ORIGINAL ARTICLE

A Preliminary Study: Optimal Caffeine Intake Variables on Cognitive Performance Increment Using Response Surface Methodology

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ABSTRACT

Introduction: Caffeine is a popular psychoactive stimulant consumed globally, although academics debate its benefits and drawbacks. Benefits like improved reaction time, attention, and mood are well known, but side effects including heart palpitations, sleeplessness, and anxiety pose significant health risks. Research on the effects of caffeine is studied, usually only tests on one to three doses at a certain amount of time after consumption. This research attempts to study the effects of caffeine dose and time across the design space using Response Surface Methodology (RSM) and aims to obtain a recommended optimal caffeine dose for the public. **Materials and Methods:** This research is designed using RSM to determine the optimal caffeine variable on cognitive function increments. Data points from other journals will be used as preliminary data to develop a model relating the caffeine variables and cognitive performance increment. **Results:** A set of 13 data points obtained from other research related to the study of caffeine dose, activation time and cognitive performance are collected and pre-processed. A model is developed using RSM by inputting the data points. A mean cognitive performance increment of 26.08% was predicted with 0.7mg/kg body mass of caffeine at 33.5 minutes post-consumption of caffeine, while the optimised caffeine variable for 25.46% cognitive performance increment was 0.727mg/kg body mass at 32.2minutes. **Conclusion:** A model relating caffeine variables and cognitive performance increment is obtained using RSM and the model is used to predict cognitive performance increment and develop an optimised caffeine variable.
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Keywords: Caffeine, Cognition, Central nervous system agents, Humans, Preliminary data

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INTRODUCTION

Caffeine (1, 3, 7-trimethylxantine) is one of the most often used psychoactive substances in the world, commonly found in coffee, tea or energy drinks [1, 2]. Its widely known usage is to combat drowsiness and fatigue [3, 4] by stimulating the central nervous system and brain. Caffeine is metabolised in the liver, and the metabolites can affect the function of various organs, mainly the brain. It functions by blocking adenosine, a neurotransmitter that relaxes the brain and energizes the person [4, 5]. Although some studies suggest that caffeine offers numerous health benefits, some reported adverse reactions to the consumption of caffeine, such as heart palpitations, headaches, and sleeplessness [1, 3, 6, 7]. Research is mixed with conflicting findings on the effects of the beverage with the benefits and adverse effects of caffeine consumption. However, it also found that specific dosages of caffeine and appropriate consumption can have a beneficial influence on cognitive human performance [4, 8, 9]. Several studies have been conducted to determine the effect of caffeine variables on cognitive performance. Table I shows recent related studies investigating caffeine's effect on cognitive performance.

