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Article Title: The effects of cigarette smoking and abstinence on auditory verbal learning
Year of publication: 2008
Citation: Soar, K., Dawkins, L., Begum, H. and Parrott, A. C. (2008),'The effects of cigarette smoking and abstinence on auditory verbal learning'. *Human Psychopharmacology: Clinical and Experimental*, 23(7), pp. 621–627.

Link to published version:
http://dx.doi.org/10.1002/hup.968

The effects of cigarette smoking and abstinence on auditory verbal learning

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ABSTRACT

Smoking has been associated with both enhanced and impaired cognitive performance; across a variety of domains, but there is limited evidence demonstrating the effects on verbal learning. The current study assessed the effect of smoking and abstinence on verbal learning, immediate memory and retention using the Auditory Verbal Learning Test (AVLT; Rey's, 1964). Three groups: 20 smokers, 20 abstaining smokers and 20 non-smoking adults were assessed on the AVLT on two occasions. At session one, abstaining smokers refrained from smoking for 12 hours (pre-cigarette), whilst smokers had continued to smoke to satiety. Session two commenced after a 15 minute break when both smoking groups were instructed to smoke a cigarette, followed by administration of the second version of the AVLT (post-cigarette). Abstaining smokers showed significant deficits in learning compared to smokers during the pre-cigarette session. Following re-initiation of smoking in the abstaining smokers, these learning decrements were no longer evident. There were trends towards significant group findings in immediate memory and retention during the pre-cigarette session, which again were no longer evident in the post-cigarette session. These findings provide further evidence that smoking abstinence affects verbal learning and furthermore smoking simply restores cognitive performance to pre-abstinence levels.

INTRODUCTION

Whilst smokers commonly subscribe to the cognitive-enhancing effects of cigarette smoking, the research literature on nicotine's effect on cognition is fuelled with inconsistencies. Some maintain that apparent cognitive gains associated with nicotine administration are simply due to a reversal of nicotine-associated withdrawal effects (Bell *et al*., 1999; Parrott and Kaye, 1999; Parrott, 2006). Others propose that nicotine may confer a 'true' enhancing effect on some tasks in some people (Newhouse, Potter and Singh, 2004; Kumari *et al.*, 2003; Trimmel and Wittberger, 2004).

It is possible that such discrepant research findings reflect task specific effects of nicotine (Bell *et al*., 1999), although even within a specific cognitive domain, consistent findings are rarely found. For example, using the *N*-back task to tap working memory, Xu *et al*., (2005) reported longer latencies during abstinence compared with a satiety condition. Mendrek *et al*., (2006), by contrast, found that although abstinent smokers were impaired relative to non-smokers on this task, their deficits were not reversed by smoking a single cigarette.

One area of nicotine's effects on cognition that has received comparatively little attention is verbal memory and learning. Two studies which have recently explored the effects of chronic smoking on these functions using the Auditory Verbal Learning Test (AVLT; Rey, 1964) again report inconsistent findings. Starr *et al*., (2007) reported higher immediate verbal recall rates among non-smokers and ex-smokers compared with current smokers (abstinence status not specified). Paul *et al*., (2006) by contrast found no differences between current smokers (tested after 2 hours of abstinence) and non-smokers on immediate verbal recall, although older smokers were worse than younger smokers and non-smokers on the delayed recall component of the task. Neither of these studies however, aimed to explore the acute effects of nicotine, nor did they distinguish between the memory and learning components of the task.

Jacobsen *et al*., (2005) assessed immediate verbal memory, delayed verbal memory and learning (the increase in the number of words successfully recalled over four/five

consecutive presentations of the same word list) in a younger population of adolescent smokers and non-smokers using the Hopkins Verbal Learning Test-Revised (HLVL-R). Smokers were assessed ad libitum and following 24 hours abstinence. There were no group differences between smokers and non-smokers; however, relative to the ad libitum condition, abstinence was associated with a decline in immediate and (a trend in) delayed verbal memory, but not with verbal learning.

Evidently, comparisons across studies are complicated by differences in specific study aims (e.g. exploration of chronic versus acute effects of smoking or nicotine), methodologies (e.g. presence or absence of non-smoking control group; mode of nicotine administration), and variations in abstinence criteria (e.g. between 2 and 24 hours). Thus, although several studies have explored effects of smoking on verbal memory and learning, it remains unclear as to a) whether acute effects of smoking do indeed improve verbal memory and learning relative to an abstinent condition, and b) whether any putative benefit associated with smoking is due to the reversal of nicotine withdrawal or reflects a 'true' cognitive enhancement.

