Everyday Memory Deficits Associated with Anabolic-Androgenic Steroid Use in Regular Gymnasium Users

Thomas M. Heffernan*, Lisa Battersby, Patricia Bishop and Terence S. O'Neill

Collaboration for Drug and Alcohol Research (CDAR), Department of Psychology, Northumbria University. Newcastle-Upon-Tyne, NE1 8ST, UK

Abstract: *Background*: This study compared a group of 47 regular gym users who take androgenic-anabolic steroids (the AAS group) as part of their recreational sport, with a group of 48 regular gym users who do not use AAS (the Non-AAS group) on self-reports of Retrospective memory (RM), executive function (EF) and prospective memory (PM), which are all critical to everyday remembering.

Methods: All participants were tested using an on-line Survey Monkey method. The Prospective and Retrospective Memory Questionnaire (PRMQ) assessed everyday RM and PM deficits and the Executive Function Questionnaire (EFQ) assessed self-reported problems in EF. A drug-use questionnaire and a mood questionnaire were also administered

Results: After observing no between-group differences on alcohol or mood, omitting anyone who drank excessively or had drank recently, smoked or reported using any illegal drug, three one-way ANCOVAs (controlling for age) revealed that the ASS group reported significantly more RM deficits, EF deficits, and PM deficits, when compared with the Non-ASS group.

Conclusion: It was concluded that AAS use in a recreational sports context is associated with RM, EF and PM deficits, indicating that AAS use may damage everyday remembering.

Keywords: Androgenic anabolic steroids, retrospective memory, executive function, prospective memory.

INTRODUCTION

Anabolic-androgenic steroids (AAS) were firstly introduced to the public in 1889 by physiologist Charles E. Brown-Sequard when he made claims that by injecting AAS into his body, increases in strength, intellect, as well as a range of physiological benefits were noticeable [1]. By the mid-twentieth century, athletes were using ergogenic drugs in the form of AAS compounds in order to trim body fat and increase muscle size in an attempt to gain the edge over their rivals; although it should be noted that the prevalence of their use in sports varies widely [2]. Since the introduction of AAS, the covert use of these drugs in a sporting context has permeated populations of athletes, sports coaches and recreational users in an attempt to improve muscle mass and enhance sporting regimes, with some recent figures estimating as much as 38% of gym users taking steroids [3, 4]. Along with any potential benefits AAS use might bring, they have also been linked with a range of physical and psychiatric problems. For example, skin lesions, edema, cardiac palpitations, cardiovascular diseases, as well as collateral effects such as reproductive toxicity, behavioural changes, hepatic and renal disorders, lowered fertility and sexual dysfunctions, have all been reported [5-10]. In addition, a range of behavioural and neuropsychiatric symptoms have also been uncovered; ranging from mild irritation to uncontrolled aggression, hostility and violence against other parties (e.g. 'Roid Rage'). At the more extreme end, the use of AAS has been associated in increased levels of depression and mania. However, the severity and frequency of these effects largely depend on the dose used and the length of time misusing AAS [11-16].

In terms of cognition, only a handful of studies have investigated the cognitive deficits associated with the long-term use of AAS. In one study, long-term AAS users showed no significant differences from a non-user comparison group on measures of response speed, sustained attention, and verbal memory. However, the AAS user group did show significantly reduced performance on a visuospatial memory task which assessed their memory for shapes and locations of objects [17]. In addition, a significant negative correlation between lifetime usage of AAS and visuospatial performance was observed in this study, suggesting a dose-related impairment. In a more recent study, 22 adult male long-term AAS users were administered 4 computerized tests from the Cambridge Neuropsychological Test Automated Battery and the Iowa Gambling Task. Analyses revealed selective cognitive deficits in AAS users, with specific deficits on cognitive measures of inhibitory control and attention, with no differences in terms of planning or decision making [18]. Taken together, these findings suggest there may be selective cognitive deficits associated with persistent AAS use.

