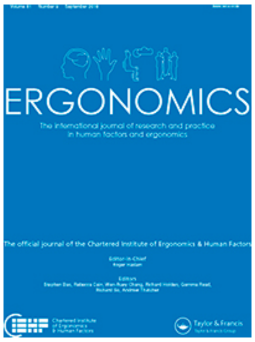

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Microbreak length, performance, and stress in a data entry task

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The effects of brief rest pauses on performance and well-being were evaluated for a highly repetitive, data entry task. Experienced data entry operators ($N=20$) performed the task in a two-day experiment in a simulated office environment. Each day was divided into six, 40-min work periods. Subjects took a brief rest pause at the workstation (microbreak) in the middle of each work period. Subjects were instructed to terminate this microbreak when ready to resume work. Keystroke rate, error rate, correction rate, heart rate and heart rate variability were scored for each half of the work period. In addition, mood states before and during the work period were assessed. Microbreaks were found to average 27·4 s in duration. High ratings of fatigue and boredom during the work period were associated with longer microbreaks, suggesting that the break period was self-adjusted relative to mood state. In addition, correction rate and heart rate were lower following long microbreaks, implying that the degree of recovery was linked to the length of the microbreak. Comparison of keystroke output and correction rate before and after the microbreak, however, revealed that performance worsened after the microbreak, suggesting that subjects terminated microbreaks before complete recovery could occur.

1. Introduction

Brief pauses lasting a few seconds occur spontaneously and frequently in most work activities, and are sometimes referred to as 'concealed breaks' (Rohmert 1973). McGehee and Owen (1940) found that spontaneous rest accounted for more than 5% of the workspell (periods of work without scheduled breaks) in a clerical task. Kogi (1972)

*This work was done while the author held a National Research Council–NIOSH Research Associateship.

observed that control room workers performing monitoring functions were not attending to their tasks for as much as 10% of the time. More recently, Sundelin *et al.* (1986) observed short, spontaneous pauses among video display terminal (VDT) operators. While it is generally acknowledged that these pauses occur in response to the fatiguing effects of continuous work (Grandjean 1979), there has been little systematic study of how these pauses affect performance and worker well-being.

As noted by Rohmert (1973), an exponential increase in fatigue over the workspell can be prevented by short, frequent rest breaks. Use of short breaks capitalizes on the rapid rate of recovery which occurs at the beginning of a rest break. When such breaks are regulated on a discretionary basis by the worker, however, it is questionable whether such pauses are of sufficient duration (Janaro and Bechtold 1985) or occur frequently enough (Sundelin *et al.* 1986) or early enough (Murrell 1971) in the workspell to prevent fatigue. For example, Sundelin *et al.* (1986) found that visual discomfort was reduced during VDT work when the frequency of rest pauses was increased by scheduling ten, 14-s micropauses each hour. Although the total number of pauses became greater when these scheduled pauses were introduced, the number of spontaneous pauses decreased by about 50%, suggesting that the workers may have felt that more frequent pauses were unnecessary. In a study using a repetitive perceptual-motor task, Henning (1987) allowed subjects to self-regulate the length of a scheduled 'microbreak' midway in 8-min work periods. Although recovery in reaction time performance was proportional to break duration, when prebreak performance was compared to postbreak performance it was found that reaction times were worse following the breaks. These results indicate that subjects terminated the breaks ($M = 9{\cdot}5$ s) before recovery was complete.

In response to a growing concern over stress disorders in VDT workers, recommendations have been made to limit the period of uninterrupted work at a VDT to no more than two hours (Johnson and Melius 1986, National Swedish Board of Occupational Safety and Health 1985). Recent studies, however, report that the accumulation of fatigue in continuous VDT work is not completely offset by conventional rest breaks (Schleifer and Amick 1989, Zwahlen *et al.* 1984). The present study investigates whether scheduled microbreaks of discretionary length are effective in controlling fatigue in a highly repetitive, computer-based task. In addition, relationships between break length and performance, physiological responses, and mood states were explored.

