

## A Case Study Investigating a Behavioural Intervention to Reduce Caffeine Consumption

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### Abstract

This case study investigated a behavioural intervention to reduce caffeine consumption in a 50-year-old female with a 35-year history of consuming >350 mg caffeine per day. The participant completed a behaviour diary for 10-weeks, recording amount of caffeine consumed, type of caffeinated drink, time, location, who she was with and the activity in which she was engaged. She also completed a 10-point performance scale, and recorded tiredness and headaches. Baseline data was recorded for one week, and then Functional Behavioural Analysis of the diary data was used to design an intervention. A graduated intervention was implemented: Stage 1 (1-week), caffeine ≤ 160 mg/day; Stage 2 (1-week), caffeine ≤ 80 mg/day; Stage 3 (7-weeks), caffeine ≤ 35 mg/day. Caffeine was reduced to planned levels during the intervention period. Perceived performance ratings were significantly improved during the three stages of the intervention relative to baseline ( $p < 0.05$ ). Frequency of daily tiredness increased during Stage 2 and decreased overall during Stage 3 relative to baseline. Headaches were at least as frequent during the intervention as they were during baseline. Findings suggest that the intervention was successful over this 2-month period. Further monitoring is recommended in order to ascertain whether headaches and tiredness (possibly symptoms of caffeine withdrawal) persist.

**Keywords:** Caffeine; Case study; Behavioural intervention; Behaviour modification

### Introduction

Caffeine is one of the most highly consumed drugs worldwide [1], with recent estimates suggesting average daily consumption for adults is approximately 280 mgs [2]. While research indicates that overall caffeine intake increases with age [3], choice of caffeinated beverage is often different across demographic groups. For example, while gender differences in total caffeine consumption are not clear, those ingesting caffeine from tea (as opposed to coffee) are more likely to be younger, female, and non-Caucasian with lower levels of education. In contrast, caffeine consumption via coffee has been linked to older age, Caucasian origin and higher income level [4]. Marketing for caffeinated energy drinks has been targeted at younger people, and consumption is common among college students [5]. Caffeine consumption also varies with other behaviours. For example, higher consumption has been found among smokers and those with higher alcohol intake [4].

Debate exists as to whether caffeine presents a risk factor to health. The literature is mixed; acknowledging caffeine consumption has both beneficial and harmful effects [1,6]. For example, moderate caffeine consumption (between 300-400 mg/d) has been associated with many short-term benefits such as enhanced arousal, attention and performance [7]. Further, caffeine in low to moderate doses is frequently used as an effective countermeasure to sleepiness [8-10]. However, in higher doses, caffeine can cause headache, trembling, anxiety, stress and sleep disruption [11,7,12].

Recent research has suggested that over the longer term, caffeine may offer protective effects against Diabetes type 2 Mellitus [13]. There is also limited, and somewhat inconsistent [1] evidence to suggest a link between excessive caffeine consumption (coffee consumption, in particular) and issues with cardiovascular function [14], triglycerides [15,16], and blood serum cholesterol [17,18]. Some individuals are particularly sensitive to caffeinated products and may consider reducing or eliminating caffeine from their diet, in order to assess whether any health benefits ensue [19].

Caffeine is considered an addictive substance [20] and research

suggests that high caffeine consumers can build up a tolerance towards the product [21,7]. Caffeine withdrawal effects can result in increased tiredness, poor concentration, moodiness, headaches and fatigue and can last from three days to two weeks depending on previous dosage consumed, type of coffee and current dosage maintained. Such withdrawal effects can act as a barrier to reducing caffeine consumption [22,23]. For this reason, interventions involving gradual reduction of caffeine over time [24] and/or maintenance at a reduced level of consumption of 25-100 mg are often preferred, as they are associated with withdrawal symptoms that are less severe.

Indeed, many behavioural modification models use progressive, gradual or staged withdrawal approaches rather than attempting to change behaviour to meet ultimate goals in a single step. Further, since there may be many social cues to undesired behaviour, such as excessive caffeine consumption, which contribute to cravings [25], substitute products, are often employed to assist in the behavioural transition. Such devices are intended to mimic the function of the original undesired behaviour, and/or to encourage the individual to engage in incompatible behaviour, making reverting to the prior undesired behaviour less likely [26]. The aim of the current study was to trial a behavioural intervention to reduce consumption of caffeinated beverages using a graduated withdrawal approach, and substitution for beverages with low or no caffeine. This included monitoring of possible withdrawal symptoms including headaches, rebound-tiredness and perceived performance capability as well as indicators of general health such as cholesterol levels, thyroid function and triglycerides.

