

FIELD STUDY ON THE EFFICACY OF THE NEW RESTART PROVISION FOR HOURS OF SERVICE REPORT TO CONGRESS

Pursuant to Section 32301 of the
Moving Ahead for Progress in the 21st Century Act (P.L. 112-141)
January 2014

Section 32301 of the Moving Ahead for Progress in the 21st Century Act (MAP-21) requires the Secretary of the U.S. Department of Transportation to complete a field study on the efficacy of the restart provisions of the Hours of Service of Drivers final rule published on December 27, 2011, applicable to operators of commercial motor vehicles (CMV) of property subject to maximum driving time requirements of the Secretary.¹ The Secretary must also provide a report describing the results of the field study to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives.

BACKGROUND

On December 27, 2011, the Federal Motor Carrier Safety Administration (FMCSA) published the Hours of Service of Drivers Final Rule.² The goal of this rulemaking was to reduce excessively long work hours that increase both the risk of fatigue-related crashes and long-term health problems for drivers and was fully implemented on July 1, 2013. The hours-of-service (HOS) regulations that were in effect until June 30, 2013, prescribed the following:

- Drivers may drive 11 hours within a 14-hour non-extendable window after coming on duty following 10 consecutive hours off duty.
- Drivers may not drive after 60/70 hours on duty in the most recent 7/8 days.
- Drivers may restart a weekly duty cycle after taking a restart break of 34 or more consecutive hours off duty (commonly referred to as the 34-hour restart rule).

The “34-hour restart” is intended to provide sufficient time for a driver to recuperate from the cumulative fatigue that may build up across duty cycles if that driver wants to work beyond the weekly maximum on duty limits. The 2011 final rule amended the 34-hour restart to require a driver to include at least two nighttime periods (from 1 a.m. until 5 a.m., based on the home terminal time zone) in the restart break. The previous restart provision did not include the two nighttime period requirements. However, based on principles of neurobiology, fatigue would be expected to build up more rapidly across duty cycles in nighttime drivers than in daytime drivers.³ Furthermore, fatigue would be expected to dissipate less effectively during 34-hour restart breaks for nighttime drivers, which include only one biological night (versus two biological nights for daytime drivers).

Drivers who end their weekly duty cycle between 1 a.m. and 7 p.m. must extend their 34-hour restart break by 1 or more hours to be compliant with this new restart rule. For study purposes, any off-duty period of 34 or more consecutive hours was considered to be a restart period. A duty cycle was any period of on-duty time between restart periods.

Pursuant to Section 32301(a) of MAP-21, to investigate the efficacy of the changes made to the restart provision, FMCSA sponsored a naturalistic field study that was conducted to assess fatigue in drivers working their normal schedules and performing their normal duties. During this study, researchers compared driver fatigue between weekly duty cycles preceded by a restart break with one nighttime period to weekly duty cycles preceded by a restart break with two or more nighttime periods. This report describes the design, methods, research findings, and conclusions of this naturalistic study. The study measured sleep, reaction time performance, sleepiness, and driving performance across two duty cycles and the intervening restart breaks for participating CMV drivers. The study's methods and findings are summarized in this report to Congress. The full report study can be accessed on FMCSA's website at <http://www.fmcsa.dot.gov/facts-research/research-technology/report/Efficacy-of-HOS-Restart-Rule-Report.pdf>.

STUDY OVERVIEW

Researchers conducted the naturalistic field study from January to July 2013 with drivers whose duty schedules used the restart provision of the previous HOS regulations. As required by MAP-21, the field study, to the extent possible, used a methodology consistent with the referenced laboratory-based study; collected data representative of the drivers and motor carriers regulated by the HOS regulations, including those drivers and carriers affected by the maximum driving time requirements; employed statistically valid analysis; and followed the plan for the Scheduling and Fatigue Recovery Project. The drivers' electronic duty logs were used to identify the periods when they were on duty and when they were driving and to define their duty cycles and restart breaks. Wrist activity monitors measured driver sleep/wake patterns. Driver fatigue levels were measured three times per day by a Psychomotor Vigilance Test (PVT) and by subjective sleepiness scores, where drivers rated themselves on a scale of 1 (extremely alert) to 9 (extremely sleepy). The Karolinska Sleepiness Scale (KSS), developed by the Karolinska Institute in Stockholm, Sweden, was used for subjective sleepiness scores in this study. Finally, lane deviation (variability in lateral lane position) was measured using a truck-mounted lane tracking system.

