INFLUENCE OF RAMADAN ON NEUROPERFORMANCE IN HEALTHY WORKERS

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ABSTRACT

Background - During Ramadan, Muslims refrain from eating and drinking from dawn until sunset. In 2012, Ramadan took place during summer, with fasting periods up to 19 hours. Previous studies have reported delays in sleeping and waking time and consequently decreased daytime alertness. Nevertheless, data on the effects of Ramadan on neuroperformance are scarce.

Aims - We investigated the impact of Ramadan on tiredness and neuroperformance in Belgian Muslims.

Methods - 20 Subjects were tested outside of Ramadan, halfway through Ramadan and in the last week of Ramadan. Tiredness was assessed with the Fatigue Assessment Scale (FAS) and alertness with the Stanford Sleepiness Scale (SSS).
Neuroperformance was tested with the simple reaction time for reaction time (REA-t) and concentration (REA-sd), symbol digit substitution for visual perception (SDS), digit span backwards for short term memory (DSB) and hand-eye coordination test (EYE).

Results – Ramadan had no effect on FAS. SSS increased during Ramadan, but remained within normal physiological boundaries. There was no significant effect on REA-t and SDS. Ramadan had beneficiary effects on REA-sd, DSB and EYE. There were no correlations between FAS or SSS and other neuroperformance parameters.

Conclusion – Daytime sleepiness moderately increases during Ramadan. Neuroperformance remains mostly unaffected. Concentration improved during Ramadan, but we observed are large interindividual differences.

Keywords: *ramadan; fasting; cognitive function; vigilance; sleepiness*

1. INTRODUCTION

During Ramadan, Muslims refrain from eating and drinking from dawn till sunset. In 2012, Ramadan started July 20th and finished August 18th. In Europe, this implied fasting periods of about nineteen hours at the beginning of Ramadan to around sixteen hours at the end.

Many studies report changes in circadian rhythms during Ramadan, with general delay in both bedtime and waking up hour (Ziaee et al 2006, BaHammam 2005, BaHammam 2006). In Islamic countries, daytime activities and working hours are often adapted to the changed rhythm during Ramadan (BaHammam et al 2010, Roky et al 2001). Many studies suggest a decreased daytime alertness during Ramadan in Islamic countries (BaHammam 2006, Roky et al 2000). The question arises whether this is also the case in western countries where working hours remain unchanged.

European employers have expressed concerns about the alertness of Muslim employees while performing potentially dangerous activities or keep concentrated during mentally straining tasks.

Most studies assessing alertness or sleepiness by questionnaires during Ramadan measured an increased subjective perception of sleepiness during daytime (Roky et al 2000, Zerguini et al 2008). Objective sleepiness measured by EEG seems slightly increased between 10:00 and 12:00 h. At other times of the day there were no important differences with results outside the Ramadan (Roky et al 2003).

Previous studies did not provide an answer to whether increased subjective sleepiness leads to a diminishment of neuroperformance. Data on neuroperformance parameters is scarce and results are contradictory. Two studies found a slower reaction speed during the first week of Ramadan (Roky et al 2004, Dolu et al 2007), while measurements in the second half of Ramadan showed no effect on reaction speed (Roky et al 2000, Tian et al 2011). Information processing speed and concentration were decreased in the first week of Ramadan in one study (Roky et al 2004), but were better than normal in another study (Lotfi et al 2010). Short time memory was better during Ramadan in one study (Lotfi et al 2010), while unaffected in another. (Tian et al 2011).

The aim of this study was to assess the impact of Ramadan on subjective sleepiness and neuroperformance in a non-Islamic Western country.

2. METHODS AND SUBJECTS

Volunteers were recruited via posting messages near mosques and on Islamic forums in Belgium. The study was approved by the Medical Ethics of the Catholic University of Leuven (reference number: S54398). Participants were informed of the objectives of the study and the confidentiality of their results in accordance to the declaration of Helsinki. Finally, 20 healthy subjects agreed to participate in an observational study including three test sessions.

Reference test sessions took place a week before Ramadan or a month after Ramadan, depending on the availability of the participant. During Ramadan, two sessions took place: the first one halfway (R1) and the second one in the last week of Ramadan (R2). Timing of the sessions varied between 12:30h and 20:30h. Each individual participant was always tested around the same time of day.

