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Is the Strength of Implicit Alcohol Associations Correlated with Alcohol-induced Heart-rate Acceleration?

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Background: Heart rate (HR) acceleration during the ascending limb of the blood alcohol curve has proven to be a reliable measure of the sensitivity to the activating effects of alcohol. In this study, we investigated the correlation between an ethanol-induced cardiac change and the strength of implicit alcohol-related arousal and approach associations and attentional bias for alcohol-related stimuli in heavy drinkers. These 3 types of implicit alcohol-related cognitions have been proposed to reflect the strength of incentive sensitization that is experienced after repeated alcohol use.

Methods: Forty-eight heavy drinking men performed a modified version of the Implicit Association Test (IAT) to measure their implicit alcohol arousal and approach–avoidance associations. A modified version of the emotional Stroop was used to measure attentional bias for alcohol-related stimuli (blocked and unblocked). Next, a high dose of alcohol (1.0 mL/kg body weight 95% USP alcohol) was administered in a short period of time. Resting baseline HR, blood alcohol concentrations, mood, and craving for alcohol were assessed before alcohol administration and for 2 hours post–alcohol consumption.

Results: Contrary to our hypothesis, a negative association was found between implicit arousal associations and alcohol-induced HR change. This indicates that strong arousal associations were correlated with a decrease in alcohol-induced HR. Approach associations and attentional bias were not correlated with alcohol-induced HR change, but both were correlated positively with each other.

Conclusions: Alcohol-arousal associations and other implicit cognitions (attentional bias, approach associations) are not positively related to individual differences in the sensitivity to alcohol's activating effects, at least not in the present sample consisting primarily of family history-negative heavy drinkers.

Key Words: Implicit Alcohol Cognitions, Implicit Arousal Associations, Implicit Approach Associations, Attentional Bias, Alcohol-induced HR Change.

ALCOHOL MISUSE AND dependence are 2 of the most prevalent diagnoses of psychiatric disorders in the Netherlands. Almost 20% of Dutch men develop lifetime alcohol; abuse and 9.0% develop alcohol dependence (Bijl et al., 1998). Almost 90% of the Dutch population drinks alcohol; obviously, the majority of this group does not become a problem drinker (Bijl et al., 1998; Van Dijck and Knibbe, 2005). The focus of this study is on possible mechanisms that are of importance in the development of alcohol problems. Not everybody is equally at risk. People show individual differences in their sensitivity to the effects of alcohol (Newlin and Thomson, 1991). These have been identified on several levels such as genetics, physiological responses, subjective responses, and cognitions.

One hypothesized marker of risk for alcohol problems is how a person responds to alcohol. Newlin and Thomson (1991) proposed a biphasic model with different risk factors. When blood alcohol concentrations (BACs) increase, individual differences in experiencing stimulating and positive effects are important. During the falling limb of the BAC curve, negative and sedating effects become more prominent (Martin et al., 1993). First, a low level of reaction or a reduced responsiveness during the declining limb of the blood alcohol curve has been found to be an important mediator in the risk of developing alcoholism (Schuckit and Smith, 1996). Because of tolerance during the falling limb, less impairment and less aversive consequences of drinking are experienced. It has been hypothesized that certain individuals, particularly those with a family history (FH) of alcoholism, are less likely to regulate their drinking pattern and more likely to develop alcohol problems because they experience fewer negative

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subjective and behavioral consequences of alcohol intoxication (Schuckit and Smith, 1996). In accordance with Newlin and Thomson's (1991) model, there is also evidence suggesting that risk for alcoholism is associated with heightened subjective, physiological, and biochemical responses to alcohol when blood alcohol levels are increasing (Conrod et al., 1997, 2001; Erblich et al., 2003; Martin et al., 1993; Newlin and Thomson, 1991). The focus of the present article is on this stimulant reaction during the ascending blood alcohol curve. Individuals with a FH of alcoholism (FH+), especially men with a multigenerational FH of alcoholism and sensation seekers (Brunelle et al., 2004), display a strong alcohol-induced heart rate (HR) acceleration after a high dose of alcohol during the rising limb of the blood alcohol curve (Conrod et al., 1997; Peterson et al., 1996). Alcohol-induced HR acceleration has proven to be a reliable and valid measure of the sensitivity to the psychomotor stimulant effects of alcohol (Conrod et al., 1997, 2001).

According to the influential incentive sensitization theory of Robinson and Berridge (1993, 2000, 2003), the mesocorticolimbic reward system in the brain becomes sensitized after repeated alcohol use. Alcohol as well as alcohol-related cues become salient to the individual and can (unconsciously) activate the dopamine reward system, leading to psychomotor stimulation. This can be experienced as craving or "wanting." The individual displays a heightened state of attention for alcohol-related stimuli (an attentional bias) and shows more goal-directed behavior to obtain the drug. So far, the process of sensitized "wanting" has mainly been studied in animals. A second hypothesized system, "liking," is understood as mediating the pleasurable effects of the drug and is not subject to sensitization. It has been suggested that alcohol-induced HR acceleration in humans reflects individual differences in the sensitivity of the mesocortical reward system to alcohol and, thus, may reflect the degree to which an individual is susceptible to alcohol sensitization or "wanting" with repeated administrations (Conrod et al., 1997, 2001). Given earlier work of Conrod et al. (1997, 2001), we hypothesized that alcohol-induced HR increase could be a measure of sensitization in humans.

On a cognitive level, several mechanisms underlying alcohol use and misuse have been investigated. Alcohol expectancies predict up to 50% of the variance in drinking behavior and also predict the development of problematic alcohol use (see Goldman et al., 1999b, and Jones et al., 2001, for reviews). Based on multidimensional scaling, (most) expectancies can be placed in a 2-dimensional space consisting of a valence dimension (positive–negative) and an arousal dimension (arousal–sedation). Heavy drinkers display positive arousal expectancies (e.g., "Drinking alcohol makes me energetic"), while light drinkers show sedation expectancies (e.g., "Drinking alcohol makes me sleepy"; Goldman et al., 1999b). Expectancies can be influenced by various distal influences such as genetics and FH, metabolism, personality factors, and social environment (Goldman et al., 1999a). Individuals with special variants of, e.g., the ALDH2 gene (McCarthy et al., 2001), the D2 gene (Young et al., 2004), or those who have a positive FH for alcoholism have alcohol expectancies (Wiers et al., 2000) that differ from those without a FH of alcoholism.

Expectancies have mainly been studied with explicit measures, that is, in a direct way by means of questionnaires. In the past few years, however, new tools have been developed to assess automatic associations with alcohol. These so-called implicit or indirect measures have certain advantages over explicit measures. First, they are less sensitive to socially desirable answers (Fazio and Olson, 2003). Second, they might be able to measure ongoing processes that the participant cannot introspect upon (Wilson et al., 2000). Another reason to not solely rely upon explicit measures is the finding that implicit measures can explain an additional part of the variance in alcohol consumption above the variance explained by explicit measures (Stacy, 1997; Wiers et al., 2002). Fourth, explicit and implicit measures might tap into different underlying constructs (Stacy, 1997; Wiers et al., 2002). This is reflected in the fact that explicit and implicit measures usually show low correlations (Wiers et al., 2002, 2005). Furthermore, different brain structures seem to be involved in explicit and implicit processing: explicit outcome expectancies seem to be mediated by cortical regions such as the prefrontal cortex, while implicit processes are primarily located in subcortical structures (Berridge, 2001; cf. Phelps et al., 2000).