Table I: Recent studies related to caffeine effects on cognitive performance

References	Types and dosages of caffeine	Cognitive Assessment	Physiological signals / Measurements	Subjects	Remarks
[10]	40mg of tea and 75mg of coffee	-Trail-making tests -Digit symbol coding -Paired associates learning test	Behavioural result	415 530 healthy subjects (≥ 65 years old)	There is no evidence for the causal long-term effects of habitual coffee consumption on global cognition or memory.
[11]	80 mg of Red Bull	Memory assessment	Behavioural result	24 healthy adults (18- 40 years old)	Improved working memory reaction time.
[12]	130 mg Ai Reload (Air)	-Erikson Flanker Test (attention) -Go/No-Go test (reaction time) -n-back test (working memory) -Hand grip strength and finger tap speed	Behavioural result	9 healthy (19-23 years old)	-No effect on attention and memory. -Increased processing speed.
[13]	-Traditional hot beverages (herbal tea and Columbian coffee) -Cognition-enhancing hot beverages (two types of tea and one type of coffee)	Task battery: mental arithmetic task -Rapid visual processing: attention task -Stroop task: conflict resolution task	Electrodermal and brain activities	120 healthy subjects (18-38 years old)	Enhanced hot beverages showed improved neural efficiency over that of traditional beverages.
[14]	Caffeine capsule (200 mg)	Keep Track Task (working memory)	Behavioural result	88 healthy adults (18- 35 years old)	Decrease in sadness, no effect on other mood states. No effect on working memory.
[15]	Coffee, tea, soda, espresso, and energy drinks. Daily average caffeine intake of 13.00 + 43.73 mg	Vocabulary comprehension, reading decoding, inhibitory control, working memory, cognitive flexibility, processing speed, and episodic memory	Behavioural result	11 875 healthy adolescents (9-10 years old)	Negative effect on working memory, episodic memory, and processing speed.
[16]	2.5 mg per kg body mass for each subject, then mixed with a decaffeinated beverage	Psychomotor vigilance test, executive GoNoGo inhibition task, and 2-NBack working memory task	Brain activity	24 healthy subjects (mean age: 33.7 years)	The caffeine dose slows down the triggering of sustained attention deficits related to the time-on-task effect.
[17]	50 mg caffeinated drink	Visuomotor processing speed, working memory, and attention	Brain activity	25 healthy men (mean age: 21 years old)	-Diminishment in resting alpha brain wave activity. -Improvement of cognitive function on working memory.
[18]	3mg/kg body mass caffeine	Digit cancellation task (attention task), reaction task	Brain activity	13 recreational runners	Attention improved by 15.6% and reaction time by 5.9%
[19]	3, 6 and 9 mg/kg body mass of caffeine	Simple reaction time (SRT), choice reaction time (CRT), attentional task (AT), mental rotation test (MRT)	Brain activity	14 female athletes	3 and 6 mg/kg improve SRT, CRT and AT significantly. 3mg/kg greatest enhancement, 9 mg/kg most side effects

The problem with the current research is that the majority selected caffeine variables from one to three distinct dosages and examined only a single variable at a time in relation to the experimental response. as indicated in Table I [10, 11, 13]. The rationale may be to minimize experimental costs by compromising on the duration of the experiment. A further issue is employing a trial-and-error approach to determine the optimal caffeine intake and response time. This method, while straightforward, fails to comprehensively examine the influence of additional variables, rendering the optimal caffeine dosage indeterminate. Another issue is that the indicator used for evaluating caffeine intake mainly depends on behavioural datasets that determine the scores and ability of subjects to respond and answer the assessment [20, 21]. The consequence of assessing based on behavioural indicators is that it neglects the understanding of body condition during caffeine intake. This is dangerous as cognitive function may be enhanced, although it can induce undesirable effects such as palpitations, dehydration, headaches, tremors, and insomnia [1, 6, 7, 19]. Therefore, the inclusion of body responses through physiological signal measurement during evaluation is a must to indicate the best caffeine variables that do not harm health [22].

The current research aims to discover the effects of caffeine variables on cognitive performance by executing the design of experiments with the Response Surface Methodology (RSM) tool, which will be further implemented in laboratory experiments that include body responses as measurement. RSM was conceived in 1951 by Box and Wilson, primarily aimed at utilizing a sequence of prepared tests to attain an optimal response [23]. It is a powerful tool for optimizing output or responses when multiple quantitative factors are present by fitting a polynomial equation to the experimental data. The RSM tool is typically employed in industrial research, chemical engineering, and agricultural sciences. However, minimal attempts have been made in the biomedical engineering field. This preliminary work will recommend an optimal caffeine dosage to be consumed with peak caffeine activation time without adverse effects on the body's condition through RSM analysis. The findings from this work will be used as a benchmark in selecting the caffeine variables for designing laboratory experiments that involve physiological indications through our published articles.

MATERIALS AND METHODS

Simulation Work

In this preliminary work, no caffeine was directly administered to participants. Instead, the study relied on secondary data extracted from 11 published, peer-reviewed journal articles indexed in Scopus (2021 – 2024) that investigated caffeine intake and cognitive performance. These articles employed various caffeine sources from coffee, tea energy drinks to pure caffeine capsules [10, 11, 14 – 16]. This preliminary work collects and analyses data on caffeine performance from previous research. The interest in finding the optimal caffeine variable to increase human cognitive performance with the lowest adverse physiological response post-caffeine consumption kickstarted this preliminary research. The target is obtaining optimal caffeine dosages and activation time after consumption.

