Psychological Test and Assessment Modeling, Volume 64, 2022 (1), 48-64

NICOTINE AND CAFFEINE USERS' BLOOD PRESSURE REGULATION DURING SUSTAINED VISUAL ATTENTION

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Abstract

Smoking and caffeine improves some aspects of cognitive performance but it also brings with it some serious cardiovascular health risks. We investigated whether quiet and focused visual attention can reduce blood pressure in nicotine and coffee consumers. Participants either smoked (n=40), or drank coffee (n=40) on a daily basis. The control group neither smoked nor drank coffee (n=40), total n=120. We measured blood pressure before and after the Attentional Blink Task (ABT) which consists of a visual perception task that requires attention to very fast appearing and disappearing targets without and with delay due to distracters. Performance gains due to nicotine and caffeine were limited to immediate perception but were sensitive to delay. The nicotine group had a significantly higher systolic and the caffeine group a significantly higher diastolic blood pressure before the ABT, but both were significantly reduced afterwards showing a blood pressure regulation effect of sustained, focused visual attention.

Keywords: caffeine; nicotine; attentional blink task; sustained visual attention, blood pressure regulation

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1. Introduction

Caffeine and nicotine are substances that are well known for their ability to improve cognitive functions such as learning, memory, executive functioning, abstract reasoning and mental processing speed (Smith et al., 1993; Spilich et al., 1992; Warburton, 1992), but they also increase blood pressure (Tsai et al., 2021) incurring an increased risk of cardiovascular disease. Effective and healthy ways exist to reduce this side effect, including salt control, weight reduction, stress management, exercise and alcohol reduction (Bowman et al., 2007). Here, we tested whether sustained visual attention in the Attentional Blink Task (ABT) would lower blood pressure in daily users of caffeine and nicotine.

1.1 Nicotine and Cognitive Performance

Smoking is well known for the harmful effects it can have on people. For example, there are 19 different carcinogenic components in processed and unprocessed tobacco that are the leading cause of cancer, heart disease, stroke and respiratory disease. Smoking also increases the blood pressure with an increased risk of sudden cardiac death (Bowman et al., 2007; Linneberg et al., 2015). There is already a pronounced risk of cardiovascular events when smoking only 1.5 cigarettes per day on average, with a baseline risk indicator of 1.63-1.72 (Pope et al., 2009). This baseline risk only gradually increases with the number of cigarettes that are smoked per day on average, with a maximal risk indicator of 1.97-2.03 when smoking on average 27 cigarettes per day. Thus, such a high risk even when smoking as little as possible, shows that a crucial aspect of nicotine use appears to be whether someone smokes or not.

However, a positive effect of nicotine use is also suggested because it enhances attention and memory (Levin et al., 1998; Warburton, 1992). Here we are interested in the effects of nicotine has on sustained visual attention. Nicotine has a positive effect upon performance on simple repetitive tasks, while it can have an adverse effect on participants' performance on problem-solving skills supported by both long-term and working memory (Spilich et al., 1992). However, individuals with Alzheimer's disease showed improved attention and memory due to low doses of nicotine via skin patches or injection (Jones et al., 1992; Parks et al., 1996; White & Levin, 1999). In addition, nicotine improved several attentional and cognitive deficits that are also associated with attention deficit hyperactivity disorder, Alzheimer's disease, Parkinson's disease, and lifespan cognitive decline (Drobes et al., 2006; Levin et al., 1998; Newhouse et al., 2004). However, results from other studies oppose the notion that nicotine enhances attention (Hindmarch et al., 1990). Given the mixed evidence of the effect of smoking on cognition, further research is warranted.

1.2 Caffeine and Cognitive Performance

Studies on caffeine use have shown that its use improves various aspects of cognition (Ruxton, 2008; Smith, 2002): Caffeine improves psychomotor speed, vigilance, reaction times, and alertness as well as short-term recall.

There seems to be agreement on a non-effect of caffeine on inhibition, which is a component of executive function (Miyake et al., 2000). Tieges et al. (2009) used the stop-signal task and found an improvement in alertness, psychomotor speed and vigilance, but no change in the inhibition processes that are required in the stop-signal task. In addition, Hameleers et al. (2000) also investigated the effect of caffeine intake by using the Stroop test in a life-span sample of 24- to 81-year-olds, but did not find a positive association between attention and habitual caffeine intake, again showing that caffeine did not have an effect on inhibition.

In contrast, other functions of executive function appear to benefit from caffeine. Managers took faster decisions with caffeine intake and made people work harder without noticing it, while those managers who abstained were less effective (Smith et al., 1999). It seems that caffeine has an optimal effect on brain function (Van der Stelt, 1999) as increased mental speed and attention both seem to be a direct effect of caffeine. Caffeine not only accelerated reaction times but also improved verbal memory and visuospatial reasoning (Jarvis, 1993).

A lifetime coffee intake is positively associated with long-term and short-term memory, recall, language, calculation, attention, and orientation (Johnson-Kozlow et al., 2002). Moreover, Cao et al. (2012) could show an absence of progression to dementia in people with a mild cognitive impairment when they had high levels of caffeine in the blood. However, despite these advantages, like nicotine, also caffeine increases blood pressure and thus represents a risk to cardiovascular health (Grosso et al., 2017) in older populations (Lawes et al., 2004), but also in younger people (Nwabuo et al., 2021).