In a study by Wiers et al. (2002), alcohol associations of heavy drinkers were assessed indirectly by means of an adapted version of the Implicit Association Test (IAT; Greenwald et al., 1998). The IAT is a categorization task that measures the relative strength of 2 target concepts (e.g., alcohol vs soda) with 2 attribute categories (e.g., positive vs negative). Stimuli that appear on the screen have to be categorized by means of 2 response keys (e.g., alcohol+negative words are assigned to the left response key and soda+positive words to the right response key). In a second combination phase, the position of the target switches and is again combined with the attribute category (e.g., soda+negative to the left, alcohol+positive to the right). The IAT effect is the difference in reaction times between both combination blocks (see Wiers et al., 2002, 2005, for a more detailed description). The assumption underlying the IAT is that the stronger the association between 2 concepts is represented in memory, the faster the reaction time will be (Greenwald et al., 1998, 2003). Results indicated that light and heavy drinkers both displayed a strong negative association with alcohol. On the arousal–sedation dimension, however, only the heavy drinkers demonstrated strong associations between alcohol and arousal. This seems to be an indication that the main difference between heavy and light drinkers is on the arousal dimension: heavy drinkers showing strong arousal associations. These findings have been replicated in heavy drinkers (Wiers et al., 2005) and in alcoholic patients (De Houwer et al., 2004).

Palfai and Ostafin (2003) used a modified version of the IAT to measure implicit approach and avoidance tendencies in heavy drinkers and their relationship with drinking behavior. They found that strong approach associations were positively correlated with binge drinking. Also, approach associations were positively associated with the subjective anticipatory urge to drink alcohol and with arousal reactivity in a cue reactivity paradigm where the participant was exposed to his or her favorite drink. These findings of implicit arousal and approach associations have been theoretically linked to the development of incentive sensitization (Wiers et al., 2002). Arousal as well as approach associations have both been found to correlate with subjective arousal and craving in a cue-reactivity paradigm (Krank et al., 2005; Palfai and Ostafin, 2003).

In the present study, an adapted version of the IAT was used (Houben and Wiers, 2005). Instead of measuring associations in a bipolar way (e.g., arousal vs sedation), which leads to a "relative" IAT effect score, we measured the attribute categories in a unipolar fashion (e.g., arousal vs neutral, sedation vs neutral; cf. Jajodia and Earleywine, 2003). As the effects of alcohol are biphasic, with activating effects when BACs are increasing, and sedating effects when BACs are falling, it may be advantageous to assess both associations separately.

Other implicit measures such as the emotional Stroop task have been developed to measure attentional bias for alcohol-related stimuli (MacLeod, 1991; Williams et al., 1996). In the emotional Stroop task, participants respond to the color the word is printed in while ignoring the contents of the word. Emotionally relevant stimuli grab the attention, which interferes with the color naming response. This leads to slower reaction times. In an eye-movement study with a pictorial dot-probe task for smokers (Mogg et al., 2003), it was found that mainly attentional disengagement from the emotionally relevant stimulus was difficult. To alcohol-dependent patients, alcohol-related words can be seen as emotionally relevant stimuli. Therefore, their response tends to be slower to alcohol-related words compared with neutral words (Johnsen et al., 1994; Sharma et al., 2001; Stormark et al., 2000). Attentional bias for alcohol-related stimuli in heavy drinkers has only been found after some form of priming the participant: a sip of their favorite drink (Jones and Schulze, 2000), priming with an alcohol beverage word (Kramer and Goldman, 2003), exposure to the sight and smell of an alcoholic beverage (Cox et al., 2003), or exposure to alcohol advertisements (Cox et al., 1999). In alcoholic patients, however, an emotional Stroop effect has been found repeatedly without priming (for reviews: Cox et al., 2006; Bruce and Jones, 2006). Attentional bias for alcohol-related stimuli has also been linked to the development of incentive salience (Franken, 2003). Hence, an attentional bias for alcohol, implicit arousal (Wiers et al., 2002), and approach associations (Palfai and Ostafin, 2003) have all been theoretically linked to the development of sensitized "wanting," likely reflecting the cognitive representation of incentive motivation for alcohol consumption.

In conclusion, the present study investigates the relationships between biological and cognitive measures of psychomotor stimulation in heavy drinkers. Alcohol-induced HR increase seems to reflect the sensitivity to psychomotor stimulation during the ascending BAC curve (Conrod et al., 1997, 2001). We hypothesized that alcohol arousal and approach associations (measured with the IAT) and attentional bias for alcohol-related stimuli (measured with the emotional Stroop) might reflect sensitized "wanting" in humans. Therefore, it was expected that these 3 cognitive constructs would show a positive correlation with HR increase after the rapid consumption of a high dose of alcohol. Furthermore, we expected the 3 implicit measures to correlate positively with each other as they might all tap into the underlying mechanism of incentive sensitization.

MATERIALS AND METHODS

Participants

Participants were 48 male heavy drinkers (mean age = 20.4 years, SD = 3.5) who were recruited via flyers at Maastricht University, several colleges, and pubs. They were subsequently screened by telephone on several inclusion and exclusion criteria. The main inclusion criterion was a mean alcohol consumption of 15 alcoholic standard consumptions per week and at least 1 binge episode in the past 2 weeks. Age range was between 18 and 45 years. Eighteen is the minimum age required for legal drinking in the Netherlands and 45 was used as the upper limit to exclude individuals with possible heart problems. Exclusion criteria were the regular use of drugs other than alcohol and cigarettes; any native language other than Dutch; medical conditions such as liver problems, diabetes, or heart complaints; the use of medication for which alcohol consumption is contraindicated; dyslexia; color blindness; psychiatric problems in the past; and a positive family history of schizophrenia, depression, bipolar disorder, or suicide. One participant indicated not being from Dutch origin, but was included in the analyses as he was a native Dutch speaker. After completion of the experiment, participants received a monetary compensation of €40 (equivalent to $45).

Materials and Measures

Alcohol Use. Alcohol use was measured with a quantity-frequency questionnaire (Wiers et al., 1997) based on the Time Line Follow-back method (Sobell and Sobell, 1990). Participants indicated how many drinks they had had on each day of the previous week and whether it was more than, less than, or equal to what they typically drank on that particular day of the week. From this information the average alcohol consumption per week could be calculated. Furthermore, they filled out how many binges (defined as 5 drinks or more in a drinking episode) they had had in the past 2 weeks. The mean weekly consumption was 33.8 standard drinks (SD = 14.5). The mean number of binges in the past 2 weeks was 4.8 (SD = 2.17).

Alcohol-related Problems. The Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) was used to screen for the development of possible alcohol problems. The 10 items question consumption (first 3 items) and problems related to alcohol dependence (other 7 items). The mean AUDIT score of our sample was 13.6 (SD = 4.5). According to Fleming et al. (1991), a cutoff score of 11 should be used in college samples as an indication of alcohol abuse. The internal consistency of the AUDIT was 0.77 (Cronbach's α). Furthermore, the 18-item version of the Rutgers Alcohol Problem Index (RAPI; White and Labouvie, 1989) was used, which correlates 0.99 with the 23-item version (White and Labouvie, 2000). Participants indicated on a 5-point Likert scale how often several alcohol-related problems had occurred. The mean score was 19.7 (SD = 8.5), and the internal consistency was 0.73. The AUDIT and RAPI questionnaires correlated highly, $r = 0.74$.