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## Method

### Participant

The participant was a 50-year-old Caucasian female, who had a history of sleep disorders, frequent headaches, hormonal problems, weight gain (BMI=28, overweight). Recent blood tests revealed the early stages of hypothyroidism low HDL cholesterol and elevated triglyceride levels. She was not currently, and had never been a smoker. She was completing a Bachelor of Psychological Science degree, and as part of an assignment for her Health Psychology course, she was asked to choose a health-related behaviour, and using functional behaviour analysis [26], design and trial an intervention for positive behaviour change. This class exercise spanned two weeks, including one week of diary records of baseline behaviour, a behaviour interview and intervention plan and one week of post-intervention diary records of behaviour. While the timing and approach to this behavioural intervention began as a class exercise, the design and detail in monitoring and length of intervention and follow-up that the participant developed went beyond the simple 2-week demonstration of principles required by the course. As primary author on this paper, the participant is in the rare situation whereby her consent for her data to be used in research and published is clear from her submission of the paper.

Upon review of her health-related behaviours, while she felt that she engaged in recommended levels of exercise and maintained a healthy diet, she noted that her caffeine consumption was consistently high. She had been drinking coffee for at least 35 years. In particular, from 1996-2009, during full time work she was regularly consuming at least 7 cups per day. In 2009, she began studying and reduced her regular pattern of consumption to 3-4 cups per day. Issues with stress, sleeping problems, headaches and elevated cholesterol levels prompted her to consider a further reduction in caffeine consumption. In particular, she had a 20-year history of insomnia, characterised by experiencing 1-2 hours of wake in the middle of the night on approximately 30% of nights. She had noticed that her insomnia was exacerbated by daytime stress levels, but also felt that her caffeine intake may have been contributing to her sleeping issues.

### Instruments

The participant completed a behaviour diary for 10-weeks, recording amount of caffeine consumed, type of caffeinated drink, time, location, who she was with and the activity in which she was engaged. In this way, the diary was designed to facilitate functional analysis of behaviour, where the antecedents (cues) and consequences for the behaviour could be identified under baseline conditions, as well as performance self-monitoring during the post-intervention period [26]. Estimated caffeine dosages per beverage were specified by Food Standards, Australia and New Zealand (2011) [cappuccino=100 mg; instant coffee=80 mg; black tea=50 mg; diet cola=45 mg; green tea=35 mg; cereal beverage=0 mg; chamomile tea=0 mg; peppermint tea=0 mg]. Cappuccino and instant coffee were prepared with milk and no sugar was added to any of the beverages. The participant also completed daily records of tiredness and headaches (present/absent) and a 10-point performance scale (1=poor performance, 10=excellent performance). This scale captured the participant's perceived concentration ability, overall alertness, memory retention, stress levels and general mood. Two months before beginning the intervention and five months later, the participant visited her GP to obtain fasting lipids studies. These included levels for triglycerides and cholesterol [high- and low-density lipoprotein (HDL and LDL respectively)].

### Study design and intervention

A single subject behavioural design using the A-B methodology was deployed (A=Baseline phase; B=Post-intervention phase) [27]. Initially a baseline was established by recording caffeine intake over one week using the behaviour diary. This diary was then used as an aid in a behavioural interview, conducted with her by a classmate, which included 12 questions aimed at determining how the participant felt about her caffeine consumption, the situations in which it occurred, any associations, perceived function, perceived benefits and losses associated with reductions in caffeine consumption and level of commitment to the behaviour change [28]. The participant reported that her caffeine intake was high and that it may be contributing to her sleep and health problems. She felt that she used caffeine to try to ameliorate her daytime tiredness and also in social situations such as meeting friends at cafes. Perceived losses associated with eliminating caffeine from her diet included missing having cappuccinos when she was out socialising as she described these as "little treats," as well as worries about how to manage her daytime tiredness and any potential rebound tiredness resulting from caffeine withdrawal. Perceived benefits included improvements to health and sleep, and in turn, longer-term improvements in daytime tiredness. The participant reported a strong commitment to behaviour change but felt that this period of monitoring her behaviour, performance, tiredness and health would provide important evidence for her further decision-making relating to future caffeine consumption.