1.3. The Current Study

We investigate the effect of nicotine and caffeine on sustained visual attention in comparison to a control group of participants who neither smoke nor drink coffee. We recruited self-identified regular users of nicotine or caffeine. We hypothesized that the measurement of their blood pressure would show an elevated baseline before the task. However, once the task has been mastered, we hypothesized that nicotine and caffeine users would feel release and the prediction was that the blood pressure would be lowered. There are relatively few scientific studies about cognitive enhancement and nicotine/caffeine because the majority of studies investigates the motivation to quit the habit (Ziedonis et al., 2017). However, given the many positive effects on cognition described above, it needs to be realized that there can be a positive and realistic expectation that caffeine and nicotine can raise achievements (Deck et al., 2021) even if it is known that, for instance, fruit, seafood and water can have similar effects without associated health hazards (Pilato et al., 2020).

We use the Attentional Blink Task (ABT) as it is one of the most accurate tools to measure sustained attention (Broadbent & Broadbent, 1987). In the ABT, participants are asked after having seen a series of letters with very short presentation times in rapid serial visual representation (RSVP) whether target letters were present, or not, amongst distracters. In particular, the ABT model predicts that when two targets (T = target, T1, T2) have to be identified, the successful identification of T2 depends on the gap (lag) from T1. Specifically, the ABT shows the two following effects, first, when T2 is shown immediately after T1, then T2 is very likely to be identified. This phenomenon is called Lag-1 sparing. Second, when T2 is displayed within a time window of about 500 milliseconds and after distractors were shown following T1, then T2 is likely to be missed, and this phenomenon is known as the Attentional Blink (AB) effect (Arnell & Shapiro, 2011; Raymond et al., 1992). The AB effect is maximal with a lag of 300 milliseconds (Hommel & Akyürek, 2005) and does diminish when longer lags are tested.

The hypotheses are, first, that participants who habitually daily consume caffeine and nicotine will perform better than the control group in the ABT, and second, that after an initially more elevated blood pressure than in the control group, the blood pressure of caffeine and nicotine users will drop after the task.

2. METHOD

2.1. Participants

G*Power 3.1 (Faul et al., 2009) was used to calculate the sample size for an ANOVA with three substance groups and gender as between-subject factors and one repeated measurements factor with two levels. To obtain a reliable effect with an effect size of $\eta p2 = .25$, power $(1\text{-}\beta) = .95$ and an α level of $p = .05$, a sample size of 90 is required. Participants were students from a London (UK) university in an urban area studying various disciplines such as Computing, Law, and Social Sciences. We obtained a gender-balanced sample of $n = 120$. There were 40 participants in each group, 20 males and 20 females. Their age range was 18 to 38 years, with a mean age of 25 years.

One group consisted of caffeine consumers, the other nicotine consumers, and in the control group individuals did consume neither caffeine nor nicotine. Participants were assigned to their groups with a questionnaire assessing their daily consumption. To be included in one of the groups, individuals had to drink at least a cup of coffee or more daily (for caffeine consumers) and smoke at least one cigarette or more per day (for nicotine consumers). Vaping consumers were excluded as the amount of nicotine is not the same as in tobacco. Exclusion criteria for caffeine consumers were individuals who were drinking only Coca-Cola, black tea and Red Bull because the doses in those drinks are much lower than in coffee. All participants had normal to corrected vision.

2.2. Materials and Apparatus

2.2.1. Blood Pressure Measurement

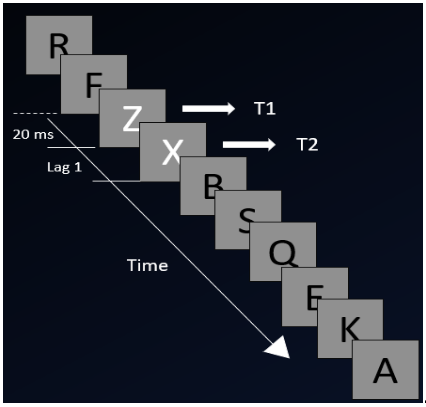
A digital blood pressure monitor Omron Basic M2 was used to measure systolic and diastolic blood pressure.

2.2.2. Attentional Blink Task

We used a Viglen computer with Windows 10 and the experimental software SuperLab 5.0 to create the original Attentional Blink Task (ABT) (Nakatani et al., 2012) and included two effects, the Lag1 sparing and the AB effect. There were four lists that each contained ten letters. In 16 RSVP practice lists, 8 with the target present and 8 with the target absent, each letter was presented for 60 milliseconds (ms) with an interstimulus interval (ISI) of 80 ms. After the practice trials, there were 288 RSVP test lists where each letter was presented for 20 ms, followed by an interstimulus interval (ISI) of 80 ms adding up to 100 ms which is the minimum time needed for stimulus processing (Gathercole & Broadbent, 1984). The code is available on https://osf.io/t8p3u/.

Two of the lists included the white letter X, and two of them did not. The first list included two targets (T). The two T targets were the white letters Z (T1) and X (T2). T1 and T2 were presented one after the other with no distractors in between (—distractor—T1—T2—distractor) and it was this list that was supposed to produce the Lag1 sparing effect (R, F, Z, X, B, S, Q, E, K, A) (see **Figure 1A**). To test the AB effect, the second list included the letters W (T1) and X (T2) as the white letters. They were presented as T1—distractor—distractor—T2 (O, G, A, W, M, S, X, T, M, I) (see **Figure 1B**).

Figure 1: ***The Experimental Design of the Attentional Blink Task (ABT)***



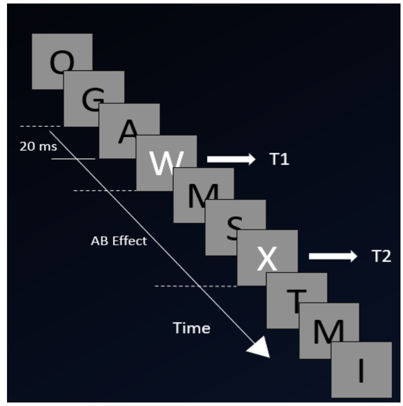


Figure 1A. Lag1 sparing **Figure 1B. Attentional blink (AB) effect**

The other two of the four lists contained only distractors. They were created with ten random letters including one and two random white letters. The total number of trials was 320. The order of the four lists was pseudo-randomised per participant. Participants had to press the keyboards 'y' for correct (yes) or 'n' for incorrect (no) each time the question whether the list that had appeared before contained a target. Participants were not pressing the response button when a target appeared because of the very short presentation times of 20 ms of each stimulus in the lists.