A total of 106 individual CMV drivers completed the study. The drivers consisted of 100 men and 6 women, ages 24 to 69. Their commercial driving experience ranged from less than a year to more than 39 years with a mean of 12.4 years of driving experience. The drivers represented a variety of trucking operations: 44 were local drivers, 26 were regional drivers, and 36 were over-the-road drivers. Participating drivers provided a total of 1,260 days of data and drove a total of 414,937 miles during this field study. Each driver in the study sample contributed data from two weekly duty cycles. Because this was a naturalistic study, the conditions associated with those two duty cycles could be the same or different. Each driver received compensation for participating in the study. For the 106 drivers included in the study sample, the breakdown was as follows:

- **Group A:** 20 drivers had a restart break with one nighttime period preceding both duty cycles.
- **Group B:** 5 drivers had a restart break with one nighttime period preceding their first duty cycle and a restart break with two or more nighttime periods preceding their second duty cycle.

- **Group C:** 26 drivers had a restart break with two or more nighttime periods preceding their first duty cycle and a restart break with one nighttime period preceding their second duty cycle.
- **Group D:** 55 drivers had a restart break with two or more nighttime periods preceding both duty cycles.

Thus, 25 drivers had one nighttime period in the restart break preceding their first weekly duty cycle (Groups A and B), and 46 drivers had one nighttime period in the restart break preceding their second weekly duty cycle (Groups A and C). In total, 51 drivers (48.1 percent of the sample) had a restart break with one nighttime period preceding at least one of their weekly duty cycles.

The results of this naturalistic field study indicate that having at least two nighttime periods from 1 a.m. until 5 a.m. in the restart break helps to mitigate fatigue as measured both objectively and subjectively. This constitutes evidence in support of the efficacy of the new restart rule.

STUDY DESIGN AND PROCEDURES

Upon starting a new weekly duty cycle (i.e., at the end of a restart break), each participating driver met with a research assistant. During these meetings, research assistants explained the study procedures, and each driver gave written, informed consent. Every driver was given a smartphone to use during the study. Drivers used the smartphones to enter sleep/wake logs, record caffeine use, test reaction time performance on the PVT, and report subjective sleepiness. Smartphone features such as calling and texting were disabled, and the PVT application was blocked while the truck was in motion. Drivers were also given wrist activity monitors to wear continuously throughout the study. Finally, each driver was assigned a truck that was equipped with a data acquisition system that collected vehicle characteristics and performance metrics continuously while the driver was on duty.

Each driver participated in the study through two consecutive weekly duty cycles and the intervening restart break. During the study, drivers performed their normal driving and duty tasks and managed their schedules and restart breaks naturalistically. Three times per day, drivers took a 3-minute PVT on the smartphone: once immediately before starting a duty day, once during a break about halfway through the duty day, and once immediately after ending a duty day. On restart days, drivers took the PVT once within 2 hours of waking, once in the middle of the day, and once within 2 hours before going to bed. Each driver's typical daily time commitment for the study was less than 30 minutes.

Drivers also used their issued smartphones for the following:

- To provide scores for subjective sleepiness on the KSS.⁴
- To enter responses on other self-report assessments.
- To update sleep/wake logs.
- To record times of caffeine intake.

Drivers who participated in the study maintained daily contact with research assistants to review compliance with the smartphone assessments and to ask and/or answer any questions relating to distractions or other unusual events that might have impacted their schedules or data collection. At the end of the second duty cycle of the study—when study participation ended—each driver met with a research assistant again. During this meeting, research assistants completed the following:

- Downloaded data from the wrist activity monitor and reviewed it with the driver.
- Discussed and resolved any inconsistencies, mistakes, or missing entries in the sleep/wake and caffeine logs.
- Discussed any apparent outliers in the PVT performance data and/or subjective sleepiness scores.
- Solicited feedback on the study and any other relevant issues.

Finally, researchers downloaded the drivers' official duty logs for the period of the study from their respective carriers' duty log databases.

The compliance date for the new restart rule was July 1, 2013. The field study was completed in July 2013, and none of the drivers' schedules was impacted by the new rule during the study. No crashes were reported by any of the drivers during their study participation.

