMs external validity with predictors such as alcohol consumption and physical and/or social context, as well as adding features like response force or virtual reality to the Breindebaas app. To conclude, the current study encourages further improvement and use of the Breindebaas app, while emphasising a need for accounting for this study's limitations, to hopefully establish significance on the psychometric properties of the AABM and AABT feature of the app.

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# Appendices

## Appendix A: Invitation to participate in the Study

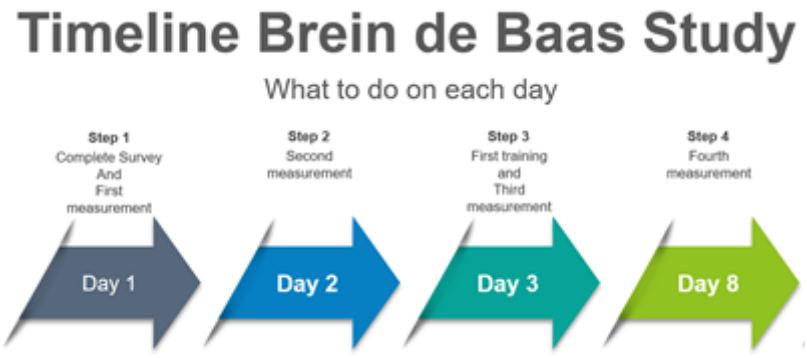
***Version for Dutch participants***

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:
https://utwentebs.eu.qualtrics.com/jfe/form/SV_cA7Z2buUdhhTCZM (Qualtrics questionnaire) and afterwards go to: https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing ( Breindebaas manual).

Sincerely, Milan Verhoeven & Laura von Deetzen

***Version for German Participants***

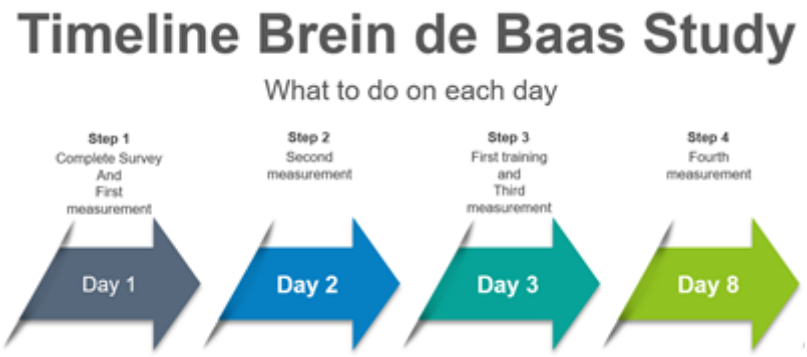
Dear …,

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: https://utwentebs.eu.qualtrics.com/jfe/form/SV_cA7Z2buUdhhTCZM (Qualtrics questionnaire) and afterwards go to: https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing ( Breindebaas manual).

Sincerely, Milan Verhoeven & Laura von Deetzen

**Appendix B: Qualtrics Questionnaire**

https://utwentebs.eu.qualtrics.com/jfe/form/SV_cA7Z2buUdhhTCZM

**Appendix C: Breindebaas Manual**

**https://docs.google.com/document/d/1oK3PBmrnxUGjQkqx0i-AOQqq-WsjKjBPZmScc0LKpUE/edit?usp=sharing**

**Appendix D: Reminder mails**

***Reminder Mail for 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

***Reminder Mail for 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