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The Effect of Non-specific Response Inhibition Training on Alcohol Consumption: An Intervention

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Abstract

Objective: Excessive alcohol consumption increases the risk of alcohol-related disease and injury. Poor response inhibition; the inability to intentionally override a pre-potent response, has been associated with greater alcohol consumption. The aim of the present study was to clarify if non-specific response inhibition training could improve response inhibition, and reduce alcohol consumption.

Method: One hundred and sixty-eight undergraduates were randomly assigned to either an inhibition or active control condition, and completed a stop-signal task once a day for four consecutive days. The inhibition condition comprised a stop-signal task with a high target density (50% stop-signals), while the active control comprised a stop-signal task with a lower target density (25% stop-signals) and the instruction to ignore the signal. Before and after the intervention, participants completed measures of response inhibition, and alcohol consumption. Alcohol consumption was measured again at one month post-training. All parts of the study were completed online.

Results: Contrary to the hypotheses, participants in the inhibition condition did not have lower levels of alcohol consumption, nor improved response inhibition after the intervention, compared to participants in the active control condition.

Conclusion: It is suggested that response inhibition training needs to be specific to the target behaviour in order to be effective; however, that training did not improve response inhibition itself, calls into question the efficacy of this particular training paradigm. It is recommended that future response inhibition training paradigms consider how training intensity, and the format of administration, influences behavioural outcomes.

Keywords: Alcohol; Binge drinking; Response inhibition; Self-regulation; Stop-signal task; Stroop task; Intervention

Introduction

Excessive alcohol consumption, or binge drinking, increases the immediate risk of injury and the lifetime risk of alcohol-related diseases [1]. Dual-process theories such as the reflective-impulsive model [2] can be used to explain binge drinking [3]. According to this model, behaviour is guided by a reflective system which produces behaviour that is in line with personal goals and an impulsive system which produces behaviour more automatically on the basis of perceptual input. The system that directs behaviour is dependent upon additional factors or 'boundary conditions' [2], such as response inhibition- the ability to stop a pre-potent or impulsive response [4]. For example, it is suggested that if response inhibition is low, the reflective system cannot fully operate and impulsive tendencies are more likely to guide action [3].

A number of studies have demonstrated that poor performance on tasks said to measure response inhibition is associated with greater alcohol consumption [5-8]. In particular, studies have manipulated response inhibition to temporarily decrease this capacity resulting in increased alcohol consumption [9,10]. Conversely, studies have found that response inhibition training can lead to reduced alcohol consumption [11]. Training paradigms within these studies typically involve practicing a task that requires response inhibition, such as the Go/No-Go Task [12], or the Stop-Signal Task SST [13]. Continued execution of these tasks results in an improved ability to stop a pre-potent response [14].

Response inhibition training may employ stimuli that are either specific to a behaviour (cue-specific stimuli; e.g. pictures of alcohol) or not specific to the behaviour (non-specific stimuli e.g. pictures of geometric shapes). Currently, there is limited evidence as to whether non-specific training is efficacious. It is important to determine this, as non-specific training may be particularly beneficial given that individuals are not exposed to images of tempting stimuli, which may themselves initiate behaviour among some individuals [15]. Several studies have employed non-specific training and demonstrated null or inconsistent effects on behaviour [16-22]. However, it is difficult to draw any firm conclusions from this literature given a variety of limitations and inconsistencies across training paradigms.

The number of sessions and the presentation of stop-signals vary greatly across non-specific response inhibition training paradigms. For example, the proportion of stop-signals presented across trials in previous literature ranges from 25% of trials [19] to 50% [18], with one study increasing the proportion across blocks [16]. Results from studies training other aspects of self-control and cognition have shown that more intense training is beneficial [23,24]. For instance, alcohol consumption was reduced in the experimental group which performed four sessions of a non-specific planning ability task [25]. Another study found that alcohol consumption was reduced in participants that completed four sessions of an online-administered attentional bias modification task [26]. Moreover, it has been proposed that non-specific response inhibition training may need to be longer than a single session, in order to be effective [18]. Therefore, it was of interest to test the effect of multiple sessions of non-specific response inhibition training on alcohol consumption in the present study. However, to date studies that have administered non-specific response inhibition training across multiple sessions have been limited by low power [20], or by targeting a population that was not likely to benefit from training, i.e., one that was not engaging in the target behaviour at baseline [22]. Therefore, it is difficult to determine if training is ineffective due to a lack of power, or a lack of intensity of training.