2.2.3 Abstract Reasoning Measurement

The Baroco Short was used as a control of participants' abstract reasoning (Shikishima et al., 2011).

2.3 Procedure

The Ethics proposal was approved by the Psychology Ethics Board of the university affiliation of the first author, following the guidelines of the Code of Research Ethics of the British Psychological Society (BPS). Their blood pressure was taken immediately before the ABT. When participants had completed the task, their blood pressure was measured again. Once the blood pressure measurements were carried out, participants completed the verbal reasoning test which included five questions. There was a time limit of one minute per question.

2.4 Data

Accuracy was averaged for the identification score of T1 in the Lag1 (no delay) and the AB effect (intermittent items) across the 72 repetitions. The reasoning score was added up per participant with values ranging from 0 to 5.

3. RESULTS

We used SPSS v.27 for statistical analyses. The raw data spreadsheet as well as the output files are available on https://osf.io/t8p3u/. The three groups did not differ on the syllogism score, $F(2, 120) = 1.64$, $p = .198$, nor did men and women differ on the syllogism score, $F(1, 120) = .04$, $p = .849$ and thus the score was not included in any further analyses.

3.1 ABT Task

We ran a 2 (lag) by 3 (nicotine/caffeine/control groups) by 2 (gender) analysis of variance with repeated measures of the first factor. Pairwise comparisons within the model were corrected by SPSS using the Bonferroni method. We first report the effect of the between-subject effects followed by the within-subject group effects. Group means and standard deviations are listed in **Table 1.**

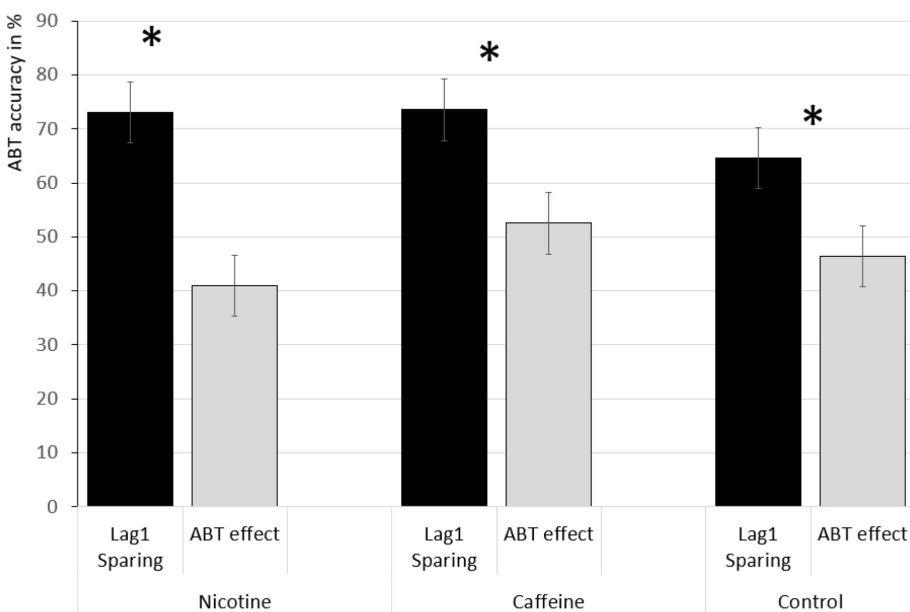
There was a main effect of gender $F(1, 120) = 19.23$, $p < .001$ with a small effect size of $\eta_p^2 = .14$. Women were more accurate ($M = 64.9$ %) than men ($M = 52.2$ %). There was the expected main effect of Lag, $F(1, 120) = 117.10$, $p < .001$, with a medium effect size of $\eta_p^2 = .51$. This effect revealed and confirmed the attentional blink phenomenon of the ABT as the Lag1 scores ($M = 70.4$ %) were lower than the AB effect scores ($M = 46.6$ %).

Importantly, the hypothesized two-way interaction of Lag with Group was also significant $F(2, 120) = 3.73$, $p = .027$, with a small effect size of $\eta_p^2 = .06$. Post-hoc paired samples t-tests (two-tailed) showed that all three comparisons between Lag1 sparing and the AB effect were significant, but the difference was largest ($M = 32.09$) in the nicotine group, $t(39) = 8.34$, $p < .001$, 95% CI [24.3, 39.9], see **Figure 2**.

Table 1: ***Descriptive Statistics of ABT Scores*** **(*N*=120) (per cent correct)**

	Males		Females		Total	
	M	SD	M	SD	M	SD
			Lag 1			
Caffeine	65.37	18.10	81.69	10.67	73.53	16.83
Nicotine	68.88	16.93	77.25	18.75	73.06	18.14
Health	59.26	12.84	69.99	16.11	64.63	15.37
Total	64.50	15.96	76.31	15.18	70.41	40.09
			AB effect			
Caffeine	50.06	18.54	54.96	21.69	52.51	20.07
Nicotine	29.80	19.41	52.14	31.37	40.97	28.12
Health	39.68	24.99	53.19	21.20	46.43	23.87
Total	39.85	20.98	53.43	24.75	46.64	24.02
			Total Scores			
Caffeine	57.72	15.77	68.32	13.22	63.02	15.33
Nicotine	49.34	22.56	64.69	22.56	57.02	20.30
Health	49.47	15.88	61.59	10.53	55.53	14.65
Total	52.18	18.07	64.87	15.44	58.52	16.76

Figure 2: ***Attentional Blink Task, Accuracy in Percent (Lag1 Sparing and the AB effect)***



Note. Bars represent the standard error

The second largest difference (M = 21.02) was found in the caffeine group, $t(39)$ = 6.40, $p < .001$, CI [14.4, 27.7] and the smallest difference (M = 18.20) in the control group, $t(39)$ = 4.19, $p < .001$, CI [9.41, 27.0].