Data from indexed journal papers in Scopus are accessed, filtered, and studied individually to narrow down relevant topics. The meaningful information from these journals was tabulated according to caffeine dosage, the time at which subjects were tested, and cognitive performance results. The extracted information was purposely used to design the variables for caffeine using RSM.

Using three keywords: “caffeine”, “cognitive” and “performance”, in the search parameter of Scopus index search engine, a total of 244 journals from 2021 until 2024 were found, and each was studied to extract relevant data. However, only 21 journals were selected and further screened to determine their suitability for research purposes. Ten journals were excluded due to the absence of performance data relative to baseline or placebo, and they did not specify the timing of the test on the subject. Only 11 journals were appropriate for data extraction in the final screening process. A total of 13 data points were obtained, as two journals employed two distinct dosages in the experiment, resulting in two data points per article. After the dataset is acquired, it is processed and input into Design Expert software to be analysed statistically using the Response Surface Methodology (RSM). Fig. 1 shows the overall process included in this preliminary work.

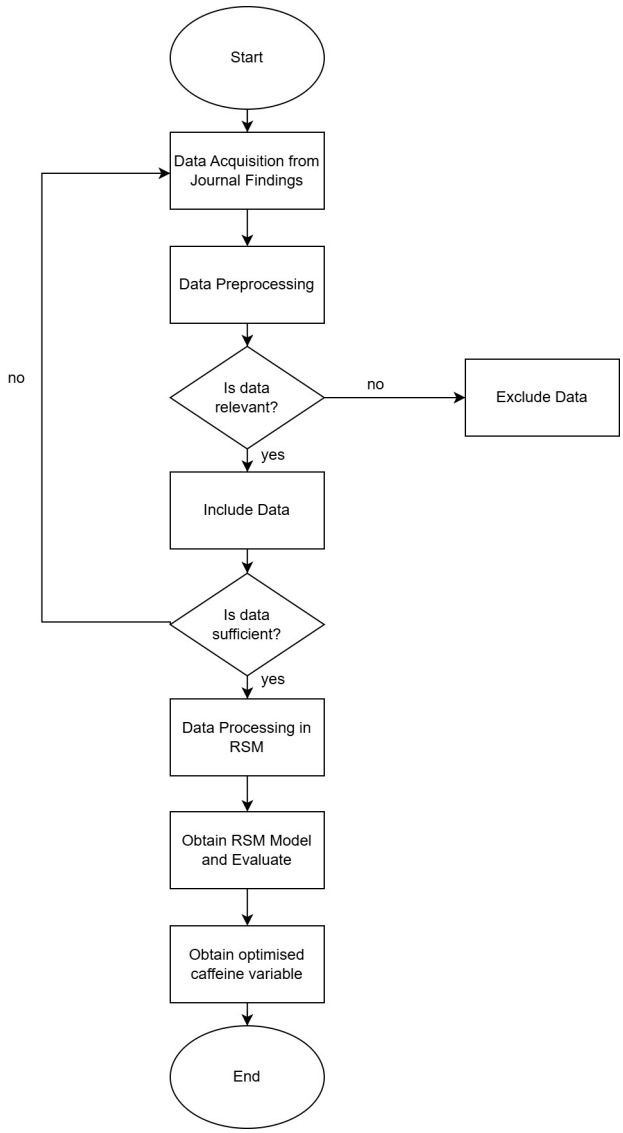

Fig 1: Flow chart of obtaining current experiment preliminary result. This preliminary work only studied previous research data that utilises caffeine variables (dose and time) as well as the outcome of caffeine consumption on cognitive performance increment. Therefore, this flow chart shows the filtering process of obtaining data points from previous work to include or omit into the RSM Model.