Another important consideration that is not addressed in previous literature is whether non-specific training improves response inhibition, and whether this translates into changes in behaviour. If training results in improved performance on another task said to measure response inhibition, and this mediates improvement in behaviour, it can be said that response inhibition is the mechanism responsible for behaviour change. Previous research has indicated a relationship between SST and Stroop task performance such that individuals who demonstrate superior response inhibition via performance on the SST, also exhibit superior performance on the Stroop task [27,28]. Therefore, change in performance on the Stroop task may be a suitable indication of improvement in response inhibition after SST training which is why the Stroop task was included as a second measure of response inhibition.

In sum, the present study adds to the existing literature by administering response inhibition training online at a greater length (four sessions) and intensity (50% stop-signals) than previous studies. Also, response inhibition was measured with two tasks (Stop-Signal Task and Stroop Task) in order to test if possible increases in response inhibition would transfer to the Stroop task.

Aims and hypotheses

The present study investigated the use of multiple sessions of non-specific training using a high stop-signal density (50%) on response inhibition and alcohol consumption. Alcohol consumption was measured at pre-test, post-test, and 1 month follow-up in order to determine the medium term effects of training. It was hypothesized that relative to an active control group, participants in the inhibition training condition would have improved response inhibition and decreased alcohol consumption following the intervention such that participants who complete response inhibition training would demonstrate 1) improved performance on the SST, 2) improved performance on the Stroop task, and 3) reduced alcohol consumption.

Materials and Method

Participants

One hundred and sixty-eight undergraduates between 18–36 years of age (M=19.4, SD=2.4; female=73.2%) were recruited from a large urban university in Australia. Participants' characteristics were similar to those of previous samples from the same University where participants were between 18 and 36 years of age, mainly Australian and the majority lived with their parents [25]. Participants were eligible to participate in the study if they were 18 years or older, consumed alcohol, and had not been diagnosed with an alcohol addiction in the past.

Stop-signal task

Pre and post-test

At pre- and post-test, participants completed the classic SST described in Verbruggen, Logan and Stevens [29]. In this task, participants were required to indicate the direction of an arrow presented on screen. On a random selection of trials (stop-signal trials) participants were presented with a sound (the stop-signal, 750 Hz, 75 ms) which indicated that they must refrain from responding to the visual stimuli [29]. The signal was presented on 25% of trials and was initially presented 250 ms after the go stimulus. This delay (stop-signal delay; SSD) varied throughout the task according to participants' responses such that when participants successfully inhibited their responses on a stop trial, the SSD increased by 50ms; when participants failed to inhibit their responses the SSD decreased by 50 ms. The dependent variable of interest is stop-signal reaction time (SSRT), calculated by the mean method which consists of subtracting the average stop-signal delay from the mean go reaction time [30]. The task consisted of four blocks of trials; one practice block with 32 trials and three experimental blocks with 64 trials. Participants were shown performance feedback on screen (10 sec.) after each block in order to increase awareness of their task performance [29]. Feedback included the number of correct responses on go trials, and the percentage of correctly suppressed responses.

Training conditions

Participants were required to complete the same SST described above; however there were two important differences according to condition: 1) participants in the inhibition training condition received the SST with stop-signals presented on 50% of trials; 2) participants in the active control received the SST with stop-signals presented on 25% of trials but were instructed to ignore the stop-signal and respond to all stimuli.