To further explore the two-way interaction, we also ran univariate ANOVAs for accuracy for Lag 1 sparing and the AB effect, respectively, with the three groups as between-subject factor. There was a significant group difference for the Lag 1 sparing, $F(1, 120) = 3.55$, $p = .032$, with a small effect size of $\eta_p^2 = .06$. Both substance groups (nicotine M = 73.1%; caffeine M = 73.5%) showed a higher accuracy than the control group (control M = 64.6%), however, the pairwise comparisons showed only statistical trends, $p < .080$. The group differences for the ABT effect were not significant, $F(1, 120) = 2.26$, $p = .108$, $\eta_p^2 = .04$. Thus, while absolute performance differences were minimal, the effect of the delay on the target detection was largest in nicotine users, followed by caffeine users, but for the control group the effect was less pronounced because the Lag 1 sparing accuracy tended to be lower.

3.2 Blood Pressure Analysis

The initial systolic blood pressure before the experiment was significantly different between the three substance groups, $F(2, 120) = 11.39$, $p < .001$, $\eta_p^2 = .16$, with smokers having the highest systolic blood pressure (nicotine M = 117.8 mmHg, caffeine M = 110.4 mmHg, control M = 104.9 mmHg). Post-hoc comparisons showed it was significantly higher compared to both the caffeine and the control group, $p_s < .022$. The initial diastolic blood pressure was also significantly different in the three groups, with coffee drinkers having the highest diastolic blood pressure $F(2, 120) = 4.15$, $p = .018$, with a small effect size of $\eta_p^2 = .07$ (nicotine M = 78.5 mmHg, M = caffeine 82.4 mmHg, control M = 75.1 mmHg). Post-hoc comparisons showed it was significantly higher compared to the control group, $p = .014$. In short, while smokers had a higher systolic blood pressure, coffee drinkers had a higher diastolic blood pressure. **Table 2** lists means and standard deviations of the three groups' blood pressure before and after the ABT.

We ran a 2 (systolic vs diastolic blood pressure) by 3 (groups) by 2 (gender) analysis of variance with repeated measures on the first factor. Because statistical results are listed in **Table 3** here, they are not again mentioned in the following text.

Table 2 ***Blood Pressure Before and After the Attentional Blink Task*** **(*N*=120) (mmHg)**

	Males		Females		Total	
	M	SD	M	SD	M	SD
			Systolic before			
Caffeine	113.35	8.83	107.45	8.66	110.40	9.13
Nicotine	125.10	9.88	110.50	11.97	117.80	13.11
Control	104.45	12.73	105.35	16.70	104.90	13.63
Total	114.30	10.48	107.77	12.44	110.03	11.96
			Systolic after			
Caffeine	106.50	10.50	109.35	6.07	107.92	8.59
Nicotine	109.55	9.56	101.30	9.59	105.43	10.33
Control	101.40	6.54	114.20	13.01	107.80	12.05
Total	105.81	8.87	108.20	9.55	107.05	10.32
			Diastolic before			
Caffeine	81.75	8.20	83.10	10.38	82.43	9.26
Nicotine	85.90	15.54	71.05	8.71	78.48	14.53
Control	74.40	5.58	75.90	12.01	75.15	9.27
Total	80.68	9.77	76.68	10.37	78.69	11.02
			Diastolic after			
Caffeine	75.30	10.10	80.30	11.54	77.80	11
Nicotine	79.95	9.26	71.10	7.70	75.42	9.48
Control	73.80	6.14	77.65	7.03	75.73	6.80
Total	76.35	8.50	76.35	8.76	76.31	9.10

Table 3: ***Analysis of Variance of Systolic and Diastolic Blood Pressure*** **(*N*=120)**

Statistical effect	*df*	*MS*	*F*	*p*	η_p^2
		Within Subjects effects			
SysDia	**1**	**119385.21**	**1604.23**	**.000**	**.93**
SysDia*Group	**2**	**326.88**	**4.39**	**.015**	**.07**
SysDia*Gender	1	.13	.00	.966	.00
SysDia*Group*Gender	2	198.06	2.66	.074	.04
Repetition	**1**	**1209.67**	**11.70**	**.001**	**.09**
Repetition*Group	**2**	**897.24**	**8.68**	**.000**	**.13**
Repetition*Gender	**1**	**1280.53**	**12.39**	**.001**	**.10**
Repetition*Group*Gender	2	2.64	.03	.975	.00
SysDia*Repetition	1	78.41	1.24	.267	.01
SysDia*Repetition*Group	**2**	**445.71**	**7.08**	**.001**	**.11**
SysDia*Repetition*Gender	1	182.53	2.90	.091	.02
SysDia*Repetition*Group*Gender	2	55.28	.88	.419	.01
		Between Subjects effects			
Intercept	1	4175735.21	24820.28	.000	.99
Group	**2**	**683.14**	**4.06**	**.020**	**.07**
Gender	1	480.00	2.85	.094	.02
Group*Gender	**2**	**2912.64**	**1.86**	**.000**	**.23**

Note. MS = Mean Square*; SysDia* = systolic and diastolic blood pressure factor; *Repetition* = Systolic and diastolic blood pressure before and after the ABT. Significant results are set in bold.