Subjects filled out a questionnaire about sleeping and eating habits. Dutch versions of the Fatigue Assessment Scale (FAS) (Michielsen et al 2004) and the Stanford Sleepiness Scale (SSS) (Hoddes et al 1973) were used to measure the subjective perception of respectively global fatigue in the past week and sleepiness at the time of the test. The FAS is a 10-item questionnaire in which each statement is scored between 1 (never) and 5 (always). Total FAS score varies between 10 and 50. FAS scores of 21 or higher indicate excessive fatigue (Michielsen et al 2004). The SSS is a 7-point Likert scale ranging between "Feeling active, vital, alert or wide awake" to "No longer fighting sleep, sleep onset soon and having dream-like thoughts". SSS scores may vary throughout the day between 1 and 3, which are considered normal physiological fluctuations. Scores of 4 and higher indicate sleep shortage and excessive sleepiness (Hoddes et al 1973).

Neuroperformance was assessed with four neurobehavioral tests of the computer assisted Neuroscreen test battery (Bultereys and Viaene 1994, Godderis et al 2010). Simple Reaction Time measured reaction speed (REA-t: average reaction time out of 60 measurements presented at random in intervals) and attention (REA-sd: standard deviation around the average time). Visual information processing speed was evaluated using Symbol Digit Substitution (SDS), in which subjects need to link digits to symbols as fast as possible. Five trials are given. Mean performance out of 4 trials was recorded (omitting the first trial). Digit Span Backwards (DSB) test was used to evaluate short time memory. The mean number of digits was calculated from 20 consecutive trials in which the number of digits is going up or down with one digit depending on whether the test person entered the answer correctly or not. For DSB, higher scores are better scores. Hand Eye Coordination (EYE) was assessed by asking the subjects to guide a cursor along a curve using a joystick (seven trials and two test trials). The given value for this test is the number of pixels between this curve and the actual trajectory of the cursor and is an indicator of visuomotor performance. For the EYE test, lower values are better.

For the statistical analysis, continuous data were summarized by descriptive statistics (mean and standard deviation). Changes over time of each dependent variable were analysed using multilevel analysis, which is especially suited to analyse repeated- measure data because it takes into account the dependencies among observations nested within individuals. Another advantage of this method (versus e.g. repeated measurement ANOVA) is its ability to handle missing data. Random coefficient models were fitted for all dependent variables, allowing for individual variation in intercept and regression slopes of the time-varying predictors. Two time-varying predictors were included in the model, being time of measurement (*Time*) and whether or not the measurement was taken during Ramadan (*Ramadan*). (In all models, *Time* was included as a variable with values 0, 1, 2, 3 while *Ramadan* was included as a dummy variable with 0 = measurement taken before and after Ramadan and 1 = measurement taken during Ramadan). Fixed and random effects of *Time* and *Ramadan* were tested using χ^2 tests. All models were fitted using *R* version 2.15.1 with *R*-package *nmle* version 3.1-104. Before analysis, data were examined for normality. In case of non-normal distributed data, a suitable data-transformation was applied (e.g. log-transformation on positively skewed data). One-Way ANOVA was used for checking correlations, using statistical package software SPSS 20.

3. RESULTS

10 men and 10 women aged 31.6 (SD ± 6.4) participated in this study. All subjects where tested at both sessions during Ramadan. 11 participants had one reference test before Ramadan and 4 participants had one reference session after Ramadan. 5 participants were present at both reference sessions and were tested four times in total. 15 subjects had a bachelor or master diploma. The other 5 participants had a high school diploma. 4 of the lower educated subjects and 2 of the higher educated subject had a job that could be classified as physically straining. 9 participants had at least one hour of sports training weekly. 2 participants had a completely sedentary lifestyle with less than 30 minutes of moderate exercise a day. None of the participants were smokers.

An overview of mean scores and standard deviations for FAS, SSS, REA-sd, SDS, DSB, and EYE for the four test sessions are shown in table 1. The results of the multilevel analysis are given in table 2 and visually illustrated in figure 1.

3.1. Fatigue Assessment Scale

During Ramadan, mean bedtime was 90 minutes later than normal. In the first half of Ramadan (R1) waking up was 73 minutes later than normal and by the end of Ramadan (R2) 136 minutes later. Average sleep was unchanged in R1 but was on average 32 minutes less in R2. Seven subjects had a FAS score of 21 or higher during reference measurements, eight subjects scored high at R1 and seven subjects at R2. Average FAS was 20.28 outside Ramadan, 20.05 in R1 and 20.65 in R2. Multilevel analysis revealed non-significant effects of *Ramadan* or *Time* on FAS ($\chi^2(2)=0.15$; NS).