Stroop task

Participants were required to indicate the colour in which a word was displayed on a computer screen via keyboard press. The task consisted of three trial types: neutral trials (colour patch), congruent trials (colour word printed in the corresponding colour), and incongruent trials (colour word printed in a different colour). The dependent variable of interest was interference; calculated by subtracting average response latencies on neutral trials from average response latencies on incongruent trials, where a smaller interference score indicated better response inhibition [31,32]. The Stroop task consisted of one practice block and one test block. The practice block

consisted of 60 trials in which participants responded to the colours of strings of symbols (i.e., &&&&, ====, %%%%, and ####) in order to familiarise themselves with the key that corresponded to each colour [3,31]. The test block consisted of 180 trials (60 congruent: 60 incongruent: 60 neutral).

Alcohol consumption

A measure of weekly alcohol consumption was obtained with an adapted version of the timeline follow-back questionnaire [33,34]. On the timeline follow-back questionnaire, participants were instructed to estimate the number of standard drinks they consumed on each day during the previous week, and these values were summed to calculate the total number of standard drinks consumed over the past week (one standard drink is equivalent to 10 g. alcohol/12.5 ml of pure alcohol). Participants were given a definition and an illustration of a standard alcoholic drink with each question.

Procedure

All parts of the study were completed online. Participants were randomly assigned to either the inhibition or the active control condition using a random number generator. They were informed via e-mail that they were participating in a study on self-regulation and alcohol behaviour and directed to the URL for the pre-test measures: the alcohol consumption questionnaire, the Stroop task and the SST with 25% stop-signals (pre-test).

In both conditions, participants were asked to complete one SST per day over four days. Participants in the inhibition condition completed the SST with 50% stop-signals and were instructed to refrain from responding at the sound of the stop-signal. Participants in the active control condition completed the SST with 25% stop-signals but were instructed to ignore the stop-signals and always respond to the visual stimuli [18,19].

After the four days, all participants were directed to complete the post-test measures: the alcohol consumption questionnaire, the Stroop task and the SST with 25% stop-signals (post-test). Four weeks later, participants were asked to complete the alcohol consumption questionnaire (follow-up). The pre-test, post-test and follow-up questionnaires were sent on Fridays. Friday was chosen as the day for completing the pre-test, post-test and follow-up questionnaires in order to measure alcohol consumption consistently and because more alcohol may be consumed on weekends. Participants completed one training task a day, for four consecutive days starting Monday. All participants were sent the links containing the training tasks on the same days. Because the post-test was completed on Friday and participants reported their alcohol consumption for the past seven days, the pre- and post-test measures of alcohol consumption did not overlap. Participants were granted standard course credit as an incentive for participating in the study (90 min., 1.5 credit points). The study was conducted according to the protocol approved by the University's Human Research Ethics Committee.

Data cleaning

Data cleaning for the SST was performed as recommended [29]. Participants who did not complete the SST accurately at either pre- or post-test were not included in the analysis. Individuals were excluded from analyses if their probability of responding given a signal was significantly different from 50% at either pre- or post-test [29]; 48 participants were excluded from analysis of SSRT for this reason. On the Stroop task, data reduction was performed as recommended by removing all error trials (5% of the data) and outliers (7% of the data) from the pre- and post-test data sets [31]. Outliers were all reaction times below 300ms and above 1500ms. Mean response latencies were calculated separately for congruent, incongruent and neutral trials after removal of outliers.

Results

Sample characteristics

Independent samples t-tests showed no pre-existing differences between participants in the inhibition (n=81) and active control (n=87) condition on the variables age, SSRT, Stroop interference, and timeline follow-back score at baseline, all $p>0.05$. Chi-square tests of independence showed no differences between the proportions of individuals in each condition who were female, or who completed all training tasks, all $p>0.05$. Post-test measures were completed by 127 participants (inhibition n=59; active control n=68), an attrition rate of 24%. One month follow-up measures were completed by 110 participants (inhibition n=49; active control n=61), a total attrition rate of 34%. There was no difference in SSRT, Stroop interference, alcohol consumption at pre-test, participant age, or gender, between those that did and did not complete the post-test measures or between those who did and did not complete the follow-up measure, all $p>0.05$. The rates of attrition between the response inhibition and active control conditions were not significantly different, $p>0.05$. Table 1 displays the means, standard deviation of all outcome variables for each condition at each time point.