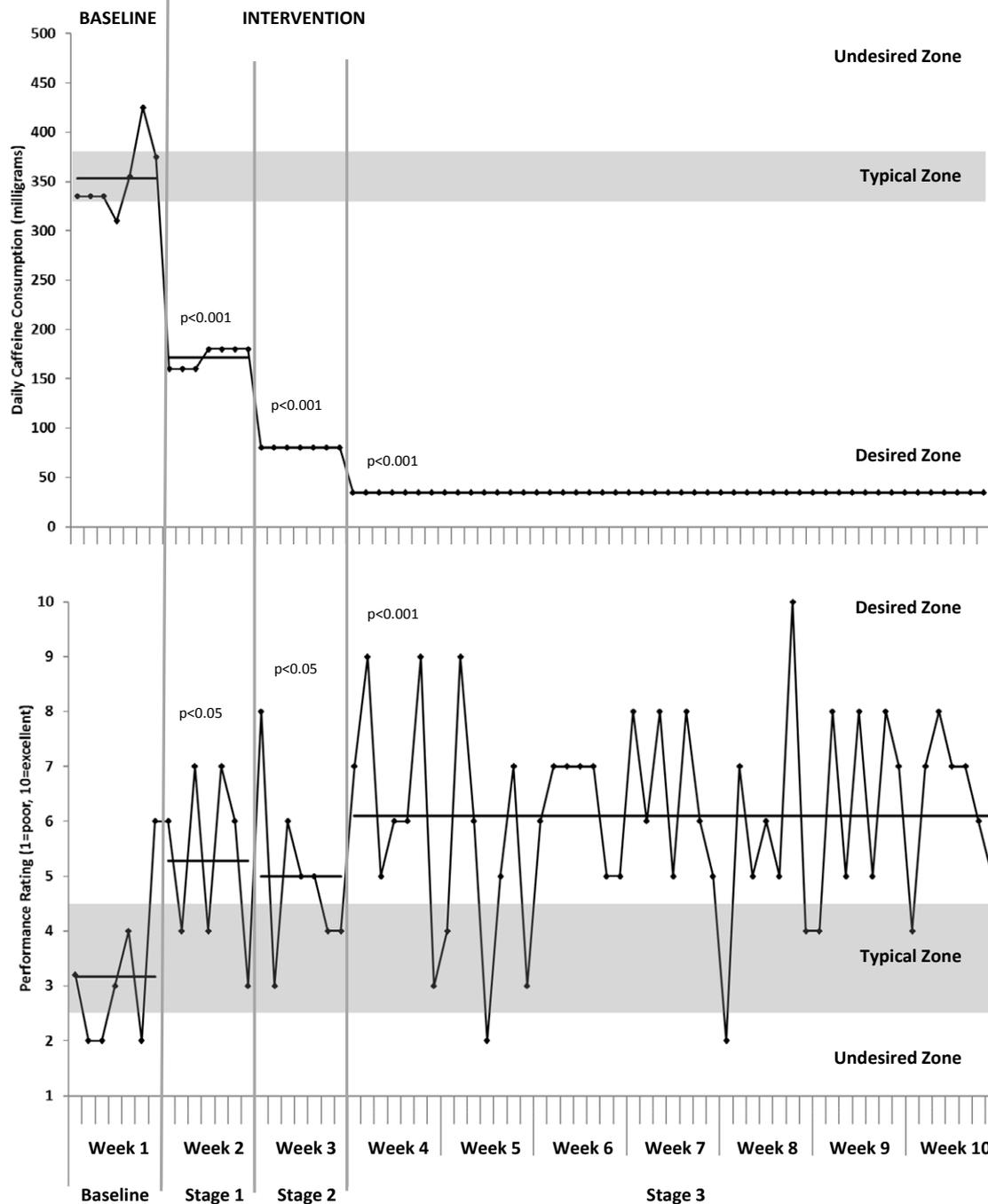
Since caffeine withdrawal symptoms take at least a couple of weeks to subside the participant underwent a nine week post-intervention period in order to determine whether any health benefits emerged. A graduated intervention was implemented: Stage 1 (1-week), caffeine $\leq$ 160 mg/day; Stage 2 (1-week), caffeine $\leq$ 80 mg/day; Stage 3 (7-weeks), caffeine $\leq$ 35 mg/day. Caffeinated beverages exceeding the daily limit were substituted with an instant cereal beverage, peppermint or chamomile tea. In Stage 3, the participant limited herself to a single green tea per day (35 mg caffeine). Excessive daytime tiredness was to be managed with short naps (<20 mins) [29].