*Address correspondence to this author at the Collaboration for Alcohol and Drug Research (CDAR), Department of Psychology, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK; Tel: 0044 191 227 4037; Fax: 0044 191 227 3190; E-mail: tom.heffernan@northumbria.ac.uk

1874-3544/15

Given the scarcity of research into the cognitive deficits associated with AAS use in a sports context, the current study aims to elucidate the links between AAS use and cognition by focusing on 3 key cognitive processes important in everyday remembering. The previous work cited [17-18] are both examples of *retrospective memory* (RM: recall of past memory for people, words, facts, and events from long-term memory) [19]. Since both of these studies were carried out under laboratory conditions, it could be argued that they lacked ecological validity. The first aim of the current study was therefore to assess whether AAS use was associated with RM deficits in a real-world context (i.e., everyday tasks). The second aim was to extend our understanding of the cognitive deficits affected by AAS use by including two other key processes involved in everyday remembering. Executive function (EF) is an umbrella term used to describe a range of cognitive processes that are used to help co-ordinate information in memory, plan and execute tasks, impulse control, and attention [20]. For example, when trying to focus on two tasks simultaneously or attempting to concentrate on a Sudoku number game, EF resources would be heavily employed. Prospective memory (PM) refers to the process of remembering a planned action or intention at an appropriate time in the future - a kind of remembering to remember [21]. For example, remembering to meet with friends on time, remembering to pay a bill before a given deadline or monitoring when to take a medication, are tasks that would all be underpinned by PM resources. Both EF and PM are interrelated processes that are thought to be critical to independent living [22-25]. A compromised EF is likely to lead to confusion, poor planning and other executive problems on everyday tasks; similarly, poor PM ability leads to varying degrees of forgetfulness which can have relatively minor consequences in everyday life (e.g. feeling embarrassed about missing a pre-planned appointment) or quite serious consequences (e.g. forgetting to take an important medication on time can have serious health implications). RM, EF and PM operate together to support effective everyday memory functioning [22], therefore, a compromised RM, as demonstrated by previous work [17, 18] should also be accompanied by deficits in both EF and PM functions.

AIMS

Developing a greater understanding of the everyday cognitive consequences of persistent use of AAS has merit. The main objective of the current study is to explore the relationship between AAS use and everyday memory in the form of RM, EF and PM functions by comparing a group of regular gym users who use AAS with a group of regular gym users who do not use AAS. The following hypothesis was tested: if regular use of AAS does compromise everyday memory then it is expected that the AAS user group should report more deficits in terms of their RM, EF and PM, when compared to a non-user group.

MATERIALS AND METHODOLOGY

Participants

An original sample of 150 individuals from varied walks of life was assessed *via* the on-line tool Survey Monkey, which was chosen as a method of data collection mainly due to its ease of use and the anonymity it provides. From this original sample, 55 were omitted from the analysis on the basis of the following exclusion criteria. 1. Given that females rarely use AAS [3] the current study focused on males only to reflect this pattern. 2. Since other drug use (e.g., excessive drinking - defined as drinking above 21 units of alcohol per week as recommended by UK Government health bodies, cannabis and ecstasy) have been linked to memory deficits independent of AAS use [26-28] anyone who reported having used one or more of the illegal substances or drinking excessively were excluded. 3. Anyone who reported using alcohol within the last 48 hours was also excluded in order to control for potential 'hangover' effects confounding the results. 4. Only participants aged between 18-30 years were included in the final sample in order to reduce any age-related memory effects. 5. Anyone who had failed to fully complete the survey was also excluded. The final sample comprised 95 participants who were regular gym users. Of these, 47 were regular AAS users (Mean age = 24.1 years (2.96); Mean occasions used per week = 2.09 (SD=0.71); Mean dose per occasion = 151 mg (SD=159); Days since last used = 5.82 (SD=9.25); Years spent using AAS = 2.44 (SD=1.89) and 48 were non-users (the Non-AAS group; Mean age = 22.4 years (2.98). Since mood has been known to affect everyday memory independent of AAS use [29, 30] this was analysed and compared between the two groups. Normal (non-excessive) alcohol use per week, along with last alcohol use in hours and the number of years spent drinking alcohol were also analysed and compared between the two groups.