Table 1. Effects of Time and of Ramadan on Fatigue and Neuroscreen Results

	SSS	FAS	REA-t (ms)	REA-sd (ms)	SDS (s)	DSB (digits)	EYE (pxls)
Before Ramadan (n=16)	2.25 ± 0.8	20.81 ± 4.4	278 ± 62	66 ± 36	14.6 ± 3.8	6.2 ± 1.3	2382 ± 1178
Halfway Ramadan (n=20)	2.50 ± 1.0	20.05 ± 6.0	265 ± 30	50 ± 15	13.5 ± 4.6	6.9 ± 2.1	1989 ± 795
Last Week Ramadan (n=20)	2.72 ± 1.3	20.65 ± 6.0	263 ± 22	51 ± 17	12.7 ± 3.6	7.3 ± 1.6	1735 ± 540
After Ramadan (n=9)	1.78 ± 0.6	19.33 ± 5.1	276 ± 37	68 ± 22	10.9 ± 3.4	7.8 ± 1.5	1569 ± 631

SSS stanford sleepiness scale; FAS fatigue assesent scale; REA-T reaction time; REA-SD concentration; SDS symbol digit substitution; DSB digit span backward; EYE eye hand coördination

Values are given as means ± standard deviation

Table 2. Results of the multilevel analysis for the different (log-transformed) dependent variables.

	SSS	FAS	log10 (REA-T)	Log10 (REA-SD)	SDS	DSB	Log10 (EYE)
fixed effect							
intercept	2.10 (0.17) ***	20.26 (1.01)***	2.42 (0.01)***	1.78 (0.03)***	2.23 (0.13)***	5.78 (0.44)***	3.55 (0.05)***
time	-	-	-	-	-0.12 (0.02)***	0.42 (0.13)***	-0.06 (0.01)***
ramadan	0.50 (0.25)**	-	-	-0.10 (0.04)***	-	0.43 (0.24)*	-0.05 (0.02)**
Variances + 95% CI							
intercept	0.35 (0.08-1.55)	3.97 (2.66-5.92)	0.03 (0.02-0.05)	0.08 (0.04-0.15)	0.52 (0.37-0.71)	1.36 (0.95-1.93)	0.15 (0.11-0.22)
slope time	-	-	-	-	-	-	-
slope ramadan	0.73 (0.32-1.64)	-	-	-	-	-	-
corr	0.36 (-0.98-0.99)	-	-	-	-	-	-
residual	0.73 (0.56-0.95)	3.77 (3.07-4.64)	0.04 (0.03-0.04)	0.14 (0.11-0.17)	0.15 (0.13-0.19)	0.89 (0.73-1.10)	0.09 (0.07-0.11)
icc	0.33	0.52	0.45	0.19	0.87	0.61	0.61
Fit-statistics							
PRV	0.31	-	-	0.14	0.43	0.29	0.50
pseudo-R2	0.71	0.67	0.62	0.47	0.95	0.47	0.86

SSS stanford sleepiness scale; FAS fatigue assessment scale; REA-T reaction time; REA-SD concentration; SDS symbol digit substitution; DSB digit span backward; EYE eye hand coordination

Values are given as means (standard deviation), and numbers (95% CI)

* *P<0.10*; ** *P<0.05*; *** *P<0.01;* - indicated a non-significant effect

3.2. Stanford Sleepiness Scale

The average SSS was 2.00 outside Ramadan, 2.50 in R1 and 2.72 in R2. One subject scored 4 on SSS during reference measurements. Three subjects scored 4 or higher at R1 and seven subjects scored 4 or higher at R2. Multilevel analysis revealed a small effect of *Ramadan*: for an average person, SSS increased with 0.50 points during Ramadan ($\chi^2(1)=4.70$; $P<0.05$) but did not exceed normal physiological values. We observed large interindividual differences in the effect of Ramadan on SSS: for a few persons, SSS could even decrease during Ramadan (see Figure 1). One-Way ANOVA was used to analyse possible correlations between the individual effect of Ramadan on SSS and different independent variables, but revealed no influence of age, sex, time of day, the amount of sleep in the previous night or the number of hours of fasting at the time of the test. No correlations could be detected between the amount of sleep and SSS or FAS.

Interestingly, the higher educated subjects were more tired during Ramadan, with a very limited and non-significant sleep reduction of 2% during Ramadan compared to the reference period. Within the group of lower educated subjects an opposite effect is shown: during Ramadan they were less tired compared to the reference period, despite an average 15% sleep reduction.