The present study attempts to investigate whether smoking abstinence causes decrements in verbal memory and learning using the Auditory Verbal Learning Test (AVLT; Rey, 1964), one of the widely used verbal memory and learning tasks. The present study differs from many previous studies since it assesses both abstaining smokers and ad libitum smokers, as well as a non-smoking control group in order to help control for potential long-term cognitive changes associated with smoking per se (as previously suggested, e.g. Paul *et al*., 2006). All participants were assessed at two time points; first after 12 hours of abstinence in the abstaining group, and ad libitum smoking in the satiated group, and second, immediately after smoking a cigarette in both groups. Such a design has only been used once previously in a study assessing the effects of smoking on mood, attention and mental arithmetic (Parrott and Garnham, 1998), here, however, only mood state was affected by abstinence (and improved after cigarette smoking).

It was therefore hypothesised that due to cognitive withdrawal effects, after 12 hours of abstinence, abstaining smokers will demonstrate poorer memory and learning than smokers and non-smokers. These deficits should be reversed after reinstatement of

smoking. Whether smoking causes long-term changes in memory and learning will also be explored by assessing performance of the smokers with that of the non-smokers at both time points.

METHOD

Participants

Sixty participants were recruited for the study, 20 non-smokers (who had never smoked or had not smoked for at least one year) and 40 smokers who had smoked for at least one year (and reported smoking on a daily basis). Of these 40 smokers, 20 were matched to the normal smoking condition (smokers) and 20 were matched to the abstaining condition (abstainers). Smokers were assigned to conditions based on age and gender. The 20 smokers comprised of 10 males and 10 females, mean age 29.5 years (SD 9.04). The abstaining smokers comprised 10 males and 10 females, mean age 26 years (SD 7.53). The non-smokers comprised: 10 males and 10 females, aged 27 years (SD 10.75). There were no significant differences in age between groups [$F(2,57)=0.87$, $p=0.426$].

Assessment Measure

Auditory Verbal Learning Task (AVLT; Rey, 1964)

The test began as immediate word span recall, with participants recalling as many words from a 15-word list (list A) read aloud to them by the examiner at a rate of one word per second. The same list was read and immediately recalled for a further 4 trials. After trial 5, word span recall was then measured for a second new distractor word list (list B). Following recall of list B, the participant was then asked to recall as many words from the first list (list A), but without presentation (trial 6). All responses were taped for subsequent scoring. The score for each trial was the number of words correctly recalled. An alternate form of the AVLT was used for the second test session, to avoid item-related practice effects (Mitushina, Kyle and D'Elia, 1999). In this case AVLT lists D and E were used (Lezak, 1995). This sequence of list presentation was the same for all participants.

The AVLT provides a measure of verbal learning which is the change in recall performance over the five acquisition trials (trials 1-5), this learning curve is indicated by the difference in recall on trial 5 and trial 1 (Mitushina, Kyle and D'Elia, 1999). Recall from trial 1 of the AVLT provides a measure of immediate memory span (Mitushina, Kyle and D'Elia, 1999; Lezak, 1995) and trial 6 (recall following interference list) measures retention of the newly learnt information and potential loss due to retroactive interference (Mitushina, Kyle and D'Elia, 1999). Interference was also measured by the number of words from list A (D for the second test session) that are recalled during the recall of list B (E) and the number of words from list B (E) that are recalled during the recall of list A (D) in trial 6. The total number of errors and word repetitions made across all trials was also recorded.

Procedure

All participants were given written aims, objectives and requirements of the study prior to participating. Informed written consent was obtained and the University of East London's School of Psychology ethics committee approved the study.

On the day of assessment, the abstaining smokers arrived at the first test session having previously been asked to abstain from smoking or using any tobacco products for 12 hours prior to the first assessment session. Compliance with these abstaining instructions were verified using a carbon monoxide (CO) tester, with a criterion of less than 10 parts CO per million being required. None of the participants in the abstaining group failed this criterion. The non-abstaining smokers were asked to continue smoking ad libitum for 12 hours prior to the first test session and to ensure they had smoked a cigarette 15 minutes prior to assessment. The non-smokers had no requirements to fulfil prior to assessment. Following verification of smoking status, participants were administered the AVLT. On completion of the AVLT all participants were given a 15 minute break, during which time all smokers (smokers and abstainers) were instructed to smoke a cigarette of their usual brand, whilst non-smokers were just asked to rest and wait. Following this 15 minute break all participants were administered an alternate version of the AVLT, with mode of

presentation being identical to the first test session. On completion of this second test participants were debriefed.