Measures

The participants completed a series of self-reported questionnaires that were uploaded onto Survey Monkey along with a participant information sheet informing them about the nature of the study, a consent button which they would click to proceed, a full debrief sheet, advice on how to withdraw their data at a later date and finally contacts for drug helplines for those who became concerned about their own substance use after participation in the study were also included in the survey

AAS Use and Other Drug Use

AAS use and other drug use (including alcohol, smoking, ecstasy and cannabis) were assessed by a modified version of the University of East London Recreational Drug Use Questionnaire (RDUQ) used in previous research [26-28].

Mood

Anxiety and depressive symptoms were measured using the Hospital Anxiety and Depression Scale (HADS) [31] which is a 14-item standardised self-report questionnaire. Seven items measured generalised anxiety symptoms and 7 generalised depressive symptoms; with the higher score on the scales indicating a greater degree of symptoms reported. The HADS has been shown to be a valid and reliable measure of mood in non-clinical samples [32].

Executive Function

The Executive Function Questionnaire (EFQ) was used to assess a range of executive deficits and was devised and validated by previous researchers [33]. The EFQ is comprised of a series of questions designed to estimate deficits in the main components of executive function - including attentional difficulties, problems in concentration, one's ability of multitask, perseverance on a task, and impulse control. The EFQ shows high internal consistency, with the reliability on Cronbach's alpha being 0.78. Examples of the items on the EFQ include: "Do you tend to "lose" your train of thoughts?" and "Do you have difficulty seeing through something that you have started?" For each item, participants responded by circling one response from a four-point scale (1) no problems experienced; (2) a few problems experienced; (3) more than a few problems experienced; (4) a great many problems experienced. Table **2** contains the full list of executive questions contained in the EFQ. The total scale score was computed by summing the responses to the six items and this total score was intended to reflect the participant's overall experience of executive problems rather than any specific aspect thereof, with a higher score indicating more executive deficits experienced.

Prospective and Retrospective Memory

Prospective memory (PM) and retrospective memory (RM) were assessed using the Prospective and Retrospective Memory Questionnaire (PRMQ) which is a standardised self-report measure developed by previous researchers [34]. The PRMQ assesses self-reported PM and RM deficits in everyday life; with a higher score on these scales indicating more deficits reported and shows high internal consistency, with the reliability on Cronbach's alpha being 0.89. On the PRMQ, 8 items pertain to PM (e.g., "Do you decide to do something in a few minutes' time and then forget to do it?") and 8 pertain to RM (e.g., "Do you repeat the same story to the same person on different occasions?"). The participant was asked to rate how often they experienced such failures on a 5-point scale from "very often" (5) to "never" (1) by circling the response that best reflects their memory ability. A mean score for PM slips/failures was calculated, along with a mean score for RM slips/failures. A mean score for each scale (the PM and RM scales) was calculated by totalling the sum of scores on each scale and dividing this by the number of questions (8), with a higher score in both cases indicating more memory slips/failures.

Procedure

The study protocol was approved by the Ethics Committee at Northumbria University in Newcastle-upon-Tyne, England, and all subjects gave their informed approval before participating. The study had a between-subjects design, with anabolic-androgenic steroids (AAS) use and Non Use as the independent factor and scores on the RM, EF and PM as the dependent factors. In addition, the use of other substances known to influence cognitive performance (e.g., alcohol, smoking, cannabis and ecstasy) and mood (anxiety and depression) were also measured for potential inclusion as covariates. Survey Monkey was used as a platform onto which all the materials were uploaded. Participation was voluntary and each participant was tested individually for approximately 15 minutes.