3.3. REA-t

The average reaction speed (REA-t) was 278.38ms outside Ramadan, 264.57ms at R1 and 263.82ms at R2. Reaction speed was slightly better during Ramadan, but multilevel analysis showed that this effect was statistically not significant, nor was the effect of *Time* ($\chi^2(2)=2.80$; NS). To correct for non-normality, the multilevel analysis was carried out with log-transformed REA-t.

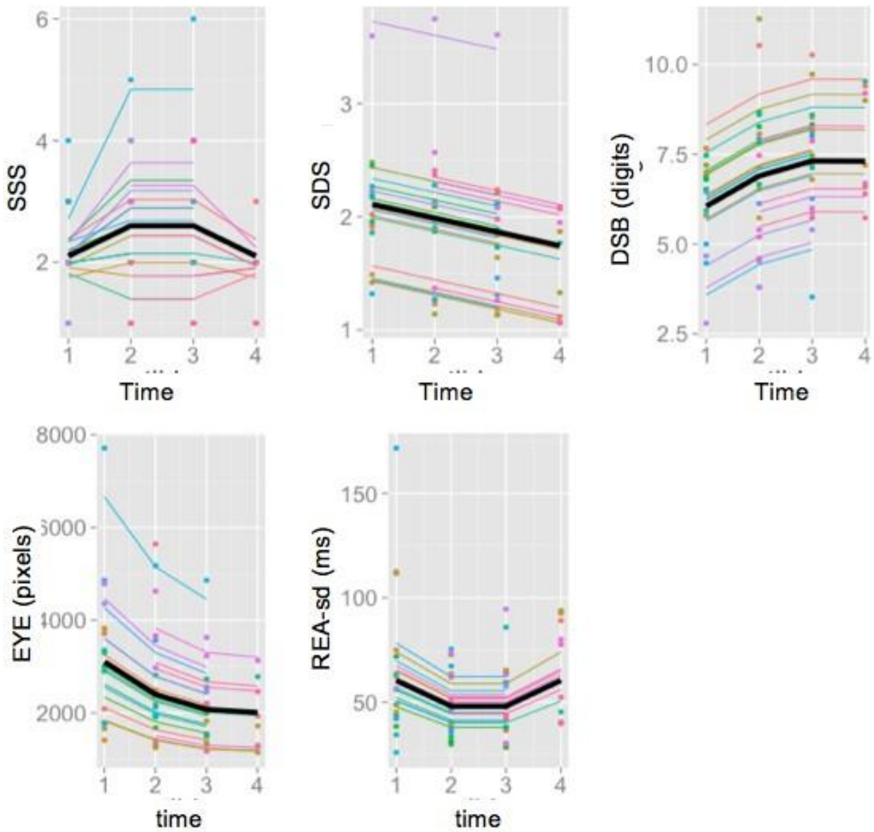
3.4. Rea-sd

Multilevel analysis showed a significant effect of *Ramadan* on the (log-transformed) REA-sd. Log10(REA-sd) was 1.68 during Ramadan and 1.78 outside Ramadan. REA-sd decreased with around 12ms during Ramadan for an average person ($\chi^2(1)=7.31$; $P<0.01$). This means that concentration improved during Ramadan; see Figure 1). Time had no effect on concentration. Average REA-sd was 64.71ms at the first session, 47.26ms at the second session and 54.66ms at the third session. Five participants went through the test for a forth time with an average REA-sd of 72.32ms.

3.5. SDS

Average SDS was 14.60s before Ramadan, 13.48s at R1, 12.68s at R2 and 10.86s after Ramadan. Multilevel analysis showed that *Time* significantly effected SDS: for an average person, SDS decreases with 0.12 points for each unit-increase in time ($\chi^2(1)=26.00$; $P<0.001$). *Ramadan* did not significantly affect SDS ($\chi^2(1)=0.53$; NS). There were large interindividual differences in SDS in the reference condition (ICC – a measure indicating the percentage of variation in SDS due to the hierarchical structure in the data was equal to 87%) (See table 2 and figure 1).