Data Analysis

Data was analysed using SPSS 15. Separate one-way ANOVAs with a between-subjects factor of group (non-smokers, smokers and abstaining smokers) were conducted for each test session (i.e. pre-cigarette and post-cigarette) for each measures of the AVLT (i.e. immediate memory [recall from trial 1], learning [recall on trial 5 minus recall on trial 1], and retention [recall from trial 6]). One-way ANOVAs were also conducted for group differences in the number of errors, repetitions and intrusions (A and B / D and E) for each test session. Post hoc comparisons (to compare abstinent smokers versus smokers, abstinent smokers verses non-smokers, and smokers verses non-smokers) using Tukey HSD were conducted on any significant (or near-significant) between group effects. Effects were considered significant if $p<0.05$.

RESULTS

AVLT - Immediate Memory

Tables 1 and 2 shows the mean recall for each group for immediate memory span, for each test session (pre-cigarette and post-cigarette respectively). This is otherwise illustrated as trial 1 in figures 1 and 2 (pre-cigarette and post-cigarette respectively), for non-smokers, smokers and abstaining smokers. During the pre-cigarette session, ANOVA indicated a group difference on immediate memory span which approached significance $F(2,57) = 5.02$, $p=0.065$. Post hoc Tukey HSD tests indicated that there were no significant differences between the abstaining smokers versus smokers ($p=0.882$), no significant differences between abstaining smokers versus non-smokers ($p=0.181$) and a difference between non-smokers and smokers which approached significance ($p=0.07$). During the second test session (post-cigarette), ANOVA showed no significant group differences on immediate memory, $F(2,57) = 0.733$, $p = 0.485$.

[insert figure 1 here]

[insert figure 2 here]

AVLT - Learning

AVLT learning is represented as the change in the number of words recalled from trial 1 to trial 5. This learning curve is illustrated in figures 1 and 2 (pre-cigarette and post-cigarette respectively), as the slope of the line across trials 1-5, or otherwise identified as the difference in recall in trial 5 and trial 1 for both test sessions (tables 1 and 2 respectively). An ANOVA on the pre-cigarette data, revealed a significant group difference on the rate of learning over the 5 trials, $F(2,57) = 3.48$, $p=0.037$. Post hoc Tukey HSD tests indicated that the abstaining smokers demonstrated significant learning impairments relative to smokers ($p=0.037$). There were no significant differences between smokers and non-smokers ($p=0.143$), or between non-smokers and abstaining smokers ($p=0.814$). Following reinstatement of smoking in the abstainers i.e. at the post-cigarette test session, a separate ANOVA indicated there were no longer any group differences in learning, $F(2,57) = 1.11$, $p = 0.335$.

[insert tables 1 & 2 here]

AVLT - Retention

Tables 1 and 2 show the mean recall for each group for the retention of the newly learnt material for each test session (pre-cigarette and post-cigarette respectively). This is otherwise illustrated as trial 6 in figures 1 and 2 (pre-cigarette and post-cigarette respectively). During the pre-cigarette session ANOVA indicated a group difference which approached significance $F(2,57) = 2.86$, $p = 0.066$. Nevertheless, post hoc Tukey HSD tests indicated no significant differences between either the abstaining smokers versus smokers ($p=0.105$), abstaining smokers versus non-smokers ($p=0.105$) or non-smokers versus smokers ($p=1.00$). During the post-cigarette session, all groups recalled a similar number of words, i.e. there were no

significant group differences on the retention of the newly learnt material, $F(2,57) = 0.00$, $p = 1.00$.

Errors, repetitions and intrusions

Tables 1 and 2 show the total number of errors and repeated words across all trials as well as the number of intrusions for both test sessions (pre-cigarette and post-cigarette). ANOVAs indicated that there were no significant group differences in the number of errors at the pre-cigarette sessions, $F(2,57) = 0.181$, $p = 0.835$; and a group difference that approached significance at the post-cigarette session, $F(2,57) = 3.015$, $p = 0.057$. Post hoc Tukey HSD tests revealed that this reflected fewer errors made by non-smoker than smokers ($p=0.068$), rather than a difference between smokers and abstaining smokers ($p=0.135$) or abstaining smokers versus non-smokers ($p=0.944$).

Concerning the number of repetitions, there were no significant group differences at either the pre-cigarette ($F(2,57) = 0.181$, $p = 0.835$) or post-cigarette ($F(2,57) = 0.682$, $p = 0.510$) session. There were no significant group differences in the number of intrusions from list A or B at the pre-cigarette session ($F(2,57) = 1.652$, $p = 0.201$; $F(2,57) = 0.668$, $p = 0.517$, respectively). Nor were there any significant differences in the number of intrusions from list D and E at the post-cigarette test session ($F(2,57) = 0.053$, $p = 0.945$; $F(2,57) = 1.949$, $p = 0.152$, respectively).