Statistical Analyses

All data were tested using the Statistical Program for the Social Sciences (SPSS v 21) for Windows. Descriptive analyses were applied to the data on age, alcohol and smoking indices, mood (HADS anxiety and depression scores), executive function scores (from the EFQ) and prospective memory and retrospective memory scores (from the PRMQ), in order to observe trends across the AAS and the Non-AAS groups. A series of 6 one-way analyses of variances (ANOVAs) were applied to the non-memory data to observe any between-group differences on age, alcohol indices (units per week, number of years drinking, and last alcohol use in hours), anxiety scores and depression scores. Three one-way analyses of co-variances (ANCOVAs: controlling for age) were applied to the memory data to observe any between-group differences on RM, EF and PM. A p value of <0.05 was considered significant.

RESULTS

Table **1** shows the means and standard deviations across the AAS users and the Non-AAS group on age, alcohol indices, mood, RM, EF and PM. Five 1-way ANOVAs revealed no significant differences between the AAS and Non-AAS groups on alcohol use in units per week, alcohol use in years, alcohol last used in hours, nor in terms of HADS anxiety scores or HADS depression scores, however, there was a significant between-groups difference in terms of age (see Table **1** for df, F and p values). Age was therefore included into the main analyses on the RM, EF and PM scores (as a covariate) that follow. Three 1-way ANCOVAs (controlling for age) compared the AAS and Non-AAS groups on the RM, EF and PM scores. This revealed significant differences between the AAS and Non-AAS groups on retrospective memory scores (PRMQ-RM), executive function scores and prospective memory scores (PRMQ-PM) (see Table **1** for df, F and p values). Looking at means from Table **1** it is concluded that the AAS users reported significantly more retrospective memory deficits, executive function deficits, as well as more prospective memory deficits when compared with the Non-AAS group (Table **2**).

DISCUSSION

The results of the present work support the working hypothesis that the consumption of AAS within a sporting context is associated with self-reported RM deficits, EF deficits, PM deficits. These findings cannot be attributable to the use of illegal substances (e.g. cannabis, ecstasy), smoking, excessive alcohol use or having drunk alcohol recently - since anyone reporting these were excluded from the study. Since no between-groups differences were found on weekly (non-excessive) alcohol use or general mood (in terms of anxiety and depression scores), these too can be ruled out as potential confounds. It is therefore concluded that the use of AAS compromises everyday memory function - of which RM, EF and PM play important roles [22]. The

Table 1. Means and standard deviations (in brackets) comparing the AAS and Non-AAS groups on age, alcohol use in units per week, how long they had used alcohol in years, last alcohol use in hours, HADS Anxiety and HADS Depression scores, as well as the scores on PRMQ-RM, EFQ Executive Function Scores and the PRMQ-PM scores. The last 3 columns present the df, F and p values for each variable.

	AAS Users (N=47)	Non-AAS (N=48)	df	F	p
Age	24.1 (2.96)	22.4 (2.98)	1,93	7.20	0.008
Alcohol per week	20.9 (18.4)	14.9 (13.5)	1,53	1.96	0.16
Alcohol Use in Years	6.63 (2.19)	7.34 (7.02)	1,53	0.18	0.67
Last Alcohol in Hours	196 (215)	115 (186)	1,53	2.12	0.15
HADS Anxiety	4.40 (2.07)	4.70 (2.89)	1,93	0.34	0.55
HADS Depression	5.95 (3.95)	4.91 (3.92)	1,93	1.65	0.20
PRMQ RM	2.60 (0.90)	1.90 (0.60)	1,92	21.9	0.000
EFQ	16.1 (5.13)	11.2 (5.17)	1,92	23.1	0.000
PRMQ PM	3.40 (1.12)	2.15 (0.66)	1,92	46.9	0.000

RM deficits are consistent with previous research that has revealed AAS-related deficits on visuospatial memory [17] and inhibitory control and attention [18]. However, to our knowledge, this if the first study to uncover everyday RM memory deficits associated with AAS use within a sporting context. The current study also revealed additional AAS-related everyday memory deficits that extend to EF and PM function, both of which are also critical to everyday remembering. If the long-term outcomes of AAS use include impaired everyday memory (as is suggested here) then this could affect many spheres of life, including interpersonal, occupational, educational and health, given the ubiquitous nature of everyday remembering.