Selection of Caffeine Variable and Cognitive Performance Result

Research related to caffeine consumption and cognitive performance improvement that was used as a data set in this work is depicted in Table II. The caffeine variables studied in this research are caffeine dosages and activation time after consumption. The dosage is standardised into milligrams per kilogram of body mass (mg/kg body mass). Next, the subject's caffeine activation time was tested on cognitive performance

Table II: RSM input factors and response refitted with the modified value

Std (Source)	Run	Space Type	Factor 1: Caffeine Dose per kg body mass (mg/kg)	Factor 2: Activation time (minute)	Response 1: Cognitive Performance increment (%)
[24]	1	Interior	3	60	11.19
[17]	2	Unknown	0.7	30	25
[25]	3	Interior	1.29	60	4.74
[26]	4	Interior	1.2	60	2.85
[19]	5	Interior	3	60	5.47
[19]	6	Interior	6	60	4.63
[27]	7	Interior	5	30	3.35
[28]	8	Interior	6	60	13.33
[18]	9	Unknown	1.05	8	1.97
[29]	10	Interior	3	60	6.65
[29]	11	Interior	6	60	10.66
[30]	12	Interior	3.45	60	4.65
[31]	13	Interior	3	60	12.6

after caffeine consumption in minutes (minute).

The journal article uses different dosing systems where some journals use fixed caffeine dosages ranging from 50mg to 200mg, and a variable dosage of 3mg/kg to 9mg/kg of body mass. To establish a standardized caffeine dosage for RSM, the fixed caffeine dose is divided by the candidate's mean body mass, resulting in a dosage of mg/kg body mass, which ranges from 0.7 to 6.0 mg/kg body mass. Simultaneously, each author employs varying durations for administering cognitive performance tests, with the interval post-caffeine consumption spanning from 8 to 60 minutes. The test time is cross-related to the caffeine's activation time in the body.

Cognitive performance increments measured by other research are task performance accuracy and reaction time of a subject post-consumption of caffeine. For inclusion in this preliminary data, the results of cognitive performance increments by the subjects must be measurable against baseline (before consumption) or placebo. The increment in scores and time taken to complete tasks are calculated into percentage scores (%) as the input for the RSM using the Eq. 1 below. Depending on the number of tasks in each experiment, these values were then averaged to obtain the mean

$$\text{Cognitive improvement} \quad t = \frac{X-Y}{Y} \times 100\% \qquad (11)$$

change in cognitive performance.

Equation 1: Changes of scores and time taken to complete tasks. This equation is used to calculate the percentage change in performance outcomes after caffeine consumption. For score-based measures, the

formula is applied directly, where higher scores reflect improvement. For time-based measures, a reduction in completion time indicates improved performance; therefore, the change is expressed as the absolute value of the percentage difference, so that decreases in time are consistently represented as positive improvements.

Where,
X = After caffeine score (or replaced with – time taken to complete tasks after caffeine)
Y = baseline score (or replaced with – time taken to complete tasks baseline)
The minimum average increase in cognitive performance was 1.97%, while the maximum average increase was 25%. Only data exhibiting statistical significance in the article was chosen as a data point. Table II shows the caffeine dose, time of test, and average cognitive performance increase, which are computed and prepared to be used as input variables for the RSM.

RSM Using Design Expert and Optimisation for Designing Caffeine Variables based Model

The software used to apply RSM was Design Expert 12.0 by StatEase. Under standard procedures for developing an RSM plot, the design of the experiment must be prepared first before collecting data. However, obtaining datasets from previous research that fit the requirement of the design of the experiment during the preliminary test is time-consuming and not practical. Hence, after the range of the independent variables of the RSM using the Central Composite Design model (CCD) is designed, the original recommended independent variable values and response values are overwritten and replaced with datasets obtained from previous research to be added to the RSM, as shown in Table II. Hence, the independent variables are modified where the minimum and maximum ranges of the caffeine dosages are 0.7mg/kg body mass and 6.0 mg/kg body mass, respectively. Next, the minimum and maximum time to test the subject is 8 minutes and 60 minutes, and finally, the minimum average cognitive performance increment was 1.97%, whereas the maximum was 25.00%.

After inputting the input variables, the modelling and fitting process is carried out by following the software's guide, until a final surface plot is obtained. The generation of the final surface plot along with the modelled equation relating between the caffeine variables and cognitive performance can be optimised using the optimisation function in the software.