STATISTICAL ANALYSIS

Researchers distinguished two study conditions for this project:

- **Restart break with one nighttime period**—when a driver's restart break included only one complete period from 1 a.m. until 5 a.m., and the driver thus would not have been compliant with the new restart rule.
- **Restart break with more than one nighttime period**—when a driver's restart break included two or more complete periods from 1 a.m. until 5 a.m., and the driver thus would have been compliant with the new restart rule.

The main objective of the statistical analysis was to examine whether there were differences in the observed levels of fatigue for weekly duty cycles following a restart break with one nighttime period (1 a.m. to 5 a.m.) versus duty cycles following a restart break with two or more nighttime periods. It should be noted that each driver contributed data from two weekly duty cycles, and since this was a naturalistic study, the number of complete nighttime periods in the restart break preceding each of their two duty cycles could be either the same or different. Thus, daytime and nighttime drivers were compared to themselves and each other in a mixed within- and between- subjects design focused on the number of nighttime periods in the restart break.

The data for on-duty status and driving status, which were in the data set at 1-minute intervals, were averaged over 1-hour intervals for each hour of the day across days in each weekly duty cycle for each driver. The same was done with lane deviation data. The key statistical outcomes of the analysis were the effects and interactions of condition (the number of nighttime periods during the preceding restart break) and hour of the day. The same methodology was applied to the sleep/wake data collected by the wrist activity monitors used during the study.

The primary fatigue outcome variable, as designated in advance during the design phase of the study, was the number of lapses of attention on the PVT. The PVT is considered a gold standard assay of fatigue, and validation studies of the 3-minute version of the PVT used in the current study have been published.^{5,6} Given that the PVT measurements were performed less frequently than the other measurements, and at discrete times rather than continuously, the data on lapses of attention were aggregated (but not averaged) in 4-hour intervals spanning the 24 hours of the day, and then collapsed (again, not averaged) across days in each weekly duty cycle for each driver. A secondary fatigue outcome variable—subjective sleepiness scores on the KSS—was analyzed in the same way as lapses of attention on the PVT.

KEY OUTCOMES

Table 1 displays the key outcomes from the study. These outcomes are discussed in greater detail in the subsequent sections of this report.

Table 1. Key findings of the naturalistic field study.

Outcome Measure	Summary of Differences between Study Conditions
Lapses of attention: significant difference between conditions	Drivers exhibited more lapses of attention, especially at night, during weekly duty cycles preceded by a restart break with one nighttime period, as compared to a restart break with two or more nighttime periods.
Subjective sleepiness: significant difference between conditions	Drivers reported greater sleepiness, especially toward the end of their duty periods, during weekly duty cycles preceded by a restart break with one nighttime period, as compared to a restart break with two or more nighttime periods.
Lane deviation: significant difference between conditions	Drivers showed increased lane deviation (i.e., more variability in lateral lane position) at night and in the morning and afternoon (but not in the evening) during weekly duty cycles preceded by a restart break with one nighttime period, as compared to a restart break with two or more nighttime periods.
Sleep: significant difference between conditions	Sleep occurred predominantly during the day in weekly duty cycles preceded by a restart break with one nighttime period and predominantly at night in weekly duty cycles preceded by a restart break with two or more nighttime periods.
On duty: significant difference between conditions	Time spent on duty occurred predominantly at night in weekly duty cycles preceded by a restart break with one nighttime period, whereas it was more evenly distributed across the hours of the day in weekly duty cycles preceded by a restart break with two or more nighttime periods.
Driving: significant difference between conditions.	Time spent driving was greater and occurred more typically at night in weekly duty cycles preceded by a restart break with one nighttime period, as compared to a restart break with two or more nighttime periods.

DUTY, DRIVING, AND SLEEP

Analysis of the drivers' official duty logs revealed that their time spent on duty and driving was distributed more or less evenly across the hours of the day when the preceding restart break contained two or more nighttime periods, whereas it was distinctly more oriented toward the

night when the preceding restart break contained one nighttime period. In other words, following a restart break with one nighttime period, a driver was likely to be driving primarily at night. Under the new rule, these nighttime drivers would have to extend their restart breaks to include a second biological night. Figures 1 and 2 below display the percent of driver hours on duty and the percent of driver hours logged as driving, respectively.