Total diary recording time was ten weeks (including one week of baseline recording). Proportion Frequency Analysis [30] was conducted to analyse changes in total daily caffeine consumption and daily performance ratings from the diaries during the three stages of the intervention compared to baseline. This approach, frequently used in Single Systems Designs, identifies a typical zone for behaviour during baseline (defined as the middle two thirds of the data points), which then enables testing of significant departures from "typical" behaviour during intervention phases.

### Results

Average baseline caffeine consumption was 353 mg/day (maximum daily consumption=425 mg) in 4.8 caffeinated beverages per day. Caffeine was primarily ingested through coffee (65% of caffeinated drinks during baseline were instant coffee or cappuccino), but also in tea (17.5%) and cola drinks (17.5%). Caffeinated beverages were primarily consumed alone (70%), and of these, 58% were connected with studying and attending lectures, 33% with breakfast and the remainder with housework or dinner. The 30% of caffeinated beverages consumed with family or friends were during meals or while out socialising.

During the 9-week intervention period, the average number of caffeinated and substitute beverages decreased to 1.7 per day. In Stage 1 (Week 2), the participant consumed two cups of coffee per day (instant or cappuccino). In Stage 2 (Week 3), the participant consumed one cup



**Figure 1:** Caffeine consumption (upper panel) and daily performance ratings (lower panel) during the baseline week and Intervention Stages 1,2 and 3 of graduated caffeine reduction (weeks run Wednesday to Tuesday). Black solid horizontal lines indicate the means for Baseline and Stages 1, 2 and 3. Grey shaded zones indicate Typical Zones for behaviour determined from baseline as per the Proportion Frequency Analysis (Bloom, Fischer and Orme, 2003). Desired and undesired zones for behaviour change are marked. P-values denote significant differences from baseline.

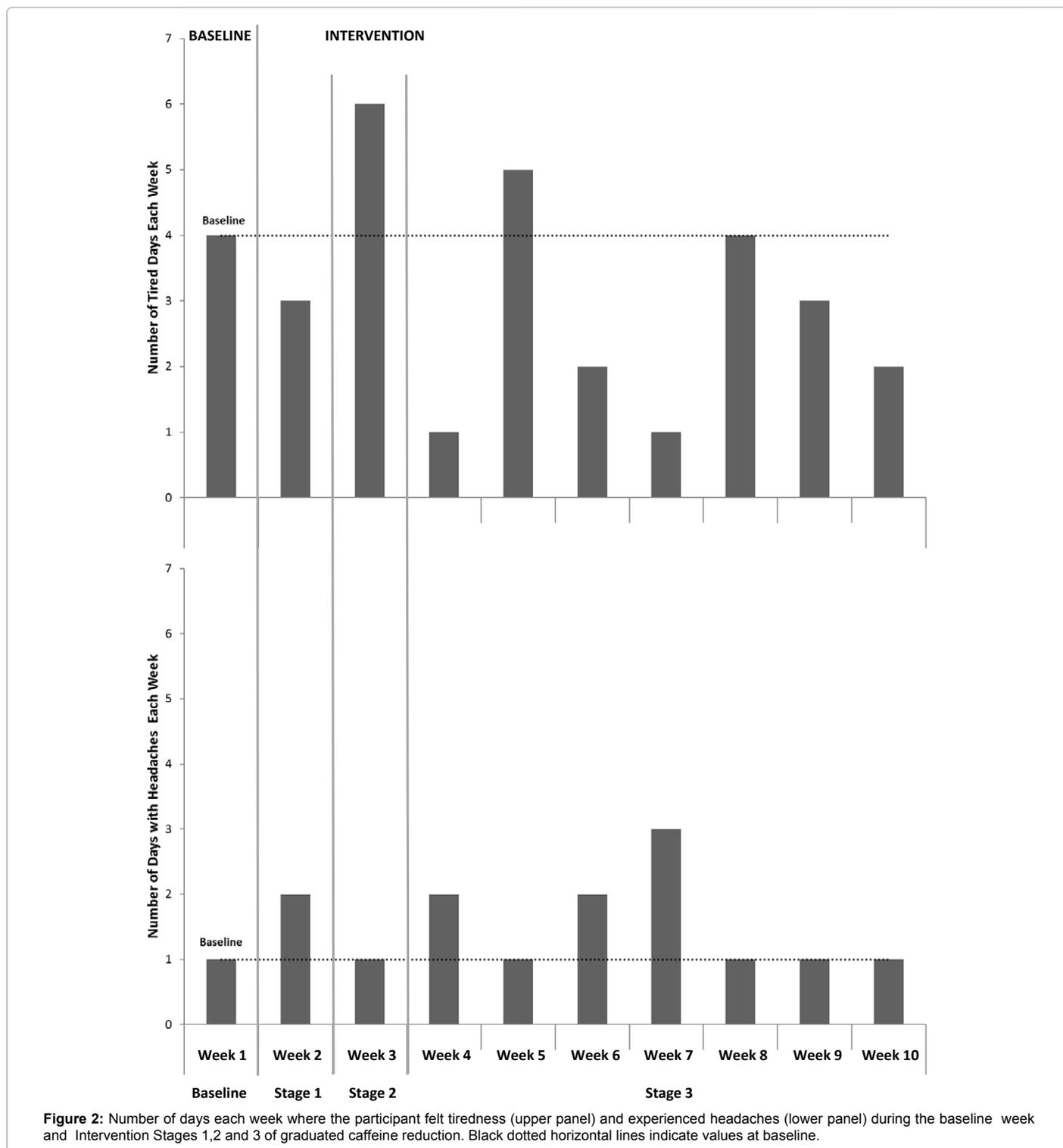
of coffee and one instant cereal beverage per day. In Stage 3 (Weeks 4-10), 64% of the beverages were green tea, with 22% cereal beverages and the remainder peppermint or chamomile tea. Throughout the intervention, the majority of caffeinated beverages or substitutes were consumed alone (86%). Of these, 27% were connected with studying and attending lectures, 62% with breakfast and the remainder with housework. The 14% of beverages consumed with family or friends were while out socialising.