	Pre-test				Post-test				Follow-up			
	Inhibition		Control		Inhibition		Control		Inhibition		Control	
	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE
Alcohol	10.77	1.9	12.99	1.7	11.19	2.03	12.76	1.81	7.28	1.66	10.02	1.49
SSRT	246.78	13.05	207.14	14.29	227.72	12.22	209.87	13.38				
Stroop	209.43	20.96	206.36	19.8	190.23	23.68	183.37	22.37				

Table 1: Means and standard error of all outcome variables for each condition at pre-test, post-test, and follow-up, Alcohol=Alcohol consumption in standard drinks measured using the timeline follow back questionnaire; SSRT=Stop-Signal Reaction Time (ms); Stroop=Stroop interference score (ms).

SSRT

A2 (pre-test vs. post-test) by 2 (inhibition vs. active control) mixed ANOVA was performed to examine the effect of the intervention on SSRT. There was a marginally significant main effect of condition, $F(1,64) = 4.386$, $p=0.040$, $\eta^2=0.064$, such that averaged across both time points, the control condition appeared to perform better on the SST, MD=28.746ms, SE=13.726, $p=0.040$. There was no main effect of time point, $F(1,64) = 0.409$, $p=0.525$, $\eta^2=0.006$, on SSRT. The interaction between time and condition was not significant, $F(1,64) = 0.729$, $p=0.396$, $\eta^2=0.011$; see Table 1 for SSRT means at each time point in each condition.

Stroop interference

A2 (pre-test vs. post-test) by 2 (inhibition vs. active control) mixed ANOVA was performed to examine the effect of the intervention on interference. There was no significant main effect of condition, $F(1,121) = 0.036$, $p=0.849$, $\eta^2<0.001$; or time point, $F(1,121) = 1.664$, $p=0.199$, $\eta^2=0.014$, on Stroop interference score. The interaction between time and condition was not significant, $F(1,121) = 0.013$, $p=0.908$, $\eta^2<0.001$; see Table 1 for Stroop interference means at each time point in each condition.

Alcohol consumption

A3 (pre-test vs. post-test vs. follow-up) by 2 (inhibition vs. active control) mixed ANOVA was performed to examine the effect of the intervention on alcohol consumption. There was a main effect of time, indicating that averaged across the two conditions there was a change in alcohol consumption over the course of the study, $F(2,106) = 10.670$, $p<0.001$, $\eta^2=0.091$. Planned contrasts indicated a significant decrease in alcohol consumption at follow-up relative to pre-test, $F(1,106) = 11.693$, $p=0.001$, $\eta^2=0.099$, and to post-test, $F(1,106) = 14.064$, $p<0.001$, $\eta^2=0.117$. However, the difference in alcohol consumption between pre- and post-test was not significant, $F(1,106) = 0.024$, $p=0.877$, $\eta^2<0.001$. The interaction between time and condition, was not significant, $F(2,106) = 0.256$, $p=0.775$, $\eta^2=0.002$. Indicating that type of training had no significant effect on alcohol consumption for either condition; see Table 1 for alcohol consumption means at each time point in each condition.

Discussion

Contrary to the hypotheses, alcohol consumption decreased significantly at one month follow-up in all conditions, irrespective of training condition, indicating that non-specific response inhibition training did not influence alcohol consumption. Further, participants who completed inhibition training did not demonstrate improvements in response inhibition compared to participants in the active control group.

Alcohol consumption decreased at one month follow-up, relative to pre- and post-test for all participants. However, there was no difference in alcohol consumption between the experimental groups, indicating that the decrease in alcohol consumption cannot be attributed to the training completed by participants in the inhibition condition. These results are in line with previous research wherein non-specific response inhibition training did not result in differences in behavioural outcomes [18,19,22] suggesting that training needs to be stimulus-specific in order to be effective. Indeed, previous research using stimulus-specific training has demonstrated significant reductions in alcohol consumption [35,36]. It is suggested that the repeated pairing of alcohol stimuli (e.g. a picture of beer) with a stop-response results in a reduction in the positive value of the stimulus and that this leads to a reduction in alcohol consumption [37]{Veling, 2008 #3492}.