Figure 1. Graph. Distribution of drivers logged as on duty, as a percentage of total driver hours for each hour of the day, during weekly duty cycles. Error bars indicate ± 1 standard error of the mean.

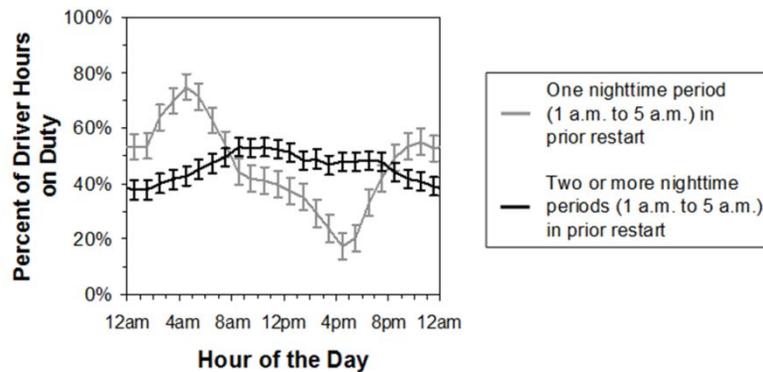
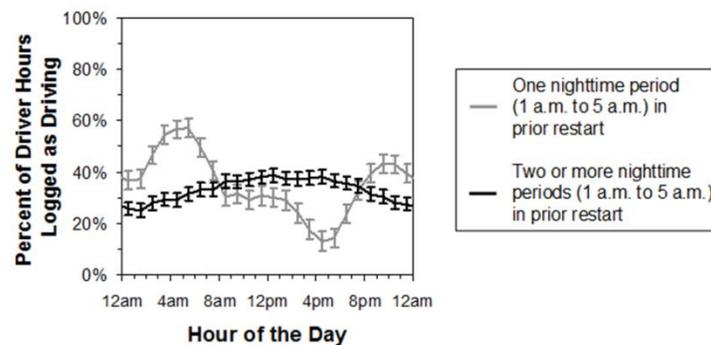


Figure 2. Graph. Distribution of drivers logged as driving, as a percentage of total driver hours for each hour of the day, during weekly duty cycles. Error bars indicate ± 1 standard error of the mean.



Sleeping (as measured with continuous wrist activity monitoring) occurred primarily during the day during weekly duty cycles preceded by a restart break with one nighttime period. Even so, the 24-hour patterns of sleeping were not the reverse of the 24-hour patterns of duty and driving, regardless of whether the preceding restart break contained one or more nighttime periods. In both conditions, the propensity for sleep was relatively increased during the night and reduced during the early evening hours.

This outcome was expected, based on the neurobiology of sleep regulation, which produces a “gate for sleep” during the night (and, to a lesser extent, during the mid-afternoon) and a “forbidden zone for sleep” or “wake maintenance zone” during the early evening.^{7,8,9} As such, given the schedule constraints on sleeping during weekly duty cycles, drivers obtained an average of 6.0 hours of sleep per 24 hours when the preceding restart break contained one

nighttime period, and 6.2 hours of sleep per 24 hours when the preceding restart break contained two or more nighttime periods.

Drivers' 24-hour profiles of sleep were substantially different during restart breaks than during weekly duty cycles, as shown in Figures 3 and 4. During restart breaks, drivers obtained an average of 8.8 hours of sleep per 24 hours when the break contained one nighttime period and 8.9 hours of sleep per 24 hours when the break contained two or more nighttime periods. In both conditions, drivers predominantly slept at night during restart breaks, and almost no sleep was obtained during the early-evening "wake maintenance zone" during the restart break. This finding appears to refute anecdotal claims that nighttime drivers would generally maintain a schedule with nighttime wakefulness and daytime sleep during their restart breaks. In contrast, it confirms the validity of the assumption in the previously-described earlier laboratory studies of the restart break: that nighttime drivers tend to transition back to a daytime waking and nighttime sleeping schedule during their restart break.

Figure 3. Graph. Distribution of drivers sleeping, as a percentage of total driver hours for each hour of the day, during weekly duty cycles. Error bars indicate ± 1 standard error of the mean.