Optimisation of the Caffeine Variables

Using the established model of the caffeine variables and cognitive performance increment, the most optimal outcome between caffeine variables and cognitive performance increment can be obtained by setting the optimisation criteria. For the dosage and activation time, the criteria were set into "within the range," with the caffeine dosage ranging between 0.7 to 3 mg/kg body mass. In contrast, the activation time was set between 8 to 60 minutes. Most of the previous research shows significant evidence of adverse effects on the body when there are high dosages and less to no adverse effects on the body when there are low dosages. For the activation time in this simulation, the most significant cognitive performance increment was observed at the 30-minute mark. Hence, the range includes all the data that falls within this time range. The cognitive increment criteria are set as "maximum" as the interest in finding the caffeine variables that provide the highest cognitive performance increment. Any of the weightage and importance of each variable were not modified, as all 3 variables and responses are equally important. Table III below shows the criteria for setting the caffeine variables and cognitive performance increment responses.

Table III: Criteria setting for each variable and response to optimise desired caffeine variable

Variables and Responses	Criteria Settings	Range
Caffeine Dosage (mg/kg body mass)	In Range	0.7 – 3 mg/kg body mass
Activation Time (minutes)	In Range	8 – 60 minutes
Cognitive Performance Increment (%)	Maximum	1.97 – 25 %

Assumptions and Controls for Secondary Data

This RSM analysis uses study-level effects from published trials. Individual tolerance differences are assumed to be attenuated within each study's randomised or crossover framework. To improve comparability, fixed doses were converted to $mg \cdot kg^{-0}$ using the mean body mass reported in each experiment, and post-dose assessments were constrained to within 60 minutes to target a consistent absorption window. Only statistically significant contrasts versus baseline or placebo were included. A square-root transformation and quadratic fit were applied to accommodate non-linearities and mitigate skew. Residual moderators such as habitual intake and genotype were not consistently reported and therefore could not be controlled at this stage.

Ethical Clearance

This study was approved by UTM Research Ethics Committee, Department of Deputy Vice-Chancellor (Research & Innovation), Universiti Teknologi Malaysia (UTMREC-2025-113).

RESULTS

The dataset derived from article extraction was modelled into an equation that describes the correlation between caffeine dosage, activation time, and enhancement in cognitive function. A 3D response surface plot was generated to facilitate the visualization of cognitive performance enhancement at varying coffee intake levels and reaction times of interest. The software's point prediction tool enables the user to estimate a predicted mean increase in cognitive performance by modifying

the input variables. The software's optimization tool enables the user to identify the best caffeine variable that maximizes cognitive performance by setting certain outcome criteria.

Data Transformation and Model Fit Summary

For this dataset input into the RSM model, the software recommended the use of square root transformation on the model's response data as the response data range is between 1.97 (minimum) to 25 (maximum) with a ratio of 12.6904 (maximum/minimum), in which a ratio of more than 10 requires transformation on the data.

After transforming the data, it is fit into the Quadratic Model as it has the lowest Sequential p-value of 0.0122, compared to the Cubic, Linear and 2FI models which have a Sequential p-value of 0.2015, 0.9301 and 0.3156 respectively. In contrast, the Lack of Fit p-values of the Linear, 2FI, Quadratic and Cubic models are 0.0666, 0.0607, 0.4738, and 0.8925 respectively. Finally, the Adjusted R^2 for the models following the sequence prior are -0.1827, -0.1676, 0.5733 and 0.6292. Specifically, the R2 for the Quadratic model is 0.7511.