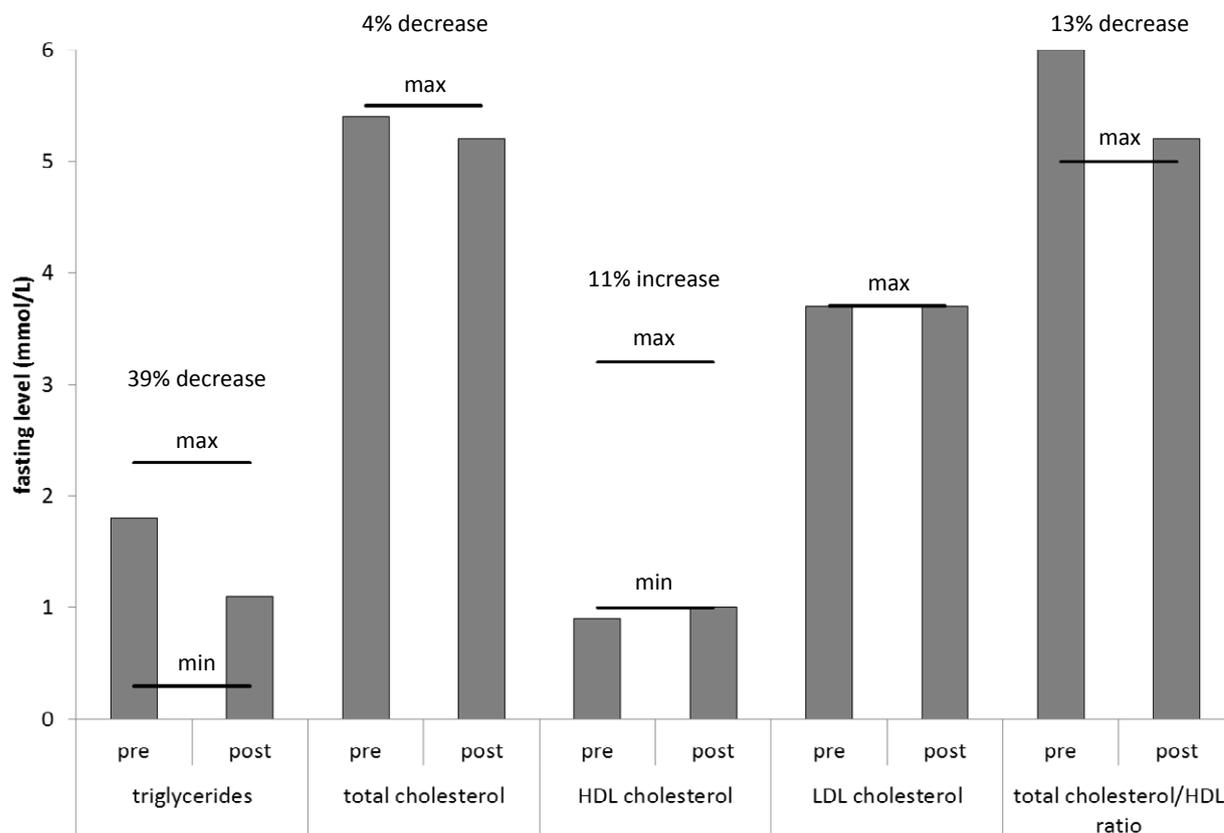
Caffeine was reduced to planned levels during the intervention period. Proportion/frequency analysis indicated that this caffeine reduction was significant ( $p < 0.001$ , Figure 1, upper panel). While there were clear daily fluctuations in perceived performance ratings, proportion/frequency analysis indicated that ratings were significantly improved during the three stages of the intervention relative to baseline ( $p < 0.05$ , Figure 1, lower panel).