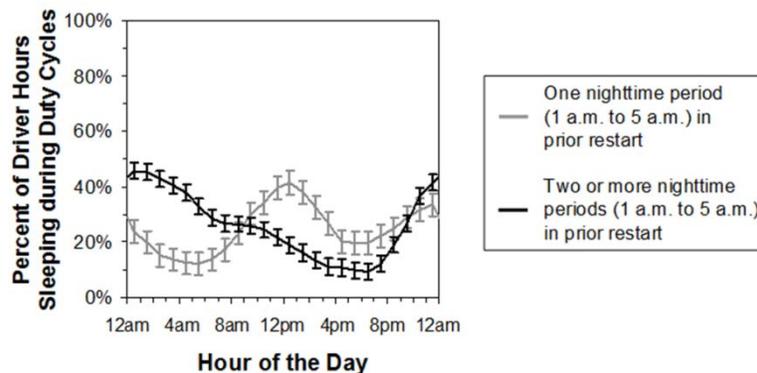
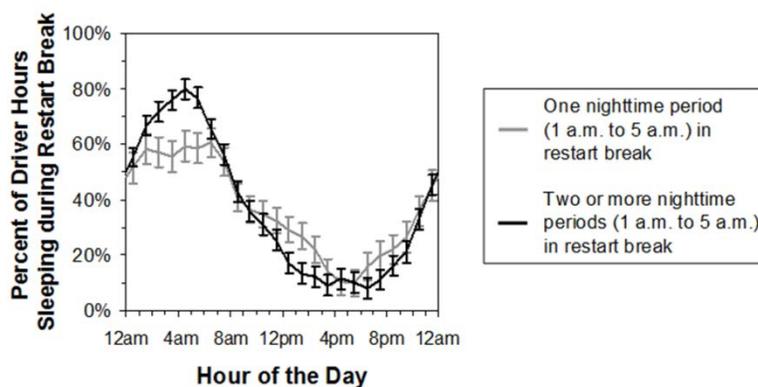


Figure 4. Graph. Distribution of drivers sleeping, as a percentage of total driver hours for each hour of the day, during the restart break. Error bars indicate ± 1 standard error of the mean.



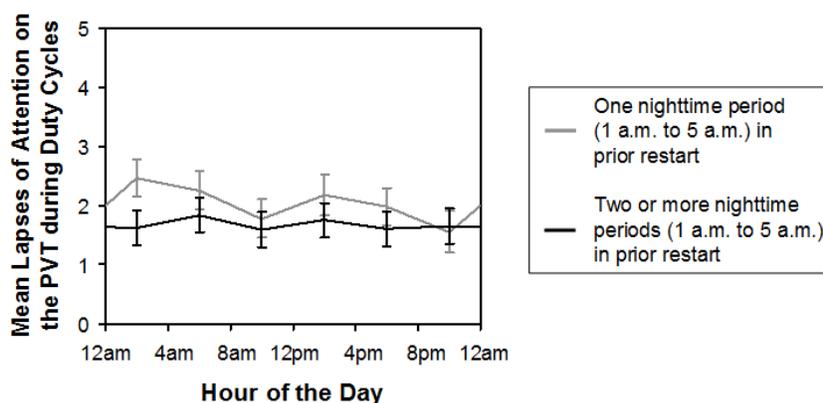
This study did not include any experimental intervention related to extending the duration of the restart break for drivers whose breaks contained one nighttime period. However, as shown in Figure 4, drivers gravitated toward the same, nighttime-oriented pattern of sleep during their restart breaks, whether their breaks contained one or more nighttime periods. Thus, it is plausible that in the condition of the restart break containing one nighttime period, extending the break to include two nighttime periods would substantively increase a driver's opportunity to obtain recuperative sleep before beginning a new weekly duty cycle. This suggests that the new rule increases the recuperative sleep potential during restart breaks and thereby helps to mitigate fatigue.

FATIGUE OUTCOMES

Psychomotor Vigilance Test Results

The primary objective measure of fatigue was the number of lapses of attention on a 3-minute PVT administered via a smartphone. The PVT was performed three times per day. The number of lapses of attention (defined as reaction times greater than 355 milliseconds) on the 3-minute PVT was significantly greater during weekly duty cycles when the preceding restart break contained one nighttime period than when it contained two or more nighttime periods.¹⁰ The overall difference during weekly duty cycles between these two conditions was 0.4 lapses of attention per 3-minute test bout, but at night the magnitude of the difference went up to 0.8 lapses of attention per 3-minute test bout (see Figure 5). For comparison, sleep restriction to 4 hours of time in bed per day has been found to result in an average daily increase of about one lapse of attention on the 3-minute PVT.¹¹ Such an increase in the frequency of attentional lapses has implications for real-world driving performance, road safety threat detection, evasive maneuvering and braking response speed, and crash risk.¹²

Figure 5. Graph. Mean lapses of attention on a 3-minute PVT, by 4-hour period of the day, during weekly duty cycles. Error bars indicate ± 1 standard error of the mean.