After the quadratic model is selected, ANOVA of the model terms and lack of fit tests are carried out by the software and tabulated in Table IV below. The F-value and p-value will determine the significance of model terms and the Lack of Fit tests for the model. Table IV shows the significance of the terms A, B, AB and B^2 with high F-values of 11.86, 13.92, 13.21 and 17.32, respectively, along with low p-values of 0.0108, 0.0074, 0.0084 and 0.0042. These 4 terms show significance in generating the quadratic surface models. Next, the low F-value of 0.8706 with a high p-value of 0.4738 in the Lack of Fit test shows that the data in this model is fitted. Using the fitted data, the software will then output a modelled coefficient for each variable according to the selected model design. The derived coefficient can be written as an equation shown in Eq. 2. The significance of the terms A, B, AB and B^2 gives a higher weightage on the coefficient whereas the term A^2 is omitted due to the high p-value of 0.3725, deeming it is not significant for this modelled equation. Next, the equation is then modelled in 3D space to generate a surface plot. The equation is also used as the point prediction function and optimisation function, which will be discussed late r.

ANOVA of RSM Model Outcome

Table IV: ANOVA of the model terms and lack of fit test calculated by the software

Source	Sum of Squares	df*	Mean Square	F-value	p-value	Significance	R^2	Adjusted R^2
Model	9.11	5	1.82	4.22	0.0433	significant	0.7511	0.5733
A – Caffeine Dose per kg body mass	5.11	1	5.11	11.86	0.0108			
B – Reaction time	6.00	1	6.00	13.92	0.0074			
AB	5.70	1	5.70	13.21	0.0084			
	0.3914	1	0.3914	0.9075	0.3725			
	7.47	1	7.47	17.32	0.0042			
Residual	3.02	7	0.4313					
Lack of Fit	0.7797	2	0.3899	0.8706	0.4738	not significant		
Pure Error	2.24	5	0.4478					
Correlation Total	12.13	12						

df: degree of freedom

Equation, Surface Plot and Point Prediction

TAn equation was derived from the model, with the coefficient as shown in Eq. 2 below.

$$\sqrt{y} = 4.7867A - 35.2456B + 12.3947AB - 34.3626B^2 - 5.32965 \quad (2)$$

Equation 2: Modelled equation for the surface plot; cognitive performance increment with respect to caffeine dose per kg body mass and caffeine activation time. The data point used in this RSM Modelling yielded an equation to relate the effects of caffeine dose per kg body mass, caffeine activation time and cognitive performance increment. Where,

y = Cognitive Performance Increment
A = Caffeine Dose per kg body mass
B = Caffeine Activation Time

Based on the equation, a 3D surface plot can be obtained and visualised to observe the relationship between caffeine dosage and caffeine activation time. The surface plot is shown in Fig. 2. The software's point prediction function allows for the forecasting of cognitive performance enhancement by modifying the input variable. The mean cognitive performance increment of 26.08% was predicted with 0.7mg/kg body mass of caffeine at 33.5 minutes post-consumption of caffeine.

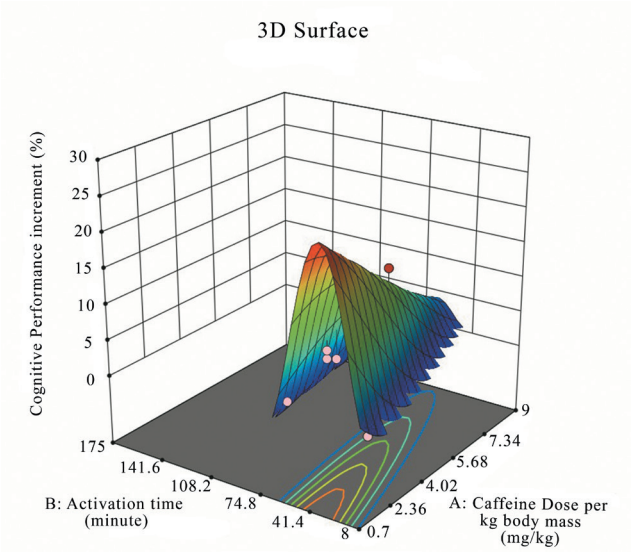

Fig 2: 3D surface plot for the current model relating between cognitive performance increment with reaction time (minute) and caffeine dose (mg/kg). After the quadratic model of the caffeine variables and cognitive performance increment is obtained, the 3D surface could be visualised to better understand the relationship between the caffeine variables and cognitive performance increment. It is observed that the increment of cognitive performance is the highest at the lowest dose of caffeine (as of the current dataset) and around the 30th-minute mark. However, the peak was not shown as there is no slope downward below 0.7mg/kg body mass of caffeine dose, suggesting that the higher cognitive performance increment could be achieved at even lower doses.