Two variables were composed to represent general measures of alcohol use and problems. The variable alcohol use consisted of the sum of the z-transformed scores of the mean alcohol consumption per week and the first 3 AUDIT items. The variable alcohol problems was calculated by adding the z-transformed scores of the remaining 7 AUDIT items and the RAPI sum score.

Explicit Alcohol-related Cognitions. Expectancies about the arousing and sedative effects of alcohol were assessed using 10-cm visual analog scales (VAS). The questionnaire consisted of 11 arousal and 13 sedation VAS items. These 24 expectancy items were derived from 2 separate measures: the Biphasic Alcohol Effects Scale (BAES; Martin et al., 1993) and the arousal and sedation IAT (as has been done previously by Houben and Wiers, 2005; Wiers et al., 2002, 2005). Of this total of 28 items, 4 appeared in both measures and were thus excluded, leaving a final 24-item VAS Expectancy questionnaire. All 24 items were presented twice: once participants were questioned about their expectancies immediately after drinking a high dose of alcohol (e.g., "Directly after drinking a high dose of alcohol I become energetic") and the second time they indicated their expectancies 1.5 hours after drinking a high dose of alcohol (e.g., "1.5 hours after drinking a high dose of alcohol I become energetic"). The scale ranged from "Absolutely disagree" (0 mm) to "Absolutely agree" (100 mm). Both VAS questionnaires were filled out *before* alcohol administration.

Implicit Association Test. All IATs were programmed in ERTS 3.18 (Beringer, 1996). The target and attribute categories both consisted of 6 exemplars each. The target categories were labeled "alcohol" and "soda." The 5 unipolar attribute categories were labeled "pleasant" (positive), "unpleasant" (negative), "active" (arousal), "quiet" (sedation), and "materials" (as irrelevant control block), all versus the category "neutral." The bipolar block carried the labels "approach" versus "avoidance." The stimuli used in the 5 unipolar IAT blocks were all rated by different participants ($N = 68$) in a pilot study, on valence, arousal, and familiarity, and were subsequently selected. The positive, negative, and neutral substantives used in the 2 valence blocks were matched on familiarity, word length, and number of syllables and were on average neutral with respect to arousal (e.g., "peace," "depression" vs "circle"). For the arousal and sedation blocks, adjectives were used also in the opposing category "neutral" (e.g., "talkative," "relaxed" vs "constant"). These were also matched on familiarity, word length, and number of syllables and were on average neutral with respect to valence. All 4 blocks (positive, negative, arousal, and sedation) had a fixed "neutral" category it was paired with. The stimuli that were used can be found in the Appendix. The presentation of the 4 unipolar attribute dimensions was partially counterbalanced according to a Latin Square design, resulting in 4 possible orders. The bipolar approach–avoidance block was always on the fifth position, because it was of a more exploratory nature. Stimuli of the approach-IAT were only matched on word length. Matching on valence seems impossible as approach words always tend to be rated as positive and avoidance words as negative. The presentation of the irrelevant control block "materials" always came last. These words were also matched with the neutral category on valence, arousal, and familiarity.

The standard IAT consists of 5 phases (see Table 1). In the first phase, the target categories "alcohol" and "soda" were practiced (e.g., "beer," "juice"). This phase was only presented once, as the first phase of the first IAT. IATs 2 to 6 were made up of 4 phases. In the target phase, all 6 alcohol and 6 soda stimuli were presented twice, resulting in a total of 24 trials. The second phase was the introduction of the attribute categories (e.g., "pleasant" vs "neutral"). Again, all 6 pleasant stimuli and all 6 neutral stimuli were presented twice, leading to 24 trials. In the third IAT phase, the first combination phase (C), the target categories, and the attribute categories were presented. Of all 4 categories, each stimulus was presented twice, with a total of 48 trials. In the fourth phase, the attribute categories were reversed (e.g., "neutral" vs "pleasant"), with a total of 24 trials, and the final phase was the reversed combination phase (R) in which the targets and reversed attributes were again combined (48 trials). The order of the 2 combination blocks was counterbalanced, with half the participants starting with the easier combination phase (CR) and the other half starting with the more difficult reversed combination phase (RC). During performance of all IAT blocks, the category labels were presented in the left and right upper corners of the computer screen and remained there during the entire task. Stimulus words were presented in the middle of the screen in black against a light gray background. The stimulus word remained on the screen until a response was generated. The intertrial interval was 250 ms. In case of an incorrect response, the feedback "wrong" was presented in red letters under the stimulus word. When a participant was too fast (< 300 ms) or too slow (> 3,000 ms) the messages "too fast" or "too slow" appeared on the screen. Reaction times and errors of all blocks were recorded. Reliabilities of the IAT blocks were calculated by correlating the practice trials (first 16 trials) with the test trials (last 32 trials) of the combination blocks. Subsequently, this correlation was entered in Spearman's Brown formula leading to Cronbach's α of the test. The internal consistencies were as follows: approach–avoidance, –0.01; materials, 0.40; positive, 0.62; sedation, 0.64; negative, 0.72; and 0.76 for the arousal IAT. The unipolar IAT has been found to show somewhat lower reliabilities compared with the bipolar IAT (Wiers et al., 2005), which usually displays α of > 0.65. Compared with other indirect measures, however, the IAT generally displays reasonably good internal consistencies (Bosson et al., 2000).

Emotional Stroop Task. The Stroop task was presented on a computer and consisted of 4 blocks. The participant was required to respond with 1 of 4 different response keys, representing the 4 colors that were used. Colors were indicated on the response keys. Before each trial, a fixation cross appeared for 500 ms, to maintain the attention in the middle of the screen. In the first block, 40 practice trials were offered. These were 10 different nonsemantic strings such as @@@@@ and $$$$$$. Every stimulus was practiced once in each of the 4 colors: red, yellow, green, and blue. The second block was a quasirandom or mixed presentation of 3 stimulus word categories: neutral, alcohol-related, and color. The presentation of a stimulus was never followed by a stimulus word from the same category. Neutral words were semantically related, belonging to the category "traffic." Four specific words were used, "car," "bus," "bike," and "plane," and 4 general words, "bridge," "asphalt," "railroad," and "station." The alcohol-related category also consisted of 8 stimulus words: "wine," "beer," "vodka," and "gin" being specific and "pub," "drink," "bar," and "liquor store" as general words. Stimuli from the neutral and alcohol-related categories were matched on number of syllables. Each stimulus word of these 2 categories was presented once in every color, leading to a total of 32 trials per category. The 4 color words were used as a third category. Each color word was presented twice in every color with a total of 32 trials. The total number of trials in the mixed block was 96. After a short break of 1 minute, the third block was presented in which the 8 neutral stimuli were all presented in a blocked fashion. Each word was presented once in every color. The fourth block was the blocked presentation of the alcohol words. Again, all 8 alcohol stimulus words were presented once in every color, leading to a total of 32

Table 1. Sequence of the Different Phases of the 6 IATs (CR Order)

