

# The Effect of Ramadan Intermittent Fasting on Cognitive Work Performance: A Natural Experimental Approach

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**Abstract:** This study aims to investigate the effect of Ramadan intermittent fasting on cognitive work performance using a more natural approach. To achieve the objective of this study, a natural experimental approach was employed by incorporating a pretest-posttest control group design. A forward-type Digit Span Test (DST) was utilized as the measure of cognitive work performance and was administered to participants twice, before and during Ramadan, with a one-month gap between the tests. Two hundred and sixty-seven participants were naturally grouped into fasting and non-fasting groups according to their report during the Ramadan session and into morning and afternoon periods, or AM and PM hours, according to their module scheduling. The results of the analyses suggest that the cognitive work performance of the fasting participants during the PM hours is better, after controlling the DST scores before Ramadan. The study also concludes that the cognitive work performance of the fasting participants between AM and PM hours does not differ. This result could be explained using the perspectives of post-lunch performance dip and the beneficial effect of breakfast. Methodological limitations and the potential practical implementation of this study are also discussed.

**Keywords:** Intermittent fasting, natural experiment, cognitive performance, Ramadan

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## Introduction

In countries of Muslim majority, such as Indonesia, Ramadan is widely observed by mainly completing an intermittent fasting during daytime hours for a lunar month (29 or 30 days). This religious-driven fasting is completed between dawn and dusk, during which they are not allowed to eat, drink, or have sexual intercourse. Fasting hours vary according to geographical location. Since Indonesia is situated around the equatorial line, Muslims in this country fast for thirteen hours per day on average, while those who are living in the Northern or Southern Hemisphere may fast for longer or shorter hours. The way people spend their day during this month generally remains unchanged. For example, students are obliged to attend classes, and employees/operators are expected to maintain their routine performance. However, slight adjustments are institutionalized, such as shorter work or school hours.

Previous studies have reported the effect of intermittent fasting on cognitive work performance. The main premise of these investigations is that the brain requires a certain level of glucose as energy to function normally [1], which is mainly supplied by calorie intake from foods or drinks [2], but during intermittent fasting the supply of calories is limited. Moreover, in contrast to the non-religious intermittent fasting which allows consumption of liquids [3], [4], Ramadan fasting observers are completely not allowed to consume any liquid. This period of total calorie deficit is therefore believed to affect the brain and, thus, cognitive functioning. It may also lead to mental fatigue as indicated by reduced attention and awareness [5].

Despite the numerous studies on intermittent fasting, the results remain conflicting. There are three general findings about the effect of intermittent fasting on cognitive work performance: (1) positive, (2) negative, and (3) no effect. Several studies reported the negative effects of intermittent fasting on cognitive work performance. For example, in the context of professional football players, a study by [6] reveals that cognitive performance was affected by intermittent fasting particularly during afternoon and evening. Another study finds that intermittent fasting negatively affect short term memory and decrease the level of verbal production [7]. In addition, the mechanism of reduced cognitive functioning during intermittent fasting period can be explained

by several reasons, such as preoccupied thoughts on food, body weight and shape [8], dehydration [9], and alterations of sleep patterns [10].

Contrary to the abovementioned results, several studies have provided evidence for the positive effect of intermittent fasting or caloric restriction. A study of [11] shows that caloric restriction improves memory function in healthy subjects through the increased insulin sensitivity and decreased inflammatory activity, that subsequently can increase synaptic plasticity in the brain. Another study concludes that physically active group showed a significant improvement in executive function, attention, inhibition, associative memory, and recognition memory throughout Ramadan [12], [13], [14]. The quest to conclude whether intermittent fasting may positively affect cognitive functioning was also studied by using animals. Intermittent fasting considerably improved cognitive function in mice, by suppressing neuroinflammation in the central nervous system [15]. Furthermore, intermittent fasting is considered beneficial in lowering vascular and neural diseases following chronic cerebral hypoperfusion that causes vascular cognitive impairment [16].