Non-specific response inhibition training was not effective at reducing alcohol consumption despite the increased stop-signal density, and training duration, used in the current paradigm. Previous research using multiple sessions of non-specific self-control training was successful at decreasing alcohol consumption [25]; however, the training paradigm used targeted planning ability, rather than response inhibition. Given that these processes are distinct [28], training planning ability may be a more effective way of reducing alcohol consumption. This explanation is plausible; however, there is strong evidence for the association between response inhibition and alcohol consumption [3,39], and more research is needed to determine the conditions under which response inhibition training has an effect on alcohol consumption.

It is unexpected that SST training did not improve SSRT. One possible explanation is that a higher stop-signal density is too taxing, and participants were therefore unable to improve across sessions. In order to clarify these results, the presentation and density of stop signals would need to be varied systematically in future studies. Given that SSRT and Stroop performance are conceptually related [40], and previous research has demonstrated a relationship between these measures [27,28], it follows that Stroop performance did not improve. However, a recent study failed to find near transfer effects of response inhibition training on the Stroop task [41], suggesting that performance on these measures may not be related. Further research is warranted to clarify the relationship between measures said to assess inhibitory control.

Strengths and limitations

As the measure of behaviour used in this study relied on self-report, responses may have been subject to inaccuracies [42]. However, participants were given a definition and illustration of a standard alcoholic drink in order to reduce the likelihood of incorrect responses, and determining the efficacy of response inhibition outside a laboratory setting is important. Additionally, while it is claimed that non-specific response inhibition training is not effective at reducing alcohol consumption in this instance, it cannot be said that behaviour-specific training is superior; as such a condition was not included in the current study. Future research should include both conditions, as well as an active control, in order to determine whether this is the case. Furthermore, the greater proportion of females should be kept in mind when interpreting the findings, as the results may vary for older or male students [43]. Moreover, it is possible that there was no effect of the intervention on response inhibition because participants in this study were University students who may already have good response inhibition, leaving less scope to improve this process through training (ceiling effects) [16]. Therefore, future studies could test the effect of the intervention on response inhibition in a population that is known to have response inhibition deficits [16].

A possible explanation for the overall decrease in alcohol consumption could be that the current results were influenced by the mere-measurement effect, meaning that participating in a study on alcohol behaviour may have resulted in participants becoming more aware of their drinking behaviour, and adjusting their alcohol consumption as a result [44]. Future research can attempt to control for this effect by utilizing designs such as the Solomon-4 group design

[45]. Finally, this was the first non-specific response inhibition training to be conducted entirely online and care should be taken when making comparisons to previous research using a different format. Although it is possible that the online format may have influenced the efficacy of the training, it is unlikely because participants who did not adhere to the task instructions were removed from the analysis. Since this study was conducted more research has been published on web-based cognitive trainings showing that non-specific response inhibition training is unsuccessful and the study results corroborate these findings [46,47]. The potential benefits of online trainings (greater reach and cost-effectiveness in dissemination) make it important to determine their efficacy and further research is warranted.

Conclusion

The present intervention contributes to the existing body of literature by showing that this particular non-specific response inhibition training paradigm had no significant effect on alcohol consumption or response inhibition. Although alcohol consumption decreased for all participants in this study, this occurred irrespective of experimental condition and cannot be attributed to the intervention. This finding is important because it demonstrates that non-specific response inhibition training had no effect on alcohol consumption outside of the laboratory and after one month, even though the training was administered at a greater length and intensity than in previous studies. Since this study was conducted more research has been published which suggests that multiple sessions of non-specific inhibition training are ineffective. More research is needed in order to understand which processes are involved in the reduction of alcohol consumption and to further the development of effective online interventions, which can be implemented on a large scale in a cost-effective manner.

Conflict of Interest

The authors declare no conflict of interest.

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