Optimal Caffeine Variables

This simulation successfully determined the optimized caffeine variable value according to the specified output criteria utilizing the software function. The software presented six solutions, each with a desirability of 1. The optimal caffeine variable identified in this simulation is number 1, which provides a caffeine dosage of 0.727 mg/kg of body mass and an activation time of 32.2 minutes post-consumption. This solution yields a cognitive performance increase of 25.46%, with an outcome desirability rating of 1. This outcome will serve as the reference value for further experiments. The optimal solution is illustrated in Fig. 3, showing the relationship between caffeine variables and the enhancement of cognitive function within the specified range.

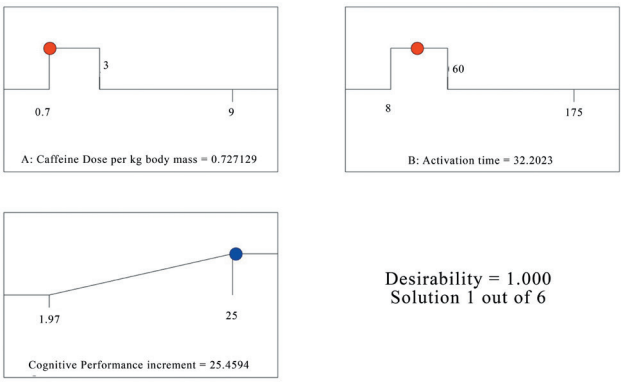

Fig 3: Selected optimised cognitive performance increment and caffeine dose per kg body mass and activation time with desirability of 1 (Solution 1st out of 6). Using the optimisation function, there are 6 solutions recommended by the software. The optimised caffeine dose and activation time that could yield the best cognitive performance increment based on the model's equation was selected as it shows the highest cognitive performance increment among other solutions.

At a caffeine dose of 0.7 mg·kg^{-0} body mass administered 30 minutes post-consumption, the RSM model predicted a mean cognitive performance increment of 25.43%. Compared with the corresponding experimental value, this yielded a percentage error of 1.72%. At a higher dose of 3 mg·kg^{-0} body mass and 60 minutes post-consumption, the model predicted a cognitive performance increment of 8.06%. When evaluated against experimental values of 5.47%, 6.65%, 11.19%, and 12.60%, the percentage errors ranged from 21.2% to 47.4%, reflecting moderate predictive deviation under this condition. Overall, the relatively close agreement between predicted and observed outcomes indicates that the RSM model achieves acceptable predictive accuracy and can be considered a suitable preliminary tool for estimating optimal caffeine dose–time variables. The percentage of error are calculated using Eq. 3 as below.

$$\% \text{ Error} = \frac{|\text{Predicted Value} - \text{Experimental Value}|}{\text{Experimental Value}} \times 100\% \quad (3)$$

Equation 3: Percentage error calculation for predicted value versus experimental value. A percentage of error calculation to compare between predicted value and experimental value that were extracted from previous articles.

Where,
Predicted Value = RSM Model Output (could be replaced with optimal RSM value)
Experimental Value = data point from published study

DISCUSSION

Choosing the Quadratic Model

After the data is transformed, the software recommends Quadratic Model fitting. The Sequential p-value of the Quadratic Model recorded was the lowest among other options, which are Linear, 2FI and Cubic. The Sequential Model Sum of Squares quantifies the variability in the regression sum of squares. Hence the model is recommended to choose a high-order polynomial where additional terms are significant while not sacrificing the model to be aliased.

The Lack of Fit test of the Quadratic Model was the second highest, compared to the Cubic Model. The Linear and 2FI models showcased the Lack of Fit is highly significant compared to the Cubic and Quadratic models, as the latter two models have low p-values for the Lack of Fit test showing that there is no significant lack of fit models. Although the Cubic Model has a higher p-value compared to the Quadratic Model, the aliased model causes the Quadratic is a better option compared to the Cubic Model.