The last group of studies in the effect of intermittent fasting, however, provides the “no effect” evidence. For example, a review by [17] concludes that there is no convincing evidence of intermittent fasting having an advantageous short-term effect on cognition. This may be due to variations in fasting patterns, total caloric intake, and the intake of specific nutrients. Intermittent fasting is arguably affected by its type since it can enhance synaptic plasticity [17]. An argument was also made that the varying outcomes of intermittent fasting might be caused by differences in the linear decline in grey matter volumes in certain brain regions as the consequence of normal aging [18]. Despite extensive disagreements among the studies above, we hold arguments stating that intermittent fasting may decrease cognitive work performance. Fasting is related to caloric deficit, therefore biological or physiological explanation regarding the decline of brain functioning and thus cognitive work performance due to caloric deficit is more convincing. Furthermore, the effect of caloric deficit is predicted to be worse as the daytime hours pass since “the fuel” to maintain energy level has gradually decreased [6].

Regarding the methodology, studies on intermittent fasting, including Ramadan fasting, were usually conducted in a controlled environment such as laboratory, e.g. [12], [6], [15], [16]. However, this approach might limit the capture of the effect of Ramadan intermittent fasting in real-world situation, particularly in a setting where it is widely and naturally observed. The actual effect of Ramadan intermittent fasting on, for example, cognitive work performance during working hours or during completion of certain tasks is still less explored. The limitation regarding participants might be the challenge in conducting studies on intermittent fasting since they must be conditioned to fast or be in caloric deficit. Country such as Indonesia, however, due to the presence of considerable number of Muslims, provides a great opportunity to naturally observe the effect of intermittent fasting during Ramadan.

Naturally observing the effect of intermittent fasting during Ramadan requires an appropriate strategy to obtain valid results. The natural experimental approach arguably fits this purpose as the approach uses naturally occurring events or settings in investigating the influence of variables without requiring direct manipulation by the researchers [19]. This approach allows them to study certain phenomenon in more ecologically valid settings and to capture the complexity of real-life situations that may not be easily replicated in a laboratory setting [20]. Consequently, the findings from natural experiments are often directly relevant to real-world situations. This is particularly important when studying cognitive performance, as the goal is to understand how individuals perform in their everyday environments.

In addition to general methodology concern, the task in a cognitive work performance research should represent the utilization of cognitive work in real-world situations and possess a good level of internal validity in the sense that it must be capable of systematic manipulation and scoring. One of the standardized experiment paradigms to capture an individual’s cognitive work performance is the Digit Span Test (DST). This test is primarily developed for assessing working memory and attention [21]. Within cognitive functions, working memory and attention stand as the main ‘machines’ upon which many cognitive activities work. Both constitute a complex system that enables individuals to comprehend new inputs while also using previously stored information [22]. Numerous studies have demonstrated that the test is a valid and reliable tool for assessing cognitive abilities related to short-term memory and attention in various settings, including clinical, educational, and laboratory research [23], [24], [25], [26], [27]. It can therefore represent the cognitive work performance of participants.

This study aims to investigate the effect of Ramadan intermittent fasting on cognitive performance in a more natural way. The novelty of this study lies in the use of the natural experimental approach in providing evidence

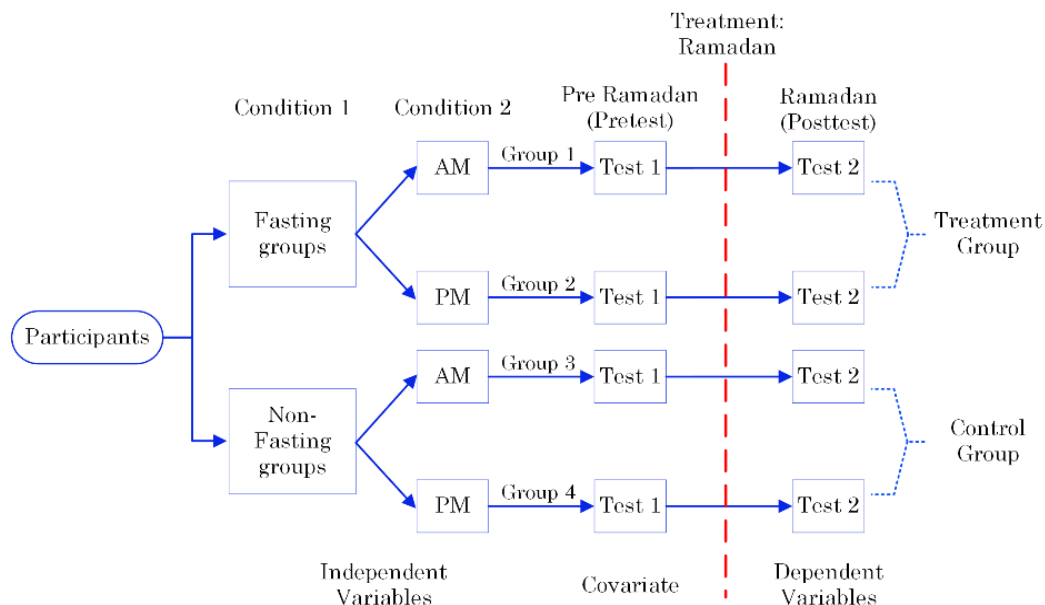
to explain the phenomenon. Furthermore, the results gained from this study may be exploited for assessing the consequences of fasting on operator's cognitive performance in real workplace situations.