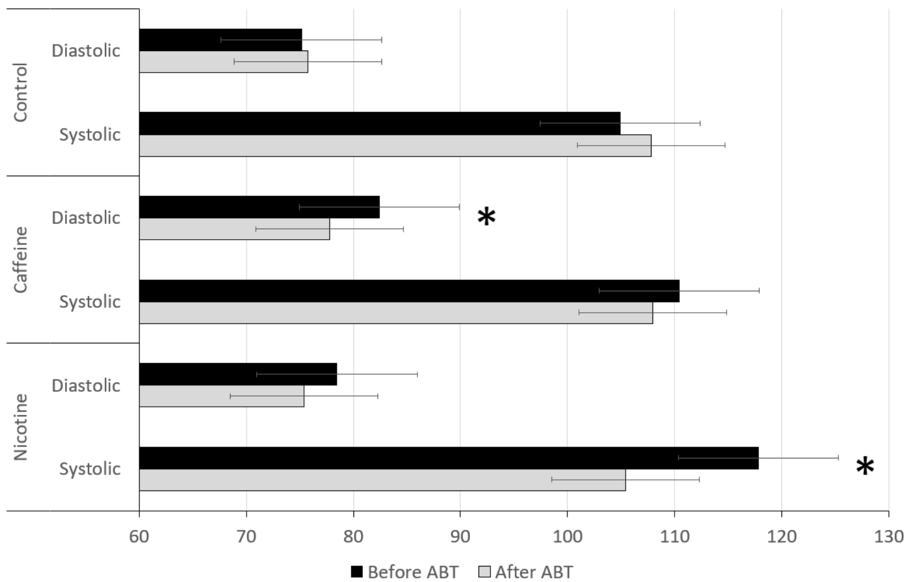
A main between-subjects effect of group showed that blood pressure was different in the three groups. While both the nicotine (*M* = 94.3 mmHg) and the caffeine group (*M* = 94.6 mmHg) had about the same blood pressure on average, pairwise comparisons (two-tailed) within the model showed that the control group had a significantly lower blood pressure (*M* = 90.9 mmHg) than the caffeine group, *p* = .033, CI [.22, 7.27]. However, the two-way interaction of group by gender showed that this effect was different in men and women. Post-hoc t-tests for independent samples (two-tailed) showed that in the nicotine group, men had a significantly higher blood pressure (*M* = 100.1 mmHg) than women (*M* = 88.5 mmHg), *t*(38) = 4.97, *p* < .001, CI [6.86, 16.31]. In the caffeine group, men had a comparable blood pressure (*M* = 94.2 mmHg) to women (*M* = 95.0 mmHg), *t*(38) = -.53, *p* = .596, CI [-3.95, 2.30]. In the control group, women had a significantly higher blood pressure (*M* = 93.3 mmHg) in comparison to men (*M* = 88.5 mmHg), *t*(38) = -2.18, *p* = .036, CI [-9.19, -.33]. Thus, men who smoked had the highest and men who neither smoked tobacco nor drank coffee had the lowest blood pressure.

With regards to the within-subject factors, there was a significant difference between the diastolic (*M* = 109.0 mmHg) and systolic (*M* = 77.5 mmHg) blood pressure which is a trivial result. However, a significant two-way interaction showed that this difference varied in the three groups. Post-hoc pairwise t-tests (two-tailed) showed that all three comparisons between diastolic and systolic blood pressure were significant, but the difference was largest (*M* = 34.66) in the nicotine group, *t*(39) = 27.40, *p* < .001, CI [32.1, 37.2], while the t-values indicated that differences in the caffeine group (*M* = 29.05), *t*(39) = 19.90, *p* < .001, CI [25.97, 32.12] and the control group (*M* = 30.91), *t*(39) = 23.19, *p* < .001, CI [28.22, 33.61], were smaller.

More importantly for the hypothesis, we found a significant main effect of the repeated measurement of blood pressure. Blood pressure was indeed higher when measured before the task (*M* = 94.85 mmHg) than afterwards (*M* = 91.68 mmHg). This effect interacted two-way with both gender and group, respectively, as well as three-way with group and the difference between diastolic and systolic blood pressure. The interaction with gender showed that blood pressure went down in men (before *M* = 97.5 mmHg; after *M* = 91.05 mmHg), but not in women (before *M* = 92.22 mmHg; after *M* = 92.32 mmHg).

Post-hoc paired samples tests (two-tailed) of the two-way interaction of repetition by group showed that in the nicotine group, blood pressure was significantly higher before (*M* = 98.14 mmHg) than after the ABT task (*M* = 90.4 mmHg), with a difference of *M* = 7.71, *t*(39) = 4.80, *p* < .001, CI [4.46, 10.96]. Also in the caffeine group, blood pressure was significantly higher before (*M* = 96.41 mmHg) than after the ABT task (*M* = 92.86 mmHg), with a somewhat smaller difference of *M* = 3.55, *t*(39) = 2.12, *p* = .040, CI [.17, 6.93]. However, there was no significant change of blood pressure in the control group (before *M* = 90.02 mmHg; after *M* = 91.76 mmHg), *M* = -1.73, *t*(39) = -1.00, *p* = .322.

Figure 3 :*Repeated Measurement of Diastolic and Systolic Blood Pressure Before and After the ABT task* (N=120) (mmHg)



Note. Bars represent the standard error

Post-hoc pairwise t-test (two-tailed) of the three-way interaction of diastolic and systolic blood pressure with repetition and group showed that there was no change in blood pressure in the control group, $p_s > .270$, see **Figure 3**. In the caffeine group, there was only a significant change in the diastolic blood pressure (before M = 82.43 mmHg; after M = 77.80 mmHg), $t(39) = 2.30$, $p = .027$, CI [.55, 8.70], but not in the systolic blood pressure, $t(39) = 1.12$, $p = .268$. In contrast, in the nicotine group, there was only a significant change in the systolic blood pressure (before M = 117.80 mmHg; after M = 105.43 mmHg), $t(39) = 6.92$, $p < .001$, CI [8.76, 15.99], but not in the diastolic blood pressure, $t(39) = 1.35$, $p = .185$.