DISCUSSION

The current study provides further evidence that smoking abstinence causes decrements in cognitive processing, in particular verbal learning, and that this can be reversed following the consumption of a single cigarette. At the pre-cigarette session, abstaining smokers showed significantly poorer learning compared to smokers (but not non-smokers). Following reinstatement of smoking (post-cigarette session), these learning decrements were no longer evident with abstaining smokers showing similar levels of learning as smokers and non-smokers. Whilst the reversal of cognitive deficits following the reinstatement of smoking in formerly abstinent smokers has previously been demonstrated (e.g. Parrott and Roberts, 1991), this is the first known

study using such a method to demonstrate these reversal effects specifically on verbal learning.

Smoking abstinence did not appear to affect immediate verbal memory and retention. Whilst there were marginally significant group differences on both measures at the pre-cigarette session, in the case of immediate memory this reflected superior performance in non-smokers versus smokers. This may be suggestive of a detrimental effect on immediate memory caused by chronic smoking, in line with that suggested by Paul *et al.,* (2006) who noted that long-term smoking appears to be associated with decreased cognitive function. Nevertheless, this difference was not replicated at the post-cigarette stage which may reflect the restorative effects of very recent cigarette smoking. Noteworthy here, moreover, is that there was no evidence of core cognitive gains derived from cigarette smoking over and above the performance of non-smokers at either the pre- or post-cigarette testing session, consistent with Parrott's, (2006) assertions.

The current study provides evidence that verbal learning, but not immediate memory and retention, is affected by smoking abstinence. This is in fact, opposite to that found by Paul *et al.,* (2006) and Jacobsen *et al.,* (2005). Jacobsen *et al* (2005) demonstrated that smoking abstinence was associated with a decline in verbal memory but not verbal learning. Again verbal memory but not learning deficits, were apparent in the older smokers in the Paul *et al.,* (2006) study , but it is difficult to establish whether these effects were a result of chronic smoking or due to abstinence, as smokers were only asked to abstain for 2 hours prior to testing. According to previous research, cognitive components of the nicotine withdrawal syndrome may develop any time between 1 to 12 hours of smoking (Bell *et al*, 1999; Gross *et al.,* 1993; Parrott *et al.,* 1996; Parrott, Thurkle and Ward, 2000). The differences between the present study and the findings of Jacobsen et al. and Paul et al. are difficult to reconcile although it is noted that Jacobsen et al., used the HLVL-R rather than the AVLT. Failure to detect significant group differences in both immediate memory and retention at the pre-cigarette stage in this study could reflect low statistical power; nevertheless, whilst power may be an issue, the study still demonstrated robust learning deficits in abstaining smokers.

The effects of smoking on learning might be mediated through an attentional mechanism. Learning requires the acquisition, encoding, storage and retrieval, of material with attention being the front-end of this process (Newhouse, Potter and Singh, 2004). Studies have repeatedly shown smoking abstinence to impair attentional functions (e.g. Absi *et al.*, 2002; Parrott and Garnham, 1998; Parrott *et al*, 1996; Parrott and Roberts, 1991) but working memory may also be involved in the learning process (e.g. Kirkpatrick and Hall, 2005; Kyllonen, 1996). Previous research has also demonstrated working memory deficits associated with smoking abstinence (Mendrek *et al.*, 2006; Jacobsen *et al.*, 2005; Xu *et al.*, 2005). Thus, the learning deficits demonstrated in abstaining smokers, may be mediated by an interrelation between attentional and working memory functioning. Nevertheless, it is unclear how such mechanisms would be specific to verbal learning rather than exerting a more general effect on immediate memory and retention as well. Clearly the mechanism through which abstinence impairs and nicotine restores learning is in need of further investigation.

The current study is not without its limitations. Although a carbon monoxide tester was used to confirm abstinence status in the abstaining group, and none of the participants failed this test, this cannot confirm the actual period of abstinence. In addition, the dose of nicotine that smokers and abstaining smokers administered in between test sessions was not controlled for. Allowing the smokers to smoke one cigarette is an imprecise measure of nicotine dosing, since people differ in their puffing and inhalation strategies in order to adjust their smoking behaviour to compensate for changes in nicotine yield. Assessment at each time point using the CO monitor could have controlled for smoking inhalation, as well as a measure of plasma nicotine and cotinine (metabolite of nicotine) concentrations to conform the delivered dose. However, regardless of this, abstinence-related learning impairments were still evident compared to smokers and non-smokers, and these were resolved after smoking.