Table 2. The full set of executive function questions used for the executive function questionnaire.

1. Do you find it difficult to keep your attention on a particular task?
2. Do you find yourself having problems concentrating on a task?
3. Do you have difficulty carrying out more than one task at a time?
4. Do you tend to "lose" your train of thoughts?
5. Do you have difficulty seeing through something that you have started?
6. Do you find yourself acting on "impulse"?

Given the fact that this is a relatively new area of study, a clear understanding of the underlying neuropsychological damage that might underpin such everyday memory deficits are far from clear. However, some recent work may throw some light on this subject. Animal research has shown that rats exposed to supra-physiological (higher than normal) doses of AAS over a period of time show signs of neurotropic unbalance and related behavioural disturbances in Nerve Growth Factor (NGF) levels in both the hippocampus and the basal forebrain of these rats [35]. Given that NGF plays a mediating role in higher brain functions that include learning and memory, the findings from animal research raises the concern that high doses of AAS within humans may lead to a depletion in NGF in the brain and result in deficits in learning and memory. Given the importance of the basal forebrain in producing acetylcholine which plays a key role in the brain's neurotransmission system [36], as well as the role the hippocampus plays in memory consolidation [37], it is feasible that the RM, EF and PM deficits observed in the current study may, at least in part, be due to a reduction in the brain neurotransmission and/or in the ability of the hippocampus to consolidate information within memory. It should be noted that this is only a theoretical possibility and that further work is needed to elucidate the links between AAS misuse, damage to NGF systems, and deficits in everyday memory in humans. A note of caution should also be considered when interpreting the results of the current study. Reporting bias refers to the likelihood that findings are published when they show 'positive' outcomes, for example, when health and memory deficits are found in AAS users. Therefore, it is feasible that studies do exist that fail to show detrimental health outcomes or cognitive deficits associated with AAS use, but these may not have been published. The publication of both significant and non-significant finding in the field should therefore be encouraged in order to gain a balanced view.

There are a number of limitations to this study. The current study was based on a cohort of student gym users, including the AAS user group. Given that AAS users are likely to come from a range of social backgrounds, future cross-sectional research is needed in order to verify the findings observed in this study by comparing them with other user groups within society. Although self-reports of everyday memory provide useful insights into the metacognitive deficits reported with regular AAS use, objective measures of everyday memory should be used alongside self-reports in order to verify the findings objectively. Objectives measure of everyday memory could include the Cambridge Prospective Memory Test as a measure of PM and Verbal Fluency Tasks as a measure of EF. On a similar note, the use of self-reported AAS use could be bolstered by the use of biological assays to accurately measure the dose of AAS in the user group. Future research might also wish to assess what impact AAS use has upon real-world everyday memory functioning, embedding RM, PM and EF into an actual real-world task, given that if persistent AAS use does impede everyday memory, then it is within a real-world context that is most

likely to have a negative impact upon everyday living. Finally, despite the widespread knowledge about the dangers of using excessive doses of AAS, the number of users continues to rise [2, 3]. A qualitative study approach could be adopted to explore the motivations behind the onset of use of AAS and those factors that may account for the continuance of its use.

CONCLUSION

This is the first study to observe everyday memory deficits associated with the use AAS in a sporting context. It is suggested that EF, PM and RM deficits be added to the growing list of neuropsychological sequelae associated with the persistent use of AAS. The use of AAS in a non-medical context is on the increase and is now seen as a major global health issue that requires further research and awareness. For example, AAS screening in high schools in the USA is on the increase [38] and the number of AAS abuse cases presenting themselves at harm reduction services in the UK continues to rise [39]. These findings may have relevance to a whole range of groups within society, including policy makers, health care professionals, as well as the general public and users themselves.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: December 18, 2014 Revised: April 15, 2015 Accepted: April 19, 2015