IAT	Phase 2 Attribute phase	Phase 3 Compatible combination phase (C)	Phase 4 Reversed attribute phase	Phase 5 Reversed combination phase (R)
1. Positive versus neutral	Pleasant–Neutral	Alcohol–Soda Pleasant–Neutral	Neutral–Pleasant	Alcohol–Soda Neutral–Pleasant
2. Negative versus neutral	Unpleasant–Neutral	Alcohol–Soda Unpleasant–Neutral	Neutral–Unpleasant	Alcohol–Soda Neutral–Unpleasant
3. Arousal versus neutral	Active–Neutral	Alcohol–Soda Active–Neutral	Neutral–Active	Alcohol–Soda Neutral–Active
4. Sedation versus neutral	Quiet–Neutral	Alcohol–Soda Quiet–Neutral	Neutral–Quiet	Alcohol–Soda Neutral–Quiet
5. Approach versus avoidance	Approach–Avoidance	Alcohol–Soda Approach–Avoidance	Avoidance–Approach	Alcohol–Soda Avoidance–Approach
6. Materials versus neutral	Materials–Neutral	Alcohol–Soda Materials–Neutral	Neutral–Materials	Alcohol–Soda Neutral–Materials

Note: Phase 1, the target phase, in which the target categories alcohol and soda were practiced, was only presented once as the first phase of the first IAT. The first four IATs were partially counterbalanced with a Latin square. IATs 5 and 6 were fixed. Half the participants received the combination phases (3 and 5) in the opposite order (RC, reversed combination phase first, then compatible combination phase).

IAT, Implicit Association Test.

trials. In case of an incorrect response, the feedback ‘‘wrong’’ appeared on the screen. If the participant was too slow (> 3,000 ms), the message ‘‘faster’’ was presented. Errors and reaction times of all 4 blocks were recorded.

Mood. The Profile of Mood States (POMS; McNair et al., 1971) and Biphasic Alcohol Effects Scale (BAES; Martin et al., 1993) were used to measure changes in mood. The short version of the POMS consisted of 5 subscales: tension, anger, vigor, fatigue, and depression. Participants indicated on a 5-point Likert scale how strong certain mood states were present at that particular moment. The BAES measured alcohol-induced mood changes and consisted of 2 subscales, Stimulation and sedation both containing seven 10-cm VAS items.

Craving. On a 10-cm VAS, craving for alcohol was measured, once before and 8 times after alcohol administration. Participants were asked to respond to ‘‘At this moment I feel . . . ,’’ with a response format ranging from ‘‘Absolutely no urge to drink’’ (0 mm) to ‘‘An almost irresistible urge to drink’’ (100 mm). The use of a single VAS to measure craving has proven to be useful (Kozlowski et al., 1996). Cronbach's α over the 9 time measurements was 0.95.

Heart Rate. Heart rate was recorded with the Polar S810. The Polar watch recorded the HR every 5 seconds from 2 sensors on the chest band that were located bilaterally on the participant's chest. Of the 10-minute baseline recording, the most artifact-free 60-second period was selected and the average was chosen to reflect sober resting HR. After alcohol consumption, HR was sampled every 5 seconds for 2 consecutive hours. Mean scores per 15 minutes were obtained by averaging the most artifact-free 3-minute period per 15 minutes (Conrod et al., 1997). In total, 1 sober resting HR and 8 postalcohol resting HR averages were obtained.

Blood Alcohol Concentrations. Blood alcohol concentrations were determined by using a Lion Alcolmeter SD-400 (Vale of Glamorgan, UK). Participants were asked to breathe strongly and constantly for several seconds until the breathalyzer signaled that the recording was correct. Blood alcohol concentrations were recorded before drinking and every 15 minutes after alcohol consumption. The variable latency to peak BAC was calculated from these measurements.

Procedure

Participants entered the lab either at 15:00 or at 17:00 in the afternoon. They had been asked to abstain from alcohol for 24 hours before the start of the study. Furthermore, they were asked not to eat or drink any coffee 2 hours before the experiment started. They signed the informed consent form and then performed the IAT and Stroop task in a balanced order. Before each task, they were sip primed for 30 seconds, with their favorite drink. They were asked to take a good look at the drink, smell it, and then take one sip. After performing the implicit measures, participants filled out several questionnaires. Participants then went to another lab where the second part of the experiment was conducted. Their weight was measured for correct alcohol dosage administration. When the Polar watch and chest band had been placed in the correct position, the participant was seated and the 10-minute baseline HR recording was started. After baseline recording, each participant received 1.0 mL/kg body weight 95% USP alcohol. Alcohol was administered in the form of 5 ‘‘shots’’ of frozen 40% vodka, based on the procedure of Conrod et al. (1997). At the rate of 1 shot per minute, the total amount of alcohol was consumed within 5 minutes. Immediately after the final shot had been consumed, the Polar watch started recording again, for 2 consecutive hours, which the participant spent in silence, reading. Every 15 minutes, BACs as well as mood (BAES) and craving for alcohol were recorded. The POMS was only administered twice after alcohol administration (after 30 and 90 minutes). After 2 hours, the HR recording was stopped and the participants received a hot meal. They stayed in the lab until their BACs had dropped to the 0.05 level after which they were brought home in a taxi. The study was approved by the Ethics Committee of the Department of Psychology of Maastricht University.

RESULTS

The ultimate goal of this study was to investigate the associations between alcohol-induced changes in HR, subjective mood, and craving, on the one hand, and measures of explicit and implicit cognition, on the other. First, we will describe the results of the explicit expectancies and their associations with other measures of interest. Second, the different implicit cognition tests will be presented and with which measures these were correlated. This will also include the main hypothesis of whether or not the implicit associations were associated with alcohol-induced HR change. Third, the physiological and subjective effects after rapid alcohol consumption and their associations with other variables will be described. Correlations between the different variables can be found in Table 2.

Explicit Alcohol-related Cognitions

The mean immediate and late arousal expectancies were, respectively, 61.21 (SD = 13.27) and 52.26 (SD = 18.82), which indicated that the heavy drinkers expected above average arousal from drinking a high dose of alcohol (the VAS ranged from 0 to 100 mm). The difference between immediate and late arousal expectancies was significant [$t(47) = 2.93$, $p = 0.005$], indicating that participants expected to be less aroused 1.5 hours after drinking than immediately after drinking. The mean immediate and late sedation expectancies were, respectively, 34.31 (SD = 11.55) and 45.48 (SD = 17.01), indicating that participants expected below average sedation from drinking a high dose of alcohol. A *t*-test revealed that the difference between immediate and late expectancies was significant, $t(47) = -5.49$, $p = <0.001$. Thus, participants expected to become more sedated 1.5 hours after drinking a high dose of alcohol. All 4 scales showed good internal consistencies (See Table 2).

Correlations Involving Explicit Immediate Arousal and Late Sedation Expectancies. As can be seen in Table 2, the immediate arousal expectancies correlated significantly with alcohol use ($r = 0.40$, $p = 0.005$) and latency to peak BAC ($r = -0.30$, $p = 0.04$). This indicates that heavy drinkers with strong arousal expectancies immediately after drinking a high dose of alcohol consume large amounts of alcohol (even within this sample of heavy drinkers) and reach their peak BAC relatively fast. The late sedation expectancies showed a significant correlation with alcohol problems ($r = 0.34$, $p = 0.017$), indicating that participants with strong sedation expectancies 1.5 hours after drinking, experienced more alcohol-related problems compared with participants with less strong late sedation expectancies.