To better understand this difference between the two conditions, consider that when driving at a speed of 60 mph, a 355-millisecond lapse of attention involves traveling a distance of more than 30 feet. Moreover, as a driver experiences more lapses of attention, the average duration of those lapses becomes longer. During a lapse of attention, a CMV driver may be missing important information or experiencing decreased ability to maintain a stable lane position. Crashes may

occur when hazardous circumstances align and the driver is experiencing a lapse of attention and cannot take the correct mitigating action. Thus, an increase in lapses of attention increases crash risk.

During the restart break, overall there were 1.3 more lapses of attention per 3-minute test when drivers' breaks contained one nighttime period versus two or more nighttime periods. The greatest difference was seen in the late morning, when a restart break with one nighttime period was associated with 1.8 more lapses of attention than a restart break with two or more nighttime periods. This elevated fatigue contributes to the evidence that drivers were unable to recuperate sufficiently during restart breaks that contained only one nighttime period.

These results are in line with the earlier laboratory studies of the 34-hour restart break.^{13,14} Those studies demonstrated that nighttime duty schedules (i.e., schedules most likely to be associated with one nighttime period in the restart break) are associated with reduced sleep and increased fatigue, which can be mitigated by extending the restart break to include a second biological night.^{15,16,17} The results of the current field study thus support the conclusion that a restart period containing two biological nights, relative to a restart period with one biological night, improves the efficacy of the restart period for nighttime driving operations, yielding a greater potential for recovery from fatigue before recycling back to the work force. These results indicate that having at least two nighttime periods from 1 a.m. until 5 a.m. in the restart break helps to mitigate fatigue, providing evidence in support of the efficacy of the new restart rule.

Subjective Sleepiness Scores

The results for subjective sleepiness scores on the KSS were similar to the results for lapses of attention on the PVT, in that subjective sleepiness during weekly duty cycles was higher overall when the restart break contained one nighttime period than when it contained two or more nighttime periods. During weekly duty cycles, the increased sleepiness was most pronounced during the late morning hours (toward the end of the driving period for most drivers whose restart break contained one nighttime period). Such a pattern is consistent with that observed in the earlier laboratory studies of the restart break. When a driver had one nighttime period in the restart break, he/she reported greater subjective sleepiness during that restart break (as opposed to during restart breaks that contained two or more nighttime periods).

These findings, combined with the other findings outlined above, suggest that the new rule requiring drivers to have at least two nighttime periods in their restart breaks has a beneficial effect on driver sleepiness in the field.

Lane Deviation

Study results indicate that the number of nighttime periods in the restart break had an effect on lane deviation during the subsequent duty cycle, for which the pattern was consistent with the effect seen on lapses of attention on the PVT. Post-hoc contrasts between conditions by hour of the day revealed that lane deviation was greater in the 4 a.m. to 5 a.m., 8 a.m. to 9 a.m. and 3 p.m. to 4 p.m. bins, but smaller in the 7 p.m. to 8 p.m. bin, after a restart break with only one nighttime period. While these effects were statistically significant, they were moderate in magnitude. However, that does not mean that the lane deviation effects, or the PVT effects for that matter, have little practical relevance for driving performance. A recent driving simulator

study of CMV drivers revealed that drowsiness degrades a driver's ability to keep lane position and steering control.¹⁸ The study indicated that crashes involving a drowsy driver are preceded by large-amplitude steering angle corrections and sporadic short intervals with no significant changes in steering angle. These phenomena may be related to lapses of attention such as those observed on the PVT.

CONCLUSION

In conclusion, the results of this naturalistic field study indicate that having at least two nighttime periods from 1 a.m. until 5 a.m. in the restart break helps to mitigate fatigue as measured both objectively and subjectively. This constitutes evidence in support of the efficacy of the new restart rule.

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