4. DISCUSSION

To our knowledge, this is the first study to show that participation in the ABT task requiring sustained and focused visual attention to capture rapidly appearing and vanishing visual targets lowers the blood pressure in persons who take in nicotine or caffeine on a daily basis. Sustained visual attention can decrease stress both when measured in terms of cortisol (Kline et al., 2020), or as in the current study, blood pressure. The study replicated the well-known attentional blink effect and could show that substance users of nicotine and caffeine showed increased sensitivity to delay. At the same time, focusing their visual perception on rapidly appearing and disappearing events on the screen lowered their blood pressure when it was increased compared to the control sample. This was especially the case in smokers who showed a reduction of more than 15 mmHG. A large meta-analysis showed that already a reduction of 10 mmHG significantly reduces the risk of major cardiovascular disease events (Ettehad et al., 2016). This reduction in blood pressure due to sustained visual attention was comparable to that in a study on smoking cessation (Tsai et al., 2021).

Thus, differences in sustained attention may potentially explain why some smokers can regulate their blood pressure and avoid common health risks. We had hypothesized that the substance user groups would show better accuracy in the ABT. We found that performance improvements due to nicotine and caffeine in the Lag1 Sparing were visible, while the AB effect performance level due to the delay was the same as in the controls. However, the relative deterioration in comparison to the Lag1 Sparing differed, with the substance groups showing significantly more deterioration due to delay than the control group. Effect sizes of these individual differences, though, were not as large as for the actual experimental effect itself. Thus, one can conclude that while some gains could be made in immediate attention due to nicotine and caffeine, similar to an effect of meditation breathing exercises (Sharpe et al., 2021), the substances did not protect against performance shortfalls due to distracters.

Also, the second hypothesis was confirmed as blood pressure was higher before the task than after the task in both substance groups, but not in the control group. Especially in nicotine users, taking part in the visual perception task had a lowered blood pressure by more than 10 mmHg which is the gold standard for all-cause mortality of cardiovascular disease events (Ettehad et al., 2016). Nicotine users showed a greater relief of systolic blood pressure, while caffeine users showed more relief of diastolic blood pressure after the ABT task. In the past, there have been different opinions about which type of blood pressure parameter is actually the more important risk factor for cardio-vascular outcomes, or whether the combined measure should be used (Flint et al., 2019). Here we can conclude that the blood pressure measurement that happened to be higher was the one that was lowered during the task.

One limitation of the study is that most of the participants in the current study were young and had blood pressure below the risk threshold of above 140/90 or 130/80. The necessity of lowering blood pressure should be clear to reduce the risk of cardiovascular events, moreover, is currently debated whether lower blood pressure could even prevent degenerative cognitive decline, with some finding no effect (van Middelaar et al., 2018), while others finding some benefits (Hughes et al., 2020). Thus, future research could use a life-span design as the risk of cardiovascular incidents increases with age (Novak & Hajjar, 2010; Waldstein et al., 2005). That we were able to find significant differences in young nicotine and caffeine users should be encouraging as blood pressure regulation gains in older people could be predicted to be even more pronounced (Jarvis, 1993).

References

Arnell, K. M., & Shapiro, K. L. (2011). Attentional blink and repetition blindness. *WIREs Cognitive Science*, *2*(3), 336-344. https://doi.org/10.1002/wcs.129

Bowman, T. S., Gaziano, J. M., Buring, J. E., & Sesso, H. D. (2007). A prospective study of cigarette smoking and risk of incident hypertension in women. *Journal of the American College of Cardiology, 50*(21), 2085-2092. https://doi.org/10.1016/j.jacc.2007.08.017

Broadbent, D. E., & Broadbent, M. H. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & Psychophysics, 42*(2), 105-113. https://doi.org/10.3758/BF03210498

Cao, C., Loewenstein, D. A., Lin, X., Zhang, C., Wang, L., Duara, R., Wu, Y., Giannini, A., Bai, G., Cai, J., Greig, M., Schofield, E., Ashok, R., Small, B., Potter, H., & Arendash, G. W. (2012). High blood caffeine levels in MCI linked to lack of progression to dementia. *Journal of Alzheimer's Disease*, *30*(3), 559-572. https://doi.org/10.3233/JAD-2012-111781

Deck, S., Nagpal, T. S., Morava, A., Farhat, J., Cisneros Sanchez, F., & Prapavessis, H. (2021). Tobacco use among varsity athletes – why do they do it and how do we make it stop: a brief report. *Journal of American College Health*, 1-5. https://doi.org/10.1080/07448481.2021.1897014

Drobes, D. J., Elibero, A., & Evans, D. E. (2006). Attentional bias for smoking and affective stimuli: a Stroop task study. *Psychology of Addictive Behaviors*, *20*(4), 490-495. https://doi.org/10.1037/0893-164x.20.4.490

Ettehad, D., Emdin, C. A., Kiran, A., Anderson, S. G., Callender, T., Emberson, J., Chalmers, J., Rodgers, A., & Rahimi, K. (2016). Blood pressure lowering for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *The Lancet*, *387*(10022), 957-967. https://doi.org/10.1016/S0140-6736(15)01225-8

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses [Article]. *Behavior Research Methods, 41*(4), 1149-1160. https://doi.org/10.3758/brm.41.4.1149