Implicit Alcohol-related Cognitions

Implicit Association Test. The results of the IAT are presented in Fig. 1. The overall percentage of errors over all 6 blocks was 4.9%. For matters of interpretation, the conventional IAT effects in milliseconds (Greenwald et al., 1998) are graphically represented. Analyses in the text will describe the new D600 algorithm as advised by Greenwald et al. (2003). According to the new D600 algorithm, practice trials are also included in the analysis and the data are standardized at the level of the participant. It will be indicated when differences were found between the conventional measure in milliseconds and the D600 measure.

Implicit Association Test effects are always difference scores, where the reaction times from the C (combination) phase are subtracted from the reaction times of the R (reversed combination) phase (R–C). If responses are faster in the compatible C phase than in the incompatible R phase, the IAT effect will be positive. Participants performed all 6 IAT blocks in 1 of the 2 variants of the IAT, CR, or RC, where the CR version usually yields larger effects (cf. Greenwald et al., 1998; Wiers et al., 2005). For some affective dimensions, the results differed between the 2 versions (e.g., Positive). Therefore, the IAT data are presented per version if differences were found as well as aggregated over versions.

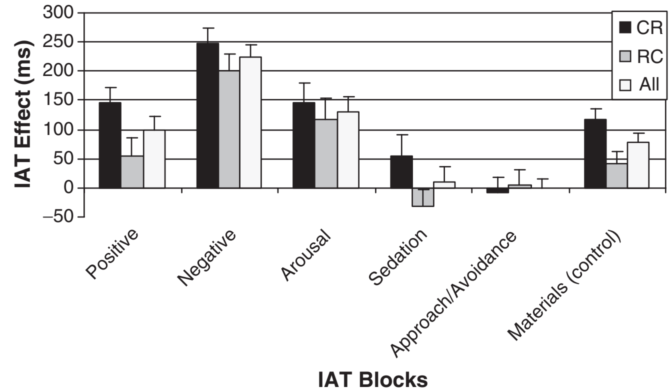

Fig. 1. Implicit Association Test (IAT) effects for the unipolar (vs neutral) blocks: positive, negative, arousal, sedation, and materials (control) and the bipolar approach–avoidance block. An IAT effect is the difference in reaction times between the compatible combination phase (C) and the reversed combination phase (R). If the response is faster in the compatible C phase (e.g., alcohol+active) than the incompatible R phase (alcohol+neutral), the IAT effect will be positive (R–C). Reaction times are represented according to the conventional algorithm in milliseconds (Greenwald et al., 1998). Half of the participants performed all IATs in CR order (starting with the easier compatible C phase, followed by the more difficult reversed R phase). The other half performed the RC order. Usually, IAT effects are stronger in the CR order. When both orders were combined (all participants), significant IAT effects were found for the negative, arousal, and materials block.

One-sample *t*-tests indicated significant IAT effects for the negative, arousal, and materials (control) blocks in both the CR and the RC conditions. The largest IAT effect was found for the Negative block, indicating much stronger associations between alcohol and negative compared with alcohol and neutral, [$t(47) = 13.69$, $p < 0.001$] for the group as a whole. The same pattern was found for arousal [$t(47) = 7.70$, $p < 0.001$]. Participants showed a stronger association between alcohol and arousal than between alcohol and neutral. The IAT effect of the materials control block was significant in both groups using the D600 measure, [$t(47) = 5.64$, $p < 0.001$], but only reached borderline significance in the RC condition using the conventional algorithm [$t(23) = 2.00$, $p = 0.06$]. The IAT effect of the positive block was found to be significant in the CR condition only [$t(23) = 6.55$, $p < 0.001$]. No significant IAT effects were found for the bipolar approach–avoidance block and the unipolar sedation block for any of the groups or the 2 algorithms.

Emotional Stroop Task. Only correct responses were used in the Stroop analyses, both for the unblocked (mixed) and for the blocked version. The overall error rate for all the trials was 4.5%. The mean reaction times for the

Table 2. Pearson Correlations for Explicit and Implicit Measures, Subjective, and Physiological Effects After Alcohol Consumption and Alcohol Measures

		Explicit measures				Implicit measures			Subjective effects								Physiological measures			Alcohol measures	
Measures	α	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Explicit measures																					
1. Immediate arousal	0.88	—																			
2. Late arousal	0.95	0.16	—																		
3. Immediate sedation	0.77			—																	
4. Late sedation	0.89	0.16	−0.53**	0.57**	—																
Implicit measures																					
5. Blocked stroop	0.64		−0.17			—															
6. Arousal IAT	0.76		−0.23		0.36*		—														
7. App-Avoidance IAT	−0.01			−0.22		0.32*	0.23	—													
Subjective effects																					
8. BAES-Stim. Asc BAC			0.28#	−0.15					—												
9. BAES-Stim. Des. BAC			0.16						0.91**	—											
10. POMS-Vigor t30			0.25#	−0.20				0.23	0.20	0.22	—										
11. POMS-Vigor t90		−0.17						0.31*	0.26#	0.39**	0.63**	—									
12. BAES-Sed. Asc. BAC		0.19		0.27#	0.22	−0.18		−0.24			−0.30*	−0.31*	—								
13. BAES-Sed. Des. BAC			0.22			−0.20		−0.16			−0.34*	−0.44**	0.84**	—							
14. Craving change Asc. BAC		0.24#		−0.16		−0.17		0.27#			0.23			0.25#	—						
15. Craving change Des. BAC				−0.16				0.18						0.25#	0.82**	—					
Physiological measures																					
16. HR change Asc. BAC			0.25#		−0.16		−0.28#		0.22	0.21	0.23						—				
17. HR change Des. BAC		−0.27#	0.18		−0.21	0.15			0.31*	0.31*	0.23	0.20				0.17	0.84**	—			
18. Latency to peak BAC		−0.30*	0.16					0.22					−0.33*	−0.29*				0.18	—		
Alcohol measures																					
19. Alcohol use	0.81	0.40**	0.22			−0.17				−0.16					0.16	0.24				—	
20. Alcohol problems	0.86			0.23	0.34*		0.28#	0.20		−0.19						0.19			0.32*	0.44**	—

*$p<0.05$; **$p<.01$; #p shows a statistical trend ($0.05<p<0.10$). Correlations with p-values >0.30 are left out. α has been provided for the explicit, implicit and alcohol measures.