## Methods

### Study Design and Hypotheses

This study applies the natural experimental approach, a type of quasi-experiment where the researcher does not manipulate the independent variable but observes the effects of the naturally occurring differences in the independent variable instead. The 'natural' element of this design is that Ramadan can naturally classify participants into fasting and non-fasting groups. Since most participants were identified as Muslims, it was expected that most participants will report 'fasting' during Ramadan. However, the reasons for 'not-fasting' reports may vary such as being non-Muslims, being female Muslim but having monthly period, or others. The participants were recruited from six different courses from the Psychology undergraduate program with various timetables and semesters, i.e., first-, second-, and third-year students. Therefore, the assignment of the participants to the treatment groups was natural due to the presence of Ramadan itself and the participants' course schedules.

A pretest-posttest control group design was also applied in this study. The independent variables are fasting conditions (fasting vs. non-fasting) and daytime hours (AM vs PM). The fasting condition was determined by the participants' self-report using a questionnaire completed in each experiment session. The daytime hours were determined by the participants' course schedule during the experiment session. The hours were divided into AM and PM, in which AM refers to the courses that were running between 7 to 12 AM, while PM refers to those between 12 AM to 5 PM. The dependent variable was cognitive work performance as measured by the Digit Span Test (DST) scores. The test targeted the working memory and the attention of the participants, so the focus of the cognitive work performance measure in this study is exclusively the memory and the attention aspects of it. It was administered twice i.e., three weeks before Ramadan and during the first week of Ramadan. This design was used to avoid the practice (carry-over) effect due to the participants' familiarity with some aspects of the experiment from the pre-test. One session before and during Ramadan with one-month separation between both sessions was considered sufficient to avoid such effect. Figure 1 represents the design of the experiment.



**Figure 1.** Design of experiment

Based on the theory and arguments presented earlier in this study and based on the design of this experiment, we set the following hypotheses to be tested.

1. There is a difference between the DST scores of the fasting and non-fasting groups during the AM and PM hours of Ramadan daytime after controlling the pre-Ramadan DST score (Hypothesis 1). The details are as follows.

- a. The DST scores of the participants in the fasting group during the PM hours of Ramadan is significantly lower (Hypothesis 1a).
- b. The DST scores of the participants in the fasting and non-fasting group during the AM hours of Ramadan are not significantly different (Hypothesis 1b).
2. There is a difference between the DST scores of fasting and non-fasting groups during AM and PM hours of Ramadan after controlling for pre-Ramadan DST score (Hypothesis 2). The details are as follows.
  - a. The DST scores of the participants in the fasting group during the AM hours of Ramadan is significantly higher than those during the PM hours (Hypothesis 2a).
  - b. The DST scores of the participants in the non-fasting group during the AM and PM hours of Ramadan are not significantly different (Hypothesis 2b).

## Participants

Two hundred and sixty-seven undergraduate students from six courses participated in this experiment. Convenience sampling was employed to determine the selected courses. Each possible course on the second semester during the 2022/2023 academic year was examined to check its eligibility (in terms of scheduling: AM and PM) and availability for this research purpose, including contacting the course convenors for permission. Table 1 shows the number of participants for each treatment and daytime hour. Due to the significant differences in the proportion between male and female students in Psychology undergraduate program, most participants of this experiment are female (see Table 2). The participation is voluntary, and the students fully participating in this experiment (completing all two sessions) will be rewarded with the eligibility to join a monetary prize-drawing available for four students. For practical and methodological reasons, the participants did not take any physical and psychological assessment prior to the experiment session. Based on the demographic questionnaire administered prior to the experiment session, there was no participant reporting serious or severe physical and/or mental health conditions. This research complies with the American Psychological Association Code of Ethics and was approved by K-PIN (Nusantara Consortium for Scientific Psychology).