Frequency of daily tiredness increased during Stage 2 and decreased overall during Stage 3 relative to baseline. Tiredness was reported more frequently than baseline levels (4/7 days) in Week 3 (6/7 days) and Week 5 (5/7 days), and during these weeks, short naps were required (on 5 days in Week 3 and two days in Week 5) (Figure 2, upper panel). Headaches were at least as frequent during the intervention as they were during baseline (Figure 2, lower panel). The participant also

reported that cravings for caffeine, which were frequent during weeks three to five, had subsided by the end of the study period.

Figure 3 illustrates results of fasting lipid studies tests conducted five months apart. The first test was conducted approximately two months prior to beginning the intervention. Clinical comment on the pre-intervention results indicated that such a profile might represent "risk factors for coronary heart disease". Post-intervention, there was a





**Figure 3:** Fasting lipid studies (for triglycerides and cholesterol) taken pre-intervention (pre) and five months later (post). Maximum and minimum recommended levels are indicated by the horizontal black lines. % changes across the 5 month period are also indicated.

39% decrease in triglycerides and a 10% increase in HDL cholesterol, with an associated 13% drop in total cholesterol/HDL ratio. Post-intervention, clinical notes indicated that the profile was considered “satisfactory.”

## Discussion

The invention successfully resulted in a decrease in caffeine consumption from an average of nearly five caffeinated beverages per day (>350 mg) to a single beverage containing a low dosage of caffeine (35 mg). This supports previous studies highlighting the benefits of graduated reduction in health intervention [24]. Further, results support the use of substitute products, rather than simply removing the substance of concern. This approach acknowledges that behaviours, even those with negative consequences, often serve important positive functions for an individual, and have cues, or triggers as part of everyday life [26]. In this case, caffeine was used to boost alertness while studying. The participant also associated caffeinated beverages with meals and socialising. She also used cappuccinos as a “little treat” for herself. The intervention design included substitutes for coffee, tea and cola in these situations. The participant was able to use herbal teas, cereal beverages and napping as substitutes.

While the reduction in caffeine was successful, increases in tiredness and headaches, particularly during week three, are consistent with caffeine withdrawal effects. This demonstrates the way in which withdrawal symptoms can become barriers to reducing caffeine consumption [22,23]. Indeed, the participant reported that when she was particularly tired, she had to nap frequently in order to fully

function during the day. Findings suggest that tiredness subsided somewhat following this peak during week three. This is consistent with the expected profile of caffeine withdrawal, which typically lasts several weeks. However, following this period, there were weeks where tiredness was still evident. Further, no reduction in headaches was observed over the two months of recording. This may suggest the participant was still experiencing withdrawal symptoms. Alternatively, the headaches may have been attributable to other causes, such as hormonal problems [31], early stages of hypothyroidism [32], or early stages of menopause [33]. Although overall, there was a significant improvement in performance ratings during the post-intervention period, this measure also indicated clear daily variability in how the participant was feeling.