Explicit measures: Two different VAS questionnaires to measure arousal and sedation expectancies immediately and 1.5 hours after drinking a high dose of alcohol, both administered *before* drinking. *Implicit measures*: Blocked Stroop, blocked Stroop effect (alcohol-neutral) reflects attentional bias for alcohol-related stimuli; Arousal IAT, unipolar IAT combining alcohol versus neutral with alcohol versus soda; App-Avoidance IAT, approach–avoidance IAT, bipolar IAT combining approach versus avoidance with alcohol versus soda. *Subjective effects*: BAES, Biphasic Alcohol Effects Scale; Stim, stimulation subscale; Sed, sedation subscale; BAC, blood alcohol concentration curve; Asc. BAC, mean change scores after drinking on the dependent variable (either stimulation, sedation, or craving) during the ascending BAC (30 and 45 minutes after drinking); Des. BAC, mean change scores after drinking on the dependent variable during the descending BAC (60 and 75 minutes after drinking); POMS-Vigor t30/t90, Profile of Mood Scales, subscale Vigor, administered after 30 minutes (ascending BAC) and 90 minutes (descending BAC); *Physiological measures*: HR Change Asc. BAC, mean changes in heart rate during the ascending BAC (30 and 45 minutes after drinking); HR Change Des. BAC, mean changes in heart rate during the descending BAC (60 and 75 minutes after drinking). *Alcohol measures*: Alcohol use, the sum of the z-transformed scores of the mean alcohol consumption per week and the first 3 AUDIT (Alcohol Use Disorders Identification Test) items; Alcohol problems, the sum of the z-transformed scores of the remaining 7 AUDIT items and the RAPI (Rutgers Alcohol Problems Inventory for Adolescents) sum score.

Table 3. Mean Reaction Times (and SDs) of the Neutral, Alcohol, and Color Words as a Function of the Word Preceding the Target Word on the Previous Trial

	Target word		
Word before	Neutral	Alcohol	Color
Neutral	X	612.1 (248)	729.8 (348)
Alcohol	626.0 (200)	X	716.8 (268)
Color	656.2 (160)	677.2 (268)	X

Note: A target word was never preceded by a stimulus from the same word category (X).

3 word categories in the mixed block were 651.2 ms (SD = 141) for the neutral words, 662.0 ms (SD = 156) for the alcohol words, and 702.8 ms (SD = 182) for the color words. All Stroop analyses given below were run on the log-transformed data to achieve a better normal distribution. Paired *t*-tests revealed that the difference between neutral and alcohol words on the one hand and color words on the other were significant ($p < 0.005$). However, the emotional Stroop effect, the difference in reaction times between alcohol and neutral words was nonsignificant [$t(47) = 1.23$, $p = 0.22$]. To further investigate the influence of a preceding color word on the reaction time of the target word (neutral or alcohol; cf. Waters et al., 2003), the data of the mixed block were reanalyzed (see Table 3 for the raw reaction times). The difference in reaction times between neutral and alcohol words preceded by a color word was nonsignificant ($p > 0.50$). As there was no meaningful variability in attentional bias, as measured with the mixed Stroop, this measure will not be included in further analyses.

Analysis of the blocked presentation of the neutral and alcohol-related words did reveal a significant emotional Stroop effect. The mean reaction times for the words in the neutral and alcohol block were, respectively, 606.4 ms (SD = 127) and 634.3 ms (SD = 146.7). A paired *t*-test showed that the difference between these 2 conditions was significant [$t(47) = 2.45$, $p = 0.018$].

Correlations Between Implicit, Explicit, and Alcohol Measures. As expected, a positive correlation between the arousal IAT and alcohol problems ($r = 0.28$, $p = 0.029$, 1-tailed) was found, as has been found in previous research (Houben and Wiers, 2005; Wiers et al., 2002). Neither of the 2 IATs of main interest correlated significantly with alcohol use. This might be due to the restricted range of drinking behavior in this sample of heavy drinkers. The hypothesized correlation between alcohol arousal and alcohol approach IAT effects (both theoretically related to incentive sensitization) was found to be in the expected direction, but was not significant ($r = 0.23$, $p = 0.12$). The arousal and approach IATs did not correlate significantly with the other 4 IAT measures. The approach IAT tended to be correlated with changes in craving experienced during the ascending BAC ($r = 0.27$, $p = 0.06$). The blocked Stroop was found to be positively associated with approach associations on the IAT ($r = 0.32$, $p = 0.028$), as hypothesized. Attentional bias was unrelated to alcohol use and problems. Consistent with earlier findings (Wiers et al., 2005), implicit arousal associations were positively correlated with late sedation expectancies as indicated on the VAS questionnaire ($r = 0.36$, $p = 0.01$).

Correlations Between Implicit Measures and Alcohol-induced HR Change. Heart rate acceleration was defined as the change in postalcohol HR compared with pre-alcohol (postalcohol cue) HR baseline (HRB). As HRB (pretest) tended to correlate positively with the arousal IAT score ($r = 0.24$, $p = 0.10$), ANOVA of change is preferred over ANCOVA in which the absolute HR posttest scores would be covaried with HRB (Van Breukelen, 2006). Heart rate change during the ascending BAC curve was calculated by averaging the mean HR changes after 30 and 45 minutes (correlation of 0.81). Contrary to our hypothesis, none of the 3 implicit measures correlated positively with alcohol-induced HR change. If anything, arousal associations were inversely related to alcohol-induced HR change during the ascending BAC ($r = -0.28$, $p = 0.053$). After partialling out the effect of alcohol problems, the correlation was found to be -0.31 ($p = 0.034$). Within the group of participants with strong arousal associations (based on a median split), the arousal IAT correlated -0.43 ($p = 0.042$) with HR change (controlled for alcohol problems). Thus, unexpectedly, individuals with stronger implicit arousal associations tended to show an HR *decrease* after alcohol consumption.

As expected of a sample of individuals without family histories of alcoholism, the mean HR hardly increased in response to alcohol consumption (a mean maximum increase of 1.6 bpm, see Fig. 2A, all participants, consistent with Conrod et al., 1997). However, due to the heavier drinking nature of this sample, we did expect to find some HR responders. Based on mean HR $\pm$ 1 SD, 11 high HR responders were identified and 8 low HR responders. An independent *t*-test revealed that these 2 groups differed significantly in their arousal associations [$t(17) = 2.14$, $p = 0.047$]. High HR responders had an average arousal IAT effect of 108 ms, whereas low HR responders had an IAT effect that was twice as large (215 ms). Hence, these 3 analyses [(partial) correlation, median split, and