**Table 1.** The proportion of participants for each treatment and daytime hour

Treatment/daytime	AM	PM	Total
Fasting	159	44	203
Non-fasting	50	14	64
Total	209	58	267

**Table 2.** The proportion of participants based on treatment and gender.

Treatment/gender	Male	Female	Total
Fasting	34	169	203
Non-Fasting	6	58	64
Total	40	227	267

## Experiment Task

As mentioned earlier, DST was utilized as a measure for cognitive work performance. DST works by presenting a participant with a sequence of two digits, and the participant needs to repeat the sequence. Each digit was presented at 800ms delay. At the end of each sequence, participants were asked to repeat the sequence by pressing the corresponding numbers on a keyboard. If the participant can correctly repeat the sequence, then a longer sequence is used. For example, if a participant can repeat the digits in a two-digit span correctly and consecutively, the trial continues with a three-digit span. The trial continues with longer spans, in this experiment up to nine-digit spans, until the participant consecutively fails to repeat the sequence, and the trial automatically ends. In this experiment, a basic type of DST, that is the forward-span variant, was used. In the forward-span variant, the participants attempt to recall the digits in the order they appeared by typing them via keypress or mouse at the end of each sequence. The DST score was automatically calculated by the program by counting the total number of sequences that the participants can repeat. A higher score indicates the ability of participants to sustain working memory span, thus, better cognitive work performance. The score was treated as the unit of analysis for this study.

The DST was programmed and administered in Psytoolkit [28], [29], a website offering running programmable online psychological experiments and surveys (<https://www.psytoolkit.org/c/3.4.2/survey?s=Vn4BM>).

## Procedure

This study comprises three sessions. The first session was conducted during the first week of the semester. This first session aims to introduce the students and set the technical requirements for the experiment, such as the use of laptop or tablet and the internet connection setting. The pre-Ramadan experiment session was conducted during the second week of the semester (three weeks before Ramadan in 2023). Meanwhile, the Ramadan experiment session was conducted during the seventh week of the semester (first week of Ramadan).

Each experiment session used the first 30 minutes of the course. Two research assistants started to run the experiment by instructing students who agree to participate to prepare their laptop/tablet and local internet connection. The assistants subsequently provided participants with a Psytoolkit URL to a survey page containing a participant information sheet, informed consent, and demographic questions. The participants were then asked to read the information sheet and signed/ticked the informed consent, followed by an instruction to complete the demographic questionnaire. The survey completion automatically opened a new tab on their browser for the experiment task. Upon participant completion of the survey, the assistants instructed the participants to start the experiment by pressing the space bar on their keyboard. The experiment task had included practice sessions to familiarize the participants with the task. Upon completion, the participants were asked to close the tab on their browser. This marked the end of the experiment session. The abovementioned procedure was implemented in all two experiment sessions (pre- and during Ramadan).

This study partially involved a deception to avoid demand characteristics that may affect the quality of the data. The deception was applied by not explicitly telling the participant about the aim of the study (i.e., to investigate the effect of Ramadan fasting on cognitive work performance). Instead, they were informed that this study investigates general cognitive work performance. At the end of the second experiment session, a debriefing session was conducted, revealing the true objective of this study, followed by an offer for data exclusion for participants who decide to withdraw their participations. To ensure the anonymity of the participants, data that allowed experimenters or researchers to identify participants, such as names or student ID number, were not collected. Instead, we asked them to create a combination of six unique numbers indicating their course code, the last four-digit of their student ID number, and a code for their sex (01 for male, 02 for female). Because this study involves repeated measures (within-subject design), this 'code' is essential for linking the data from two experiment sessions with the participants while keeping them unidentifiable.

## Data Analysis Approach

Analysis of Covariance (ANCOVA) was used to analyze the data as it provides a more powerful test of hypothesis for the pretest-posttest control group design than the repeated measure of Analysis of Variance (ANOVA) approach [30]. In this design, the DST score of the pre-Ramadan was treated as 'covariate', while DST score during the Ramadan was treated as the dependent/outcome variables. More specifically, a two-way ANCOVA was applied since there were two independent variables. Therefore, the difference between the two groups (fasting vs. non-fasting during Ramadan and AM vs. PM hour) was concluded after adjusting the DST score before Ramadan. The DST score of the Pre-Ramadan was treated as the baseline for analyzing the DST score changes during the exposure of the independent variables.