Flint, A. C., Conell, C., Ren, X., Banki, N. M., Chan, S. L., Rao, V. A., Melles, R. B., & Bhatt, D. L. (2019). Effect of systolic and diastolic blood pressure on cardiovascular outcomes. *New England Journal of Medicine*, *381*(3), 243-251. https://doi.org/10.1056/NEJMoa1803180

Gathercole, S. E., & Broadbent, D. E. (1984). Combining attributes in specified and categorized target search: Further evidence for strategic differences. *Memory & Cognition*, *12*(4), 329-337. https://doi.org/10.3758/BF03198292

Grosso, G., Godos, J., Galvano, F., & Giovannucci, E. L. (2017). Coffee, Caffeine, and Health Outcomes: An Umbrella Review. In P. J. Stover & R. Balling (Eds.), *Annual Review of Nutrition, Vol 37* (Vol. 37, pp. 131-156). Annual Reviews. https://doi.org/10.1146/annurev-nutr-071816-064941

Hameleers, P. A. H. M., Van Boxtel, M. P. J., Hogervorst, E., Riedel, W. J., Houx, P. J., Buntinx, F., & Jolles, J. (2000). Habitual caffeine consumption and its relation to memory, attention, planning capacity and psychomotor performance across multiple age groups. *Human Psychopharmacology: Clinical and Experimental*, *15*(8), 573-581. https://doi.org/10.1002/hup.218

Hindmarch, I., Kerr, J. S., & Sherwood, N. (1990). Effects of nicotine gum on psychomotor performance in smokers and non-smokers. *Psychopharmacology*, *100*(4), 535-541. https://doi.org/10.1007/BF02244008

Hommel, B., & Akyürek, E. G. (2005). Lag-1 sparing in the attentional blink: Benefits and costs of integrating two events into a single episode. *The Quarterly Journal of Experimental Psychology Section A*, *58*(8), 1415-1433. https://doi.org/10.1080/02724980443000647

Hughes, D., Judge, C., Murphy, R., Loughlin, E., Costello, M., Whiteley, W., Bosch, J., O'Donnell, M. J., & Canavan, M. (2020). Association of blood pressure lowering with incident dementia or cognitive impairment: a systematic review and meta-analysis. *Jama*, *323*(19), 1934-1944. https://doi.org/10.1001/jama.2020.4249

Jarvis, M. J. (1993). Does caffeine intake enhance absolute levels of cognitive performance [Article]. *Psychopharmacology*, *110*(1-2), 45-52. https://doi.org/10.1007/bf02246949

Johnson-Kozlow, M., Kritz-Silverstein, D., Barrett-Connor, E., & Morton, D. (2002). Coffee consumption and cognitive function among older adults [Article]. *American Journal of Epidemiology*, *156*(9), 842-850. https://doi.org/10.1093/aje/kwf119

Jones, G. M., Sahakian, B. J., Levy, R., Warburton, D. M., & Gray, J. A. (1992). Effects of acute subcutaneous nicotine on attention, information processing and short-term memory in Alzheimer's disease. *Psychopharmacology*, *108*(4), 485-494. https://doi.org/10.1007/BF02247426

Kline, J. A., VanRyzin, K., Davis, J. C., Parra, J. A., Todd, M. L., Shaw, L. L., Haggard, B. R., Fisher, M. A., Pettit, K. L., & Beck, A. M. (2020). Randomized trial of therapy dogs versus deliberative coloring (art therapy) to reduce stress in emergency medicine providers. *Academic Emergency Medicine*, *27*(4), 266-275. https://doi.org/10.1111/acem.13939

Lawes, C. M. M., Bennett, D. A., Feigin, V. L., & Rodgers, A. (2004). Blood Pressure and Stroke. *Stroke*, *35*(3), 776-785. https://doi.org/10.1161/01.STR.0000116869.64771.5A

Levin, E. D., Conners, C. K., Silva, D., Hinton, S. C., Meck, W. H., March, J., & Rose, J. E. (1998). Transdermal nicotine effects on attention. *Psychopharmacology*, *140*(2), 135-141. https://doi.org/10.1007/s002130050750

Linneberg, A., Jacobsen, R. K., Skaaby, T., Taylor, A. E., Fluharty, M. E., Jeppesen, J. L., Bjorngaard, J. H., Aring;svold, B. O., Gabrielsen, M. E., Campbell, A., Marioni, R. E., Kumari, M., Marques-Vidal, P., Kaakinen, M., Cavadino, A., Postmus, I., Ahluwalia, T. S., Wannamethee, S. G., Lahti, J., . . . Husemoen, L. L. N. (2015). Effect of Smoking on Blood Pressure and Resting Heart Rate A Mendelian Randomization Meta-Analysis in the CARTA Consortium. *Circulation-Cardiovascular Genetics*, *8*(6), 832-841. https://doi.org/10.1161/circgenetics.115.001225

Miyake, A., Emerson, M. J., & Friedman, N. P. (2000). Assessment of executive functions in clinical settings: Problems and recommendations. *Seminar of Speech and Language*, *21*(02), 0169-0183. https://doi.org/10.1055/s-2000-7563

Nakatani, C., Baijal, S., & van Leeeuwen, C. (2012). Curbing the attentional blink: Practice keeps the mind's eye open [Article]. *Neurocomputing*, *84*, 13-22. https://doi.org/10.1016/j.neucom.2011.12.022

Newhouse, P. A., Potter, A., & Singh, A. (2004). Effects of nicotinic stimulation on cognitive performance. *Current Opinion in Pharmacology*, *4*(1), 36-46. https://doi.org/https://doi.org/10.1016/j.coph.2003.11.001