Finally, the adjusted R^2 and predicted R^2 for Linear and 2FI models are in the negative region, whereas the Quadratic and Cubic models are in the positive region, hence, Linear and 2FI models are ignored. The objective of adjusted R^2 and predicted R^2 is to be maximised as new predictors added to the models should increase the predictive power of the model. However, the predicted R^2 data is not available for both the Quadratic model and the Cubic model, hence, the comparison is only made on adjusted R^2.

ANOVA of the Quadratic Model

The software will then generate a model with terms up to a power of 2, hence the Quadratic nature of the model. The model is then evaluated based on the Model Terms and Residual Terms. The F-value of 4.22 implies that the model is significant with a 4.33% chance that an F-value this large could occur due to noise. Based on Table III, the significance of the coefficient terms A, B, AB and B^2 contributed to the regression of the model due to the high F-values and low p-values, except for the A^2 term, which is not significant due to the high p-value and low F-value. Also, for the Residual Term, the Lack of Fit is not significant due to the high p-value of 0.4738.

Point Prediction and Optimisation

The Quadratic model generated an equation in Eq. 2 relating to the effect of caffeine dose and activation time with the percentage increment of cognitive performance. Hence, from this model, a percentage of cognitive performance increment can be predicted by inputting the variables of caffeine dosage and activation time. At the same time, by setting the desired cognitive performance increment, the equation can solve the optimised caffeine variables to be consumed to achieve the said cognitive performance. This model sets the stage for the optimisation of caffeine variables when more responses are added to this model with physiological indicators such as heart rate, EEG, EDA, etc. This allows the researchers to select caffeine variables that would minimise the physiological indicators that show adverse effects such as increased heart rate for heart palpitations, with increased cognitive performance by assessing cognitive test scores for the subjects.

Limitation and Potential Applications

In this preliminary finding, although the optimal caffeine dosage and activation time for the highest caffeine performance increment were determined, the adverse effects of caffeine intake that may deteriorate cognitive performance or participants' health after caffeine consumption were not adequately explored. Also, the data extracted are based on other research findings and are not tailored to the needs of current research. More data points and data types are required to understand better the effects of caffeine consumption on cognitive performance and body physiological responses.

Another limitation arises from the heterogeneous nature of the data sources used. For example, some included studies had small samples ($n < 14$) [12, 18, 19], while others tested larger cohorts ($n \geq 30$) [13, 14], and study designs ranged from tightly controlled randomised trials to less rigorous observational work. Similarly, while some experiments focused solely on behavioural indicators of cognition, others incorporated physiological measures such as EEG or electrodermal signals [12–16]. This variability in study design, populations, and measurement tools may introduce bias, reduce the accuracy of the model, and limit the generalisability of the findings.

Future laboratory experiments will explicitly control for residual moderators (e.g., habitual caffeine intake, genotype) through abstinence/washout protocols, time-of-day control, and within-subject crossover designs.

Nonetheless, future research that studies the effects of other drugs can use this method to determine the correct dosage and time for the drug to take effect on the human body. The optimised drug dose and time variable can be helpful when prescribing to the patient, keeping the effect strong while maintaining minimal impact on the body's physiological responses.

CONCLUSION

A preliminary experiment for discovering the effects of caffeine dosage and activation time after caffeine consumption on cognitive function was designed using RSM. There are several stages involved in obtaining the optimal caffeine variables in this simulation work, which are collection and transformation of data, fitting of data, selection of model, ANOVA of the model terms, and conclusion of the model. After the model concluded, a point with a mean cognitive performance increment of 26.08% was predicted at 0.7mg/kg body mass of caffeine at 33.5 minutes post-consumption of caffeine. In this simulation, the optimal caffeine variable was 25.46% cognitive performance increment with 0.727 mg/kg body mass, 32.2 minutes post consumption and desirability of 1. Due to the limitations of the dataset, the current dataset was analysed using RSM to obtain a preliminary result. Further work will be undertaken using other methods of analysis, and new set of data collection

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