The ANCOVA model for analyzing the data is expressed in the equation of:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 X_3 \quad (1)$$

as  $Y$  is the dependent variable, i.e. DST score of participants during Ramadan,  $X_1$  is the covariate (DST score before Ramadan), while  $X_2$  and  $X_3$  are the independent variables, i.e. treatment and daytime hours, respectively. The statistical analysis were conducted using R Statistical Software [31].

## Results and Discussions

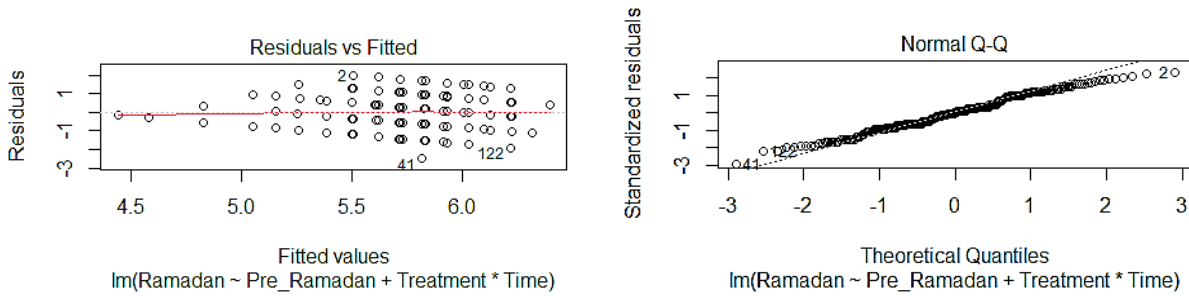
### DST Score Analysis

The assumptions underlying ANCOVA were checked. It was found that, in general, the data obtained from the DST scores did not violate the assumptions data linearity and homogeneity, variance homogeneity, and the

absence of outliers. However, the results of the Shapiro-Wilks test suggest data abnormality ( $p = 0.03$ ), which may be attributed to the large sample [32]. The Box Cox method was used to transform the data. It was performed by finding the optimum lambda value using a linear regression model and then transforming the data using the following formula.

$$y' = \frac{y^{\lambda}-1}{\lambda} \tag{2}$$

The data transformation resulted in normal residuals. As shown in Figure 2, the red trend line tend to be flat and approaching zero (left image), and most of the dots are located on a diagonal line (right image). The normality of residuals was, therefore, can be assumed.



**Figure 2.** The visualization of the data residuals

Following the data transformation, a two-way ANCOVA was applied to test the hypotheses. After adjusting the DST scores for pre-Ramadan data, a statistically significant interaction between fasting condition and daytime hours on the DST scores during Ramadan, i.e.,  $F(1, 262) = 4.625$   $p = 0.032$ , was found. The eta squared ( $\eta^2$ ) value is 0.02, indicating a small effect. This indicates that the effect of fasting conditions on the DST scores during Ramadan depends on the test time, either AM or PM hour. Table 2 below shows the results of the ANCOVA test.

**Table 2.** ANOVA table (type II tests)

Effect	DFn	DFd	F	p
Pre-Ramadan <sup>a</sup>	1	262	15.703	0.000*
Treatment	1	262	4.287	0.039*
Time	1	262	0.197	0.657
Treatment:Time <sup>b</sup>	1	262	4.625	0.032*

<sup>a</sup>Pre-Ramadan as covariate

<sup>b</sup>Treatment:Time indicates interaction between these variables

### Main Effect of Daytime Hour

A post-hoc test was conducted to specifically find the interaction by testing the simple main effect of daytime hour. A statistical significance was accepted at the Bonferroni-adjusted alpha level of 0.025, that is  $0.05/2$ . The effect of Ramadan intermittent fasting was statistically significant during the PM hours ( $p = 0.011$ ), but not during the AM hours ( $p = 0.410$ ). The pairwise comparison between the fasting and non-fasting group was statistically significant during the PM hours ( $p < 0.01$ ), in which the fasting group ( $M = 5.92$ ,  $SE = 0.132$ ) outperformed the non-fasting group ( $M = 5.15$ ,  $SE = 0.235$ ) in terms of cognitive work performance as measured by the DST scores. Meanwhile, during the AM hours, the participants in the fasting group ( $M = 5.82$ ,  $SE = 0.07$ ) slightly outperformed the non-fasting group ( $M = 5.71$ ,  $SE = 0.124$ ), but the difference was not statistically significant. Figure 3 below represents the results of the DST score differences based on the daytime hours, i.e., AM and PM.