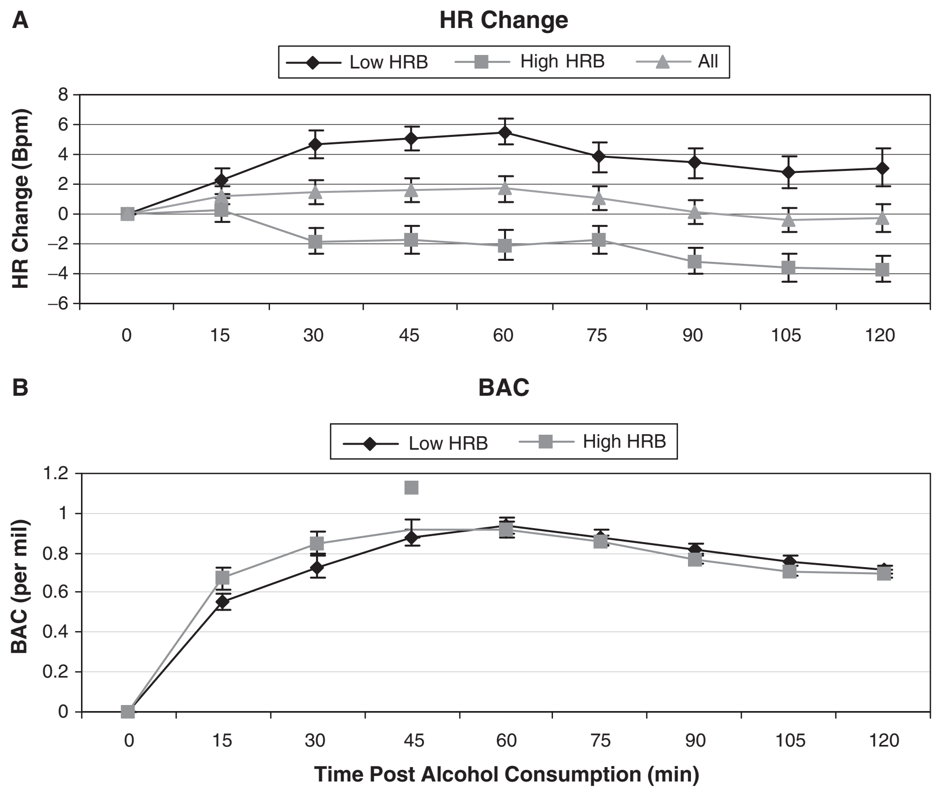

Fig. 2. After alcohol administration, changes in heart rate (HR, **A**) and blood alcohol concentrations (BACs, **B**) were measured for 2 consecutive hours. Based on a median split of heart rate baseline (HRB), participants were divided into 2 groups (low and high HRB). Different patterns in HR change emerged for both groups: participants with a low HRB showed an alcohol-induced HR increase, while participants with a high HRB showed a decrease in HR. No significant differences were found between these groups in their BACs.

extremes] all indicate that instead of the expected positive association between the arousal IAT and alcohol-induced HR increase, the reverse pattern was found.

A possible reason for the limited range of HR response was that a subgroup of participants had a relatively high HRB, leaving little room for increase. A median split of HRB (65 bpm) was used to divide the participants. In accordance with this (post hoc) hypothesis, low HRB participants showed an HR increase, significantly different from 0 at all measurement moments ($p < 0.02$), with the highest values during the ascending limb of the BAC curve (see Fig. 2A). In contrast, high HRB participants showed an HR decrease, significantly different from 0 on all measurements except 15 and 75 minutes ($p < 0.05$). This may suggest that there was a ceiling effect on alcohol-induced HR increase.

Physiological Effects and Subjective Mood Effects After Alcohol Consumption

As expected, BACs rapidly increased after alcohol intake (Fig. 2B), reaching a maximum of approximately 0.9‰ after 45 to 60 minutes. Heart rate change was not significantly correlated with BACs during the ascending limb ($p > 0.40$).

Changes in subjective mood were calculated by averaging the mean stimulation as well as sedation scores on the BAES 30 and 45 minutes after drinking (for the ascending BAC curve), corrected for baseline mood. The average of 60 and 75 minutes represented the mood changes during the descending limb. Furthermore, the scores of the vigor subscale of the POMS 30 and 90 minutes after drinking were used. All mood changes were subjected to correlation analysis with the physiological changes in HR and latency to peak BAC. During the *ascending* limb, vigor scores tended to correlate positively with HR change, but nonsignificantly ($r = 0.23$, $p = 0.12$). No significant correlation was found between the stimulation subscale of the BAES and HR change. This could be due to the unexpected finding that, compared with baseline stimulation scores, there was, on average, no evidence of an increase in subjective stimulation during the rising BAC curve ($p > 0.60$). This, in turn, could be related to the fact that only a minority of the participants displayed an alcohol-induced HR increase during the ascending limb. The sedation scores of the BAES correlated negatively with latency to peak BAC ($r = -0.33$, $p = 0.024$), indicating that participants who reached their peak BACs fast experienced more subjective sedation. During the *descending* limb, the stimulation BAES scores correlated significantly with HR change ($r = 0.35$, $p = 0.016$). Participants with an HR increase showed stronger subjective stimulation. This effect was not found for the vigor subscale of the POMS.

DISCUSSION

This study investigated the associations between implicit arousal associations, approach associations, and attentional bias on the one hand and alcohol-induced changes in HR, craving, and subjective mood on the other. The main findings can be summarized as follows: first, it should be noted that not all participants showed an alcohol-induced HR increase. Participants with a low HRB showed the expected increase in HR, while participants with a high HRB showed a decrease in HR. Second, the 3 implicit measures of main interest did not show the expected positive association with alcohol-induced HR change. If anything, implicit arousal associations correlated *negatively* with alcohol-induced HR change. Third, participants who reported strong *explicit* immediate arousal expectancies (VAS) reported higher alcohol consumption (even within this sample of heavy drinkers) and reached their peak BAC faster. Late explicit sedation expectancies were found to be positively associated with the amount of alcohol-related problems. No associations were found between explicit cognitions and HR change. Fourth, implicit approach associations, measured with the IAT, were positively associated with attentional bias for alcohol, as measured with a blocked alcohol Stroop. However, due to the lack of reliability of the approach-IAT, no firm conclusions can be drawn from the findings involving this measure (notwithstanding the fact that reliabilities of implicit measures are usually much lower compared with explicit measures). The arousal-IAT was not correlated with attentional bias on the blocked Stroop.

These findings have several implications. First, alcohol-induced HR acceleration during the ascending limb of the BAC curve appears to be a good indicator of the sensitivity to the stimulating effects of alcohol in men with a multigenerational FH of alcoholism (Conrod et al., 1997; Peterson et al., 1996) and sensation-seeking individuals (Brunelle et al., 2004). The present sample mainly consisted of men with a negative FH (FH−; only 2 participants had a first-degree relative with alcohol dependence) and report very similar HR responses to alcohol compared with FH− individuals in previous studies (Brunelle et al., 2004; Conrod et al., 1997; Fromme et al., 2004). In our study, the lack of HR increase to alcohol appeared be moderated by HRB: individuals with a low HRB showed the expected alcohol-induced HR increase, while individuals with a high HRB showed an alcohol-induced decrease in HR. Hence, especially in FH−, HRB is important to consider in an alcohol administration procedure. This study further showed that the observed strong HR increase in FH+ individuals (Conrod et al., 1997) is rarely observed in heavy drinking FH− individuals, using the exact same protocol (only 12 of 48 participants showed an HR increase of more than 5 bpm during the ascending limb). This finding suggests that alcohol-induced HR increase might not be a good general measure of a sensitized psychomotor stimulant reaction to alcohol (Robinson and Berridge, 2003), at least not in FH− individuals.

Rajan et al. (1998) found that HR variability (HRV) was a more sensitive measure than mean HR to register cue reactivity in alcoholic individuals. HRV is variation in HR influenced by both sympathetic and parasympathetic neural activity. Low HRV is indicative of defective inhibition mechanisms in the central nervous system, which could lead to dysfunctional behavior, such as alcohol problems (Ingjaldsson et al., 2003). Possibly, HRV is a more sensitive measure to reflect the psychomotor stimulant reaction than mean HR that was used in this study.