Figure 1: Predicted trends throughout time for SSS, SDS, DSB, EYE and REA-sd based on multilevel analyses



Black line: predicted trend for an average person ; coloured lines: person-specific predicted trends ; dots: observed scores for each person. For abbreviation see text, or index table

3.6. DSB

Average DSB was 6.19 digits before Ramadan, 6.91 at R1, 7.31 at R2 and 7.75 after Ramadan. Throughout time, average DSB increased with 0.47 digits per session. Multilevel analysis revealed a large significant increase of DSB per unit-increase of *Time* and a (small) significant increase during Ramadan (χ^2(2)=15.79; $P<0.001$) (See figure 1). The interaction between *Time* and *Ramadan* was not significant (χ^2(1)=0.003; NS). As with SDS, there were large interindividual differences in DSB at the beginning of measurement (ICC = 61%). (See figure 1).

3.7. EYE

Average EYE was 3340 pixels before Ramadan, 2641 at R1, 2221 at R2 and 2063 after Ramadan. Throughout time, average DSB decreased with 486 pixels per session. Multilevel analysis revealed a significant effect of *Time* and *Ramadan* on EYE: both variables lead to a decrease in EYE (χ^2(2)= 28.46; $P<0.001$) (See figure 1). The interaction between *Time* and *Ramadan* was not significant (χ^2(1)=0.03; NS). Multilevel analysis also showed large interindividual differences in (log-transformed) EYE-scores at the beginning of measurement (ICC= 61%; see table 2).

No correlations were found between FAS and neuroperformance parameters. Reaction times linked to SSS-scores of 4 or higher were an averagely 26ms longer than those linked to SSS-scores within the normal physiological range. (F=4.382; $P<0.05$) Other neuroperformance parameters were not correlated with SSS.

4. DISCUSSION

Our results confirm that Ramadan leads to reduced sleep and consequently increased moderately daytime sleepiness. Sleep reduction seemed to depend on the starting fasting hour: as fasting began very early in the morning (between 02:25h and 03:20h) most subjects skipped breakfast in R1, while in R2 most participants interrupted their sleep for breakfast before starting the days’ fast at 04:00h or later. Our data are consistent with other studies conducted in Islamic countries reporting that Ramadan causes a shift in the sleeping pattern with a delay of both bedtime and waking up (BaHammam 2006, Roky et al 2001, Roky et al 2004).

Waterhouse et al (2008) conducted a study in 2006-2007 when Ramadan took place during autumn. They compared British Muslims to Libyan Muslims and found that during Ramadan, subjects in Libya were less active and napped more frequently in the daytime while being active after sunset. Throughout the day British Muslims were more fatigued than Libyan Muslims. As subjects in Libya had a tendency to stay inside or take air-conditioned taxis when going out, the influence of climate differences is limited. Cultural differences are more likely to be a contributory factor to these differences. In western countries working hours and work activities don’t change during Ramadan.

Despite the much longer fasting period in midsummer, our global results differ from the British results of Waterhouse et al (2008), as overall fatigue seemed not to be affected by Ramadan. This might be due to the fact that Ramadan in 2012 coincided with summer holidays, which allowed some subjects to stay in bed and maintain a normal amount of sleep instead of having to get up and go to work. However, the explanation above is not supported when we divide higher and lower educated subjects. Our findings suggest that either education level, or the corresponding job (lower educated people usually have jobs with more physical activity), might play an important role in the effect of Ramadan on fatigue. Further research is required to assess whether this difference can also be reproduced in larger study populations.

In our study, Ramadan did not impair neuroperformance parameters. There seems to be no effect on reaction time and visual perception. In contrast, attention seemed to improve significantly during Ramadan and a small beneficial effect was observed on short-term memory and hand eye coordination.

Previous studies discussing the effects of Ramadan on neuroperformance were mostly performed on students or athletes. Roky et al (2000) reported longer reaction times at day 6 of Ramadan ($P<0.05$), but these were normalised at day 15 and day 28 (6).

Participants in the study by Tian et al (2011) had better reaction times during the second half of Ramadan ($P<0.01$) at the identification task of the CogState test (11). Dolu et al (2007) found that concentration of medical students at the Mesulam and Weintraum Cancellation Tasks was lower during the first week Ramadan, with less targets marked and more targets missed ($P<0.01$) (10). Lotfi et al (2010) found a significant positive effect of Ramadan, in both first and third week, on visual perception and digit span backward test in sports school students ($P<0.001$).

Overall, these results indicate towards a negative effect on concentration and reaction time during the first week of Ramadan with a return to normal values by the second half of Ramadan, and a beneficial effect on short time memory. Findings in our study are in line with these observations, as all our measurements took place after the first week of Ramadan.