Novak, V., & Hajjar, I. (2010). The relationship between blood pressure and cognitive function. *Nature Reviews Cardiology*, *7*(12), 686-698. https://doi.org/10.1038/nrcardio.2010.161

Nwabuo, C. C., Appiah, D., Moreira, H. T., Vasconcellos, H. D., Yano, Y., Reis, J. P., Shah, R. V., Murthy, V. L., Allen, N. B., Sidney, S., Muntner, P., Lewis, C. E., Lloyd-Jones, D. M., Schreiner, P. J., Gidding, S. S., & Lima, J. A. C. (2021). Long-term cumulative blood pressure in young adults and incident heart failure, coronary heart disease, stroke, and cardiovascular disease: The CARDIA study. *European Journal of Preventive Cardiology*, *28*(13), 1445-1451. https://doi.org/10.1177/2047487320915342

Parks, R. W., Becker, R. E., Rippey, R. F., & Gilbert, D. C. (1996). Increased regional cerebral glucose metabolism and semantic memory performance in Alzheimer's disease: A pilot double blind transdermal nicotine positron emission tomography study. *Neuropsychology Review*, *6*(2), 61-79. https://doi.org/10.1007/BF01875368

Pilato, I. B., Beezhold, B., & Radnitz, C. (2020). Diet and lifestyle factors associated with cognitive performance in college students. *Journal of American College Health*, *online*, 1-7. https://doi.org/10.1080/07448481.2020.1847118

Pope, C. A., Burnett, R. T., Krewski, D., Jerrett, M., Shi, Y. L., Calle, E. E., & Thun, M. J. (2009). Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke shape of the exposure-response relationship. *Circulation*, *120*(11), 941-948. https://doi.org/10.1161/circulationaha.109.857888

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, *18*(3), 849-860. https://doi.org/10.1037/0096-1523.18.3.849

Ruxton, C. H. S. (2008). The impact of caffeine on mood, cognitive function, performance and hydration: a review of benefits and risks. *Nutrition Bulletin*, *33*(1), 15-25. https://doi.org/10.1111/j.1467-3010.2007.00665.x

Sharpe, P., Whalley, B., & Mitchell, C. J. (2021). Does brief focused attention and open monitoring meditation affect the Attentional Blink? *Mindfulness*, *12*(10), 2430-2438. https://doi.org/10.1007/s12671-021-01709-2

Shikishima, C., Yamagata, S., Hiraishi, K., Sugimoto, Y., Murayama, K., & Ando, J. (2011). A simple syllogism-solving test: Empirical findings and implications for g research [Article]. *Intelligence*, *39*(2-3), 89-99. https://doi.org/10.1016/j.intell.2011.01.002

Smith, A. (2002). Effects of caffeine on human behavior [Review]. *Food and Chemical Toxicology*, *40*(9), 1243-1255. https://doi.org/10.1016/s0278-6915(02)00096-0

Smith, B. D., Davidson, R. A., & Green, R. L. (1993). Effects of caffeine and gender on physiology and performance: Further tests of a biobehavioral model. *Physiology & Behavior*, *54*(3), 415-422. https://doi.org/10.1016/0031-9384(93)90229-9

Smith, B. D., Tola, K., & Mann, M. (1999). Caffeine and arousal: a biobehavioral theory of physiological, behavioral, and emotional effects. In B. S. Gupta & U. Gupta (Eds.), *Caffeine and behavior. Current views and research trends* (pp. 87-135). CRC Press.

Spilich, G. J., June, L., & Renner, J. (1992). Cigarette smoking and cognitive performance. *British Journal of Addiction*, *87*(9), 1313-1326. https://doi.org/10.1111/j.1360-0443.1992.tb02740.x

Tieges, Z., Snel, J., Kok, A., & Richard Ridderinkhof, K. (2009). Caffeine does not modulate inhibitory control. *Brain and Cognition*, *69*(2), 316-327. https://doi.org/10.1016/j.bandc.2008.08.001

Tsai, S.-Y., Huang, W.-H., Chan, H.-L., & Hwang, L.-C. (2021). The role of smoking cessation programs in lowering blood pressure: A retrospective cohort study. *Tobacco induced diseases*, *19*, 82-82. https://doi.org/10.18332/tid/142664

Van der Stelt, O. (1999). Caffeine and attention. In B. S. Gupta & U. Gupta (Eds.), *Caffeine and behavior. Current views and research trends* (pp. 231-240). CRC Press.

van Middelaar, T., van Vught, L. A., van Gool, W. A., Simons, E. M. F., van den Born, B.-J. H., Moll van Charante, E. P., & Richard, E. (2018). Blood pressure-lowering interventions to prevent dementia: a systematic review and meta-analysis. *Journal of Hypertension*, *36*(9), 1780-1787. https://doi.org/10.1097/HJH.0000000000001829

Waldstein, S. R., Giggey, P. P., Thayer, J. F., & Zonderman, A. B. (2005). Nonlinear relations of blood pressure to cognitive function - The Baltimore Longitudinal Study of Aging [Article]. *Hypertension*, *45*(3), 374-379. https://doi.org/10.1161/01.Hyp.0000156744.44218.74

Warburton, D. M. (1992). Nicotine as a cognitive enhancer [Review]. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, *16*(2), 181-191. https://doi.org/10.1016/0278-5846(92)90069-q

White, H. K., & Levin, E. D. (1999). Four week nicotine skin patch treatment effects on cognitive performance in Alzheimer's disease [Article]. *Psychopharmacology*, *143*(2), 158-165. https://doi.org/10.1007/s002130050931

Ziedonis, D., Das, S., & Larkin, C. (2017). Tobacco use disorder and treatment: new challenges and opportunities. *Dialogues in Clinical Neuroscience*, *19*(3), 271-280. https://doi.org/10.31887/DCNS.2017.19.3/dziedonis