Second, we did not find the hypothesized positive correlation between implicit arousal associations and HR increase after drinking. This hypothesis was based on the idea that both the implicit arousal associations and the alcohol-induced HR increase could reflect a sensitized psychomotor stimulant reaction to alcohol, in heavy drinkers. Unexpectedly, the effect of implicit arousal associations on alcohol-induced HR change was even negative. Why would individuals with strong arousal associations show a decrease in HR after drinking a high dose of alcohol? There was a tendency for participants scoring high on arousal associations to show a higher HRB to start with. Possibly, the alcohol arousal-IAT does not measure the temporal effect we suspected the IAT to measure: arousal *after* drinking alcohol. Note that the IAT measures associations between alcohol and arousal, which could in principle represent both relationships: from drinking alcohol to experiencing arousal and from being aroused to starting to drink alcohol (cf. Wiers and Stacy, 2006). These findings suggest that the arousal-IAT scores might reflect arousal before drinking, possibly anticipatory appetitive arousal (cf. Krank et al., 2005; Palfai and Ostafin, 2003), which may be dampened by drinking in these individuals. As has been found in previous research, the arousal-IAT correlated positively with alcohol problems.

The positive association between HRB and the arousal-IAT could also be explained as the result of a cue-reactivity effect. Alcohol cues in the IAT and the sip-prime that the participants received before the start of the IAT might have caused an increase in resting HR before the alcohol administration procedure was started. Obviously, participants already experiencing an increase in their resting HRB would be less likely to show a strong HR increase after alcohol consumption. This might explain why we found the negative association between the arousal-IAT and alcohol-induced HR increase: a sip-prime and performing the arousal-IAT led (in some individuals) to an increase in HRB, which resulted in a less strong HR increase or an HR decrease after alcohol consumption. In this sense, the negative correlation could be an artifact of the priming procedure and IAT measurement before alcohol administration (see limitations below).

Third, we found that strong explicit immediate arousal expectancies (VAS), measured before alcohol administration, were associated with a faster peak BAC and a higher alcohol consumption. Thus, an alternative interpretation is that, at least in FH− individuals, it might not be HR change, but the speed with which the peak BAC is reached, that reflects the amount of arousal an individual expects from alcohol. Note that in this sample, these HR and BACs were not correlated. After the alcohol administration, however, measures of subjective arousal and sedation (POMS and BAES) indicated that participants who reached their peak BAC the fastest experienced more sedative (and not stimulating!) effects. Subjective stimulation was positively associated with HR increase during the falling BAC curve and nonsignificantly (but in the expected direction) during the ascending curve. No associations were found between the implicit measures (arousal, approach associations, and attentional bias), alcohol consumption, and the latency to peak BAC, indicating that implicit and explicit measures might show a dissociation. Some research has shown as well that explicit measures show stronger relationships with drinking measures compared with implicit measures (e.g., Kramer and Goldman, 2003). This is an additional indication that both measures tap into different underlying processes.

Fourth, the sip-primed emotional Stroop tasks (mixed and blocked) led to different results. The mixed Stroop, containing neutral, alcohol-related, and color words, did not reveal a significant emotional Stroop effect (the heavy drinkers did not show interference by alcohol words relative to neutral words). This was probably due to carryover effects (strong interference) of the color words (cf. Waters et al., 2003). As the color words were processed most slowly, this indicates that they grabbed the attention more than the alcohol-related words did. From our findings, it is recommended that in using a mixed Stroop, color words are not included. The blocked Stroop did reveal a significant emotional Stroop effect that correlated positively with the strength of the implicit approach associations. The same association has been found in smokers (Mogg et al., 2005). This is the first study that found a positive association between attentional bias and approach associations in heavy drinkers. Both indirect measures were not significantly correlated with implicit arousal associations, alcohol-induced HR change, latency to peak BAC, alcohol use, or problems. Thus, both attentional bias and approach associations were not related to drinking outcome measures and physiological measures, at least not in this sample. The lack of association with alcohol use and problems could be due to restriction of range, as the sample consisted of heavy drinkers only.

Several limitations to the study should be mentioned. First, the sample size of 48 participants was relatively small. Second, as the sample consisted of only heavy drinkers, effects that were there might not have been found, due to a restriction of range and therefore too little variation. We decided not to include light drinkers in this study because the development of arousal associations and incentive sensitization is not expected in this sample. Furthermore, it was judged unethical to ask light drinkers to consume 5 shots of vodka within 5 minutes. A third limitation might be the lack of FH+ men. Only 2 participants indicated having a first-degree family member with alcohol dependence. The effects of a strong alcohol-induced HR acceleration found by other researchers (Conrod et al., 1997, 2001; Peterson et al., 1996) were specific for FH+ individuals, predisposing them to the development of an alcohol problem. Stronger effects might have been found if more FH+ participants had been included, but this was not feasible. Possibly in FH− men, latency to reaching the peak BAC is important. A fourth limitation is the lack of a baseline measurement of HR before the start of the experiment, before the sip-prime and the performance of the implicit measures. These might have induced some form of cue reactivity leading to an increase in HRB. If HRB would have been measured at the start of the experiment, this speculation could have been tested. This relates to the final limitation: another association might have been found for the arousal IAT and HR change if the implicit measures would not have been performed before alcohol administration but on a separate day. Possibly, alcohol-related stimuli that were processed during performance of the IAT and emotional Stroop task led to a cue-reactivity effect that caused resting HRB to increase before the alcohol administration procedure started, leaving less room for a further HR increase after alcohol consumption.

This study was the first to combine 3 types of indirect measures (arousal, approach associations, and attentional bias) with the psychophysiological response to a high dose of alcohol. The hypothesized positive association between implicit arousal associations and alcohol-induced HR change could not be confirmed. Taking into account the small sample size and the usually small effect sizes in this type of research, the lack of a positive association could be due to a lack of power, but finding a *negative* correlation between arousal associations and HR change suggests that there is a small chance that implicit arousal associations would in fact be positively correlated to alcohol-induced HR change in FH− heavy drinking males. Taken together, one can conclude that in heavy drinkers, implicit arousal associations, HRB, explicit arousal and sedation expectancies, and a short latency to peak BAC all seem to be intertwined with each other, predisposing an individual to the development of a possible alcohol problem. The strength of explicit arousal expectancies that heavy drinkers have of the immediate effects of a high dose of alcohol seems to be influenced more by the speed at which the peak BAC is reached than by the amount of HR acceleration. Further research, including FH+ participants, is needed to unravel the complex associations between explicit and implicit alcohol cognitions on the one hand and how they relate to psychophysiological responses to alcohol on the other.

APPENDIX: IAT stimuli

Target stimuli

Alcohol: wine, beer, whisky, port, vodka, and rum.

Soda: Cassis, Sinas (both lemonades), Spa (sparkling water), Coke, tonic, and juice.

Valence attribute stimuli:

Pleasant: love, sunshine, warmth, peace, hug, rainbow.

Neutral: paper, circle, ballpoint, factory, truck, magnet.

Unpleasant: sorrow, war, depression, pain, fight, disease.

Neutral: letter, square, page, machine, scissors, window.

Arousal/sedation attribute stimuli:

Active: talkative, jovial, restless, alert, unrestrained, rambunctious.

Neutral: constant, wide, brown, digital, recent, historic.

Quiet: silent, listless, sleepy, passive, relaxed, calm.

Neutral: oval, compact, related, central, extensive, steep.

Irrelevant control block materials:

Materials: rubber, plastic, aluminum, linen, metal, marble.

Neutral: usual, curved, joined, always, completely, angular.

Approach–avoidance attribute stimuli:

Approach: Toward, to touch, to grasp, to grab, to approach, ahead.

Avoidance: From, to run away, to escape, to leave, to flee, departure.

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