The results of the test demonstrate that the PM hours determine the performance of the non-fasting group during Ramadan in the sense that it may contribute to the participants' lower DST scores. This suggests that the results oppose the hypothesis that the fasting group has significantly lower DST score, contradicting the results that the fasting group scores significantly higher than its counterpart. Hypothesis 1a, therefore, must be rejected. Meanwhile, the results of the experiment suggest that the DST scores of both groups during the AM hours are not significantly different. Hence, Hypothesis 1b is accepted.

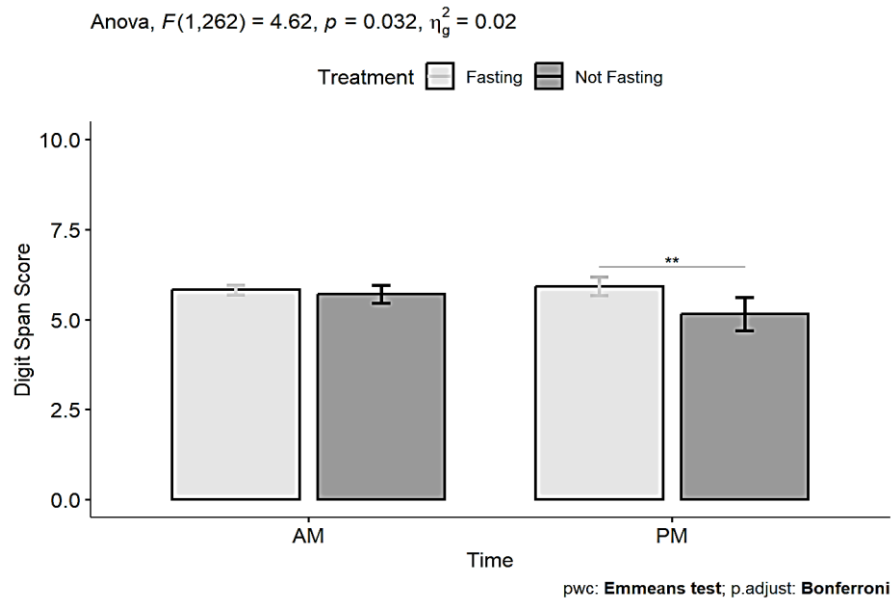


Figure 3. Differences in DST scores based on daytime hours

### Main Effect of Treatment

In this study the simple main effect of the treatment was also evaluated, which results suggest the non-significant effect in the fasting group ( $p = 0.507$ ). However, the effect of the treatment in the non-fasting group is significant at the  $p$  value of  $< 0.1$  ( $p = 0.062$ ). The pairwise comparison between the AM and PM hours is statistically significant for the non-fasting group ( $p = 0.037$ ), in which the scores of the non-fasting participants during the AM hours is higher ( $M = 5.71, SE = 0.124$ ) than those of the PM hours ( $M = 5.15, SE = 0.235$ ). Meanwhile, the scores of the fasting participants during the PM hours is slightly higher ( $M = 5.92, SE = 0.132$ ) than those of the AM hours ( $M = 5.82, SE = 0.07$ ) although the difference is not statistically significant. Figure 4 depicts the differences in the DST scores according to the treatments, i.e., fasting and non-fasting.

As seen in the figure, a significant difference in DST scores between the AM and PM hours were found in the non-fasting group. As the hypothesis predicts that the effect occurs in the fasting group, hypothesis 2a must be rejected. Furthermore, our findings suggest that the insignificant difference in DST scores between the AM and PM hours occurs in the fasting group. As the hypothesis states that the effect occurs in the non-fasting group, hypothesis 2b must be rejected as well.