The nature of the smokers participating in the study was also not closely controlled; they comprised both occasional and heavy smokers and there was no objective measure of dependence or craving. It is possible that the learning deficits seen in the abstaining smokers at the pre-cigarette session could be a result of craving, which

could possibly interfere with cognitive performance (Mendrek *et al.*, 2006). Previous research which has controlled for levels of dependence, duration of smoking and number of cigarettes smoked per day, however, have not found any relationship between these variables and cognitive performance (Jacobsen *et al.*, 2005; Mendrek *et al.*, 2006).

That the observed impairment in learning during abstinence is secondary to changes in mood or arousal rather than nicotine withdrawal per se is also a possibility. As there was no measure of participant's mood at either testing session, it remains unclear whether the decrements in learning shown in these abstaining smokers were are direct result of nicotine withdrawal or whether they are mediated through other indirect effects of nicotine on mood and arousal (Waters and Sutton, 2000). Nevertheless, there is no reason why negative affect should selectively affect learning rather than immediate memory or retention, thus this is unlikely to be an adequate explanation of the present findings.

In summary, using a sensitive and validated measure of verbal learning, immediate memory and retention, and utilising well-matched non-smoking and ad libitum smoking control groups, the present study suggests that smoking abstinence adversely affects learning, an effect that can be reversed following the consumption of a single cigarette. Parrott (2006) has emphasised the crucial role of abstinence symptoms and their normalisation by smoking in all aspects of nicotine dependency. The learning decrements observed during smoking abstinence here may further contribute to the perceived reinforcing effects of smoking and, in turn, contribute to smoking maintenance. The impact and success of any behavioural smoking cessation treatments may therefore be influenced by these learning deficits demonstrated in smokers seeking to abstain.

ACKNOWLEDGEMENTS

This research was supported by internal funds only. The authors would like to thank those who gave informal feedback on this manuscript, for their constructive comments and suggestions for improvements.

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Table 1: Mean (standard deviations) immediate memory recall, learning, retention, number of errors, repetitions and intrusions at the first test session (pre-cigarette).

Pre-cigarette	***Non-smokers***	***Smokers***	***Abstainers***	***Significance (p)***	***Observed Power***
Immediate memory[1]	5.50 (1.27)	4.55 (1.39)	4.75 (1.29)	0.065	0.54
Learning[2]	4.00 (2.43)	5.25 (1.92)	3.60 (1.79)	0.037*	0.63
Retention[3]	9.95 (2.42)	9.95 (1.90)	(8.55) 2.06	0.066	0.54
Errors	0.65 (1.38)	0.20 (0.41)	0.10 (0.30)	0.104	0.46
Repetitions	2.85 (2.62)	2.90 (1.65)	2.55 (1.50)	0.835	0.08
Intrusions from list A	0.20 (0.69)	0	0	0.201	0.33
Intrusion from list B	0.10 (0.30)	0.05 (0.22)	0.20 (0.61)	0.514	0.16

[1] Immediate memory is measured by immediate word recall on trial 1, of list A
[2] Learning is measured by word recall on trial 5 minus recall on trial 1, of list A
[3] Retention is measured by word recall on trial 6, of list A
* post hoc indicate abstainers v smokers (p=0.037)

Table 2: Mean (standard deviations) immediate memory recall, learning, retention, number of errors, repetitions and intrusions at the second test session (post-cigarette).

Post-cigarette	***Non-smokers***	***Smokers***	***Abstainers***	***Significance (p)***	***Observed Power***
Immediate memory[1]	4.50 (1.15)	4.00 (1.69)	3.95 (1.84)	0.485	0.17
Learning[2]	5.80 (2.97)	5.05 (2.54)	4.55 (2.46)	0.335	0.24
Retention[3]	10.1 (3.08)	10.1 (1.89)	10.1 (1.92)	1.00	0.05
Errors	0.40 (0.75)	0.05 (0.22)	0.10 (0.30)	0.057	0.56
Repetitions	2.00 (2.00)	2.30 (1.62)	1.70 (1.12)	0.510	0.16
Intrusions from list D	1.20 (1.19)	1.20 (1.32)	1.35 (2.30)	0.948	0.06
Intrusions from list E	0.10 (0.30)	0.10 (0.30)	0.30 (0.47)	0.152	0.39

[1] Immediate memory is measured by immediate word recall on trial 1, of list D
[2] Learning is measured by word recall on trial 5 minus recall on trial 1, of list D
[3] Retention is measured by word recall on trial 6, of list D