Interestingly, over the five month period, lipid tests indicated an improvement in cholesterol and triglycerides, such that the profile changed from presenting a possible risk for CHD, to “satisfactory.” Clearly, given the nature of this study, as well as the tentative evidence linking caffeine reduction with changes in triglycerides [15,16], cholesterol [17,18], it would be presumptive to suggest that these findings support a causal link. While there may be a relationship between the caffeine reduction and these indicators of physical health, these physical improvements may be reflecting a more broad focus on health-related behaviour for this individual, of which the caffeine reduction is only a part. The success of this caffeine reduction may be contributing to the participant’s feelings of self-efficacy in health-related behaviour change [34], and in this way, contributing more broadly to positive health outcomes.

Further, for her coffee substitutes, the participant chose green, peppermint and chamomile tea and a cereal beverage due to their suggested health benefits. This may also contribute to any positive effects seen post-intervention it should be noted that had she chosen decaffeinated coffee or tea as her coffee substitutes, she may have successfully reduced her caffeine intake, but the health benefits may not have been as marked as suggested. For example, research has suggested that consumption of green tea may increase cardiovascular health and reduce risk of cancer [35,36], peppermint tea has been linked to reduction in gastrointestinal spasm and disturbance [37] and chamomile tea has been implicated in the prevention of progress in hyperglycaemia in diabetes [38]. In addition, these substitutes, particularly green and chamomile teas are generally consumed without sugar compared to caffeinated beverages. While the participant did not add sugar to her tea or coffee (caffeinated or not), this may be a further factor that could promote positive health outcomes among those who typically drink their coffee with sugar. Although the exact guidelines are debated, there are a number of health benefits of limiting sugar intake [39,40].

It is important to acknowledge the strengths and limitations of this study. The case study plays a critical role in health psychology, providing detailed, storied accounts of clients in context. It is clearly not aimed at providing broadly generalizable findings. The AB design employed was the most basic of the single systems designs. As such, it is particularly vulnerable to the common confounders of such designs, including history [27]. During the invention, the participant reported a number of occurrences in her life, such as stress from family related issues and other health-related problems, as well as the possible beginning signs of menopause. It therefore makes it difficult to assess any direct impact of the caffeine reduction. Apart from the lipid tests, all other measures in this study were self-report. Therefore, the possible impact of social desirability [27] needs to be considered. It is also important to consider that, as a psychology student about to enter her honours year; the participant had a well-informed and developed understanding of the relationship between behaviour and health outcomes, as well as of interventions for behaviour modification in this context. It is likely that this knowledge not only assisted in her personalised intervention design, but also to her adherence to the intervention.

Future suggested improvements within a Single Systems Design framework could include more robust behavioural interventions such as multiple baseline designs (to try to control for history effects) or re-exposure designs (e.g. ABAB) with longer baseline and intervention stages. However, there are ethical issues with regard to re-exposing the participant to the addictive substance of caffeine [27]. Alternatively, a multiple-case design could be implemented to capture multiple demographics of caffeine consumption and behavioural intervention, such as those who smoke or have sugar in their beverages. A further enhancement could be to use more objective measures to assess caffeine intake (e.g. through blood or urine sampling for caffeine metabolites), performance capacity (e.g. using a validated computer-administered task) and to objectively monitor whether any withdrawal symptoms or health benefits persist, rather than rely solely on the participant's subjective judgement. The participant has never been a smoker. However, since smoking and alcohol consumption have been related to caffeine consumption [4], future studies would benefit from collecting data, particularly in regard to smoking and drinking behaviours. Undoubtedly, clinical decision-making in this area would benefit from randomised clinical trials. However, it is still important to consider the lessons learned from detailed investigations of behaviour in individuals or small groups.

In conclusion, given the sustained reduction of caffeine, the cessation of cravings and the improvements in physiological indicators of health, this study suggests that the intervention was successful. However, it is important to note that ongoing tiredness, headaches and perceived fluctuations in performance indicate that there were no clear benefits for how the participant felt, at least during the two months of monitoring. The participant has decided to remain on the reduced caffeine allowance (<35 mg/day) for a further six months, and then to review her physical health and how she feels about her daily functioning. This study lends support to intervention designs involving graduated intervention and substitution, but also highlights some of the complexities in and barriers to behaviour change.

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