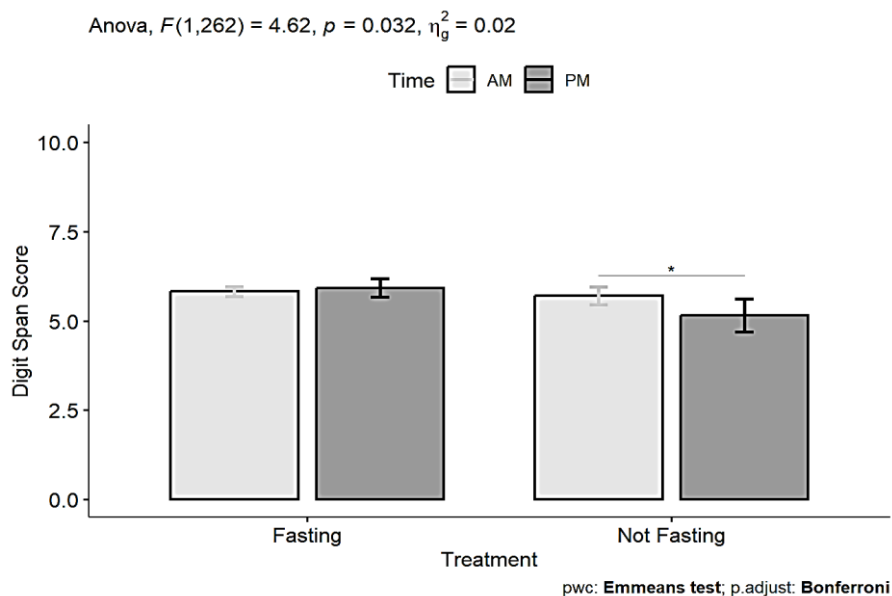


Figure 4. Differences in DST scores based on treatments

## Discussion

This experiment aims to demonstrate the effect of Ramadan intermittent fasting on cognitive work performance, as indicated by DST scores, using a natural experimental approach. More specifically, the participants performed DST in two separate sessions: before and during Ramadan. There are four hypotheses that have been tested in this experiment. Table 3 summarizes the hypotheses statements and the testing results.

**Table 3.** Hypotheses statements and testing results

No.	Hypothesis statement	Hypothesis testing results
Hypothesis 1a	The DST scores of the participants in the fasting group during the PM hours of Ramadan is significantly lower.	Rejected
Hypothesis 1b	The DST scores of the participants in the fasting and non-fasting groups during the AM hours of Ramadan are not significantly different.	Accepted
Hypothesis 2a	The DST scores of the participants in the fasting group during the AM hours of Ramadan is significantly higher than those of during the PM hours.	Rejected
Hypothesis 2b	The DST scores of the participants in the non-fasting group during the AM and PM hours of Ramadan are not significantly different.	Rejected

While the arguments stating that fasting would decline cognitive work performance are held in this experiment, the results of the analysis suggest otherwise since the evidence from this experiment cannot support that notion. Further, the findings demonstrate that fasting maintains cognitive work performance during the PM hours. As seen in Figure 3, fasting participants scored significantly higher than the non-fasting participants during the PM hours. Moreover, as the participants were grouped into treatment conditions, those in the fasting group scored relatively identical when performing DST in the AM and PM hours (see Figure 4). Contrarily, the non-fasting participants scored lower during the PM hours when compared to their fasting counterparts performing DST during the AM hours. In general, these results support previous studies stating that fasting can benefit memory functioning [11], such as executive function, attention, inhibition, associative memory, and recognition memory [12], [13], [14].

These results may be explained through several perspectives. A phenomenon known as the “post-lunch dip” may provide explanation on why non-fasting participants performed lower during the PM hours. Post-lunch dip, a naturally occurring lowest point in performance, takes place during midday, and this phenomenon could be worsened by lunch [33]. Previous studies suggested that several aspects of cognitive performance such as attention and quick-reaction decline following the consumption of meal [34]. A study by [35] also concluded that memory and attention performance indicators decrease after lunch consumption. Based on these studies, it can therefore be concluded that skipping lunch may help alleviate or prevent post-lunch dip, particularly in adults [33]. The results of this study may be in accordance with this notion. The group of participants who observed Ramadan intermittent fasting, and automatically skipped lunch, had been prevented from post-lunch dip. Contrariwise, the non-fasting group of participants seem to be affected by the post-lunch dip as they had most likely had lunch prior to the experiment session.