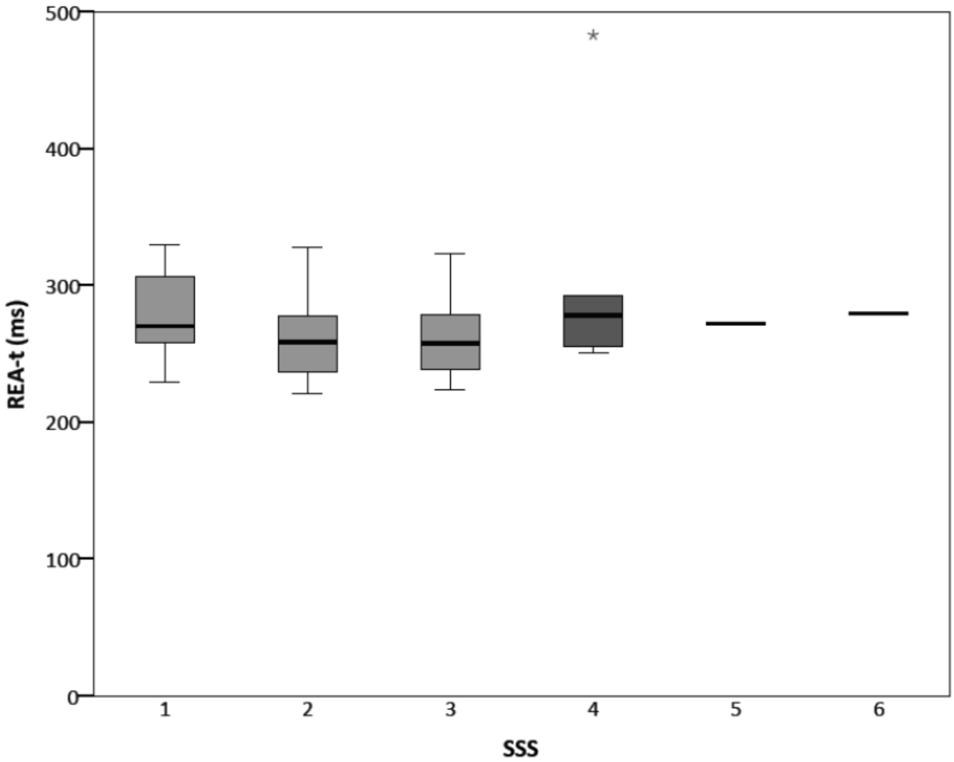
Although not anticipated, there was also an effect of time on the neuroperformance results, mainly on visual information processing and hand eye coordination. This is most likely due to learning effects, which are also documented in other studies (Tian et al 2011, Lotfi et al 2010, Doniger and Simos 2006, Halyburton et al 2007).

Halyburton et al (2007) also found a practise effect for the Digit Span Backward test, albeit significantly smaller than the time effect in our study.

Previous research by Danker-Hopfe et al (2001) indicates that SSS scores are unreliable to predict the actual state of objective sleepiness. Studies by Herscovitch and Broughton (1989) and Jewett et al (1999) showed that while sleep deprivation leads to higher SSS-scores, the effect on reaction speed and vigilance is limited.

Findings in the current study are largely concordant with these previous findings. Subjective fatigue or sleepiness is not correlated with neuroperformance parameters. The only correlation found here was that high SSS scores may lead to slower reaction time. However, as seen in figure 2, this finding might have been due to one extreme outlier. When this outlier was excluded, the correlation was no longer present.

Figure 2: Reaction speed (REA-t) by SSS score.



(Black line: median value; Box: interquartile distance; Whiskers: minimum and maximum values. Extreme outliers are represented by separate dots)

5. CONCLUSION AND LIMITATIONS

In general, the results of this study are in line with other studies performed in Islamic countries. Daytime sleepiness increases during Ramadan, but stays within the normal physiological boundaries. Neuroperformance remains mostly unaffected. On average concentration improved during Ramadan, but there are large interindividual differences. SSS or FAS scores cannot be used to predict neuroperformance results outside or during Ramadan.

In general, our results indicate that Ramadan gives employers in Western Europe no reason to withhold Muslims from jobs that require sustained attention.

Statistical significance in our study is moderate due to the small cohort size. We had to deal with big interindividual differences in the effects of Ramadan, both for fatigue and sleepiness as for neuroperformance parameters. Consequently, the lack of correlation between subjective perception of fatigue or sleepiness and neuroperformance parameters could be real or due to the small sample size. Larger studies with more power will be needed to generate more accurate results and higher statistical significance.

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