The results of this experiment, particularly the similar effect of AM hours to DST scores between the fasting and the non-fasting participants, can also be explained from the perspective of breakfast consumption. There are wealth of evidence leading the a conclusion that breakfast consumption benefits cognitive performance [36]. In the context of Ramadan, fasting observers are strongly suggested to consume meals before starting to fast at dawn (known as “*sahur*” or “*suhor*”). This type of meal can be generally considered as “breakfast” and potentially improves cognitive performance, particularly during the morning hour of fasting. In this study, approximately half of the participants reported that they consumed meals before fasting, or having *sahur*, whilst the other half reported that they have skipped it. However, this explanation must be taken carefully since this variable was not controlled in this experiment. Furthermore, there are a copious number of evidence contrasting the positive effect of breakfast, revealing that no benefit of breakfast consumption over breakfast omission [37], [38].

Due to the availability of the participants, considerable differences between male and female numbers were found, i.e., 227 females and 40 males. However, this imbalance in proportion does not affect the results of this study. In other words, the DST score differences resulting from this study can be attributable to the experimental conditions, i.e. treatments and daytime hours. In fact, it has been widely accepted that differences between male and female do not determine differences in cognitive work performance involving verbal working memory task [39]. Further, as the information was gathered from adults, there is generally no substantial



divergence between men and women in most cognitive traits. In cases where variations exist, they are typically minor. Moreover, regarding memory, the distinction between sexes is less clear, especially in adults. Some studies indicate a notable difference, while others do not find any significant variation. [40].

The results of this study should be considered in the light of some limitations. Here limitations that are most likely to have impacts on the interpretation of the findings and conclusions are presented. The most important one to consider, possibly, is that this study exercised a natural experimental approach. The participants of this study were naturally assigned to the experiment groups, i.e., fasting vs. non-fasting and AM vs. PM hours. Theoretically speaking, in a natural experiment, researchers have a minimum to zero control to extraneous variables, and this means that the results are much more likely to be affected by them [41]. More specifically, in the context of this study, cognitive work performance during fasting is a complex phenomenon that is more likely to be related to many factors, such as sleep quality and quantity, metabolic mechanism, specific nutrients, and existing caloric intake [17]. Due to both practical and methodological limitations, these variables were not controlled. Nevertheless, a natural experimental approach has an advantage in terms of higher ecological validity compared to lab-based experiment, that is able to control everything. It can be said that, by utilizing natural experimental approach, researchers can capture the effect of a treatment in real-world situations, particularly those that are difficult or impossible to manipulate [19]. The result from a natural experiment, therefore, can be more relevant to the true condition in the field.

The genuine idea of this study is to investigate the effect of Ramadan fasting to cognitive work performance in a more realistic situation. This was motivated by, one of which, the availability of conditions that allow the observation of fasting and its effect in a more natural way, such as the natural presence of Ramadan and participants who observed fasting (and those who did not). Despite some beforementioned methodological limitations, this study provides valuable lessons from the perspective of human factors or ergonomics. The results from this study may support the notion that Ramadan intermittent fasting does not affect any type of works or services that involve cognitive performance, particularly short-term memory. This also provides a scientific as well as practical basis for maintaining policies or regulations that promotes productivity during Ramadan. In other words, Ramadan is not different compared to other months in terms of the way a work should be performed, since the real-world evidence suggests that there is no decline in cognitive work performance both in the morning and in the afternoon hours of Ramadan, compared to performance before Ramadan. In Indonesian context, cultural and regulatory supports, such as slightly reduced work hour or the presence of fasting co-workers, could retain the effect as well.

## Conclusions

Utilizing a natural experimental approach, this study concludes that the DST scores of the fasting participants are higher than the non-fasting ones during the PM hours or the afternoon of Ramadan, after controlling the DST scores before Ramadan. Moreover, the DST scores of the non-fasting participants are higher during the AM hours than those during the PM hours. This study also finds that there is no difference in DST scores between fasting and non-fasting participants during the AM hours of Ramadan. For fasting participants, our study finds that there is no difference in their DST scores between the AM and PM hours of Ramadan. The results could be explained by the ability of fasting in alleviating post-lunch performance dip and the potentially beneficial effect of breakfast, including *sahur*, even though this notion must be taken carefully. In general, our results supports previous studies arguing that fasting can benefit memory functioning [11], such as executive function, attention, inhibition, associative memory, and recognition memory [12], [13], [14]. Despite using a single measure, the results from DST scores as demonstrated in this study may predict the cognitive work performance of the participants. Furthermore, taking methodological limitations into account, the results from this experiment may also be exploited as a scientific and practical basis to improve policies or regulations regarding work productivity during Ramadan.

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