2. Method

2.1. *Subjects*

Subjects (20 females; ages 18–40, $M = 27{\cdot}4$) were experienced data entry personnel recruited through a local temporary employment agency. Subjects were capable of numeric data entry at a minimum rate of 7000 keystrokes per hour. (The restricted age range and high level of minimum performance were imposed to reduce the influence of age and experience-related factors in later analyses). Subjects were paid \$6·00/h (consistent with local pay scales). Subjects were required to pass a medical exam and tests of visual acuity. Subjects gave informed consent before participating in the study.

2.2. *Design and procedure*

The within-subjects experiment was conducted in a NIOSH laboratory which simulated an office environment. Subjects were familiarized with the experimental

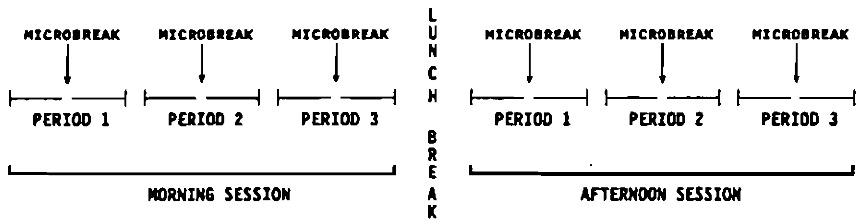

Figure 1. Timeline showing the three, 40-min work periods in each morning and afternoon session of each day of the experiment. The first and second half of each work period was separated by a microbreak.

protocol and practiced the data entry task one day prior to the experiment. Experimentation was conducted over the two subsequent days.

Each day of the experiment consisted of three, 40-min work periods in the morning session and three, 40-min work periods in the afternoon session as shown in figure 1. Morning and afternoon sessions were separated by a lunch break of approximately 45 min. Subjects took 10-min breaks away from the workstation between the 40-min work periods.

Subjects were given a brief rest break (microbreak) after 20 min of work within each 40-min work period. The length of this microbreak was self-regulated by subjects. Subjects were instructed to resume work: '.... when you feel ready to continue the data entry task'.

A mood survey was computer-administered to the subjects immediately before and after each 40-min work period. The survey appeared on the subject's monitor, and subjects responded using their keypad.

Subjects received no performance guidelines (e.g., goals for speed or accuracy), but were instructed to 'put in a good day's work'.

2.3. *Experimental task*

A PC-AT microcomputer was used to administer a data entry task and to monitor performance. A single line of randomized, numeric characters, 3 to 13 characters in length, was displayed in large type on a remote terminal (Model 3163, IBM Corporation). Line length was fixed within work periods, but varied randomly across work periods.

Subjects used the terminal's numeric keypad to enter the displayed characters and then typed a carriage return to enter the line of characters into a data base. A new line of characters was then presented and the cycle was repeated. Subjects could use the backspace key for correction of keying errors, but corrections were limited to the most recent character keyed so that multiple backspacing could not occur. Correction of keying errors was not possible after the line had been entered.

2.4. *Measures*

2.4.1. *Microbreak length:* The length of microbreaks was measured by the computer to within 1 s.

2.4.2. *Performance:* The following performance measures were computer-scored for each half of each 40-min work period: (1) keystroke output (total number of keystrokes); (2) error rate (total character errors/total keystrokes $\times 100$); and (3) correction rate (total backspaces/total keystrokes $\times 100$).

2.4.3. *Heart rate:* Subjects wore disposable, surface-mounted electrodes (Lead II) to record heart rate. The R-waves of the amplified electrocardiogram were discriminated by an R-wave detector (model HR–934, CWE Corporation). A computer-interfaced digital clock (CTMO5, Metrabyte Corporation) measured the time in milliseconds (± 1 ms) between consecutive R-waves. Two heart rate measures were calculated for each half of each 40-min work period: (1) mean interbeat interval; and, (2) heart rate variability due to respiratory-sinus arrhythmia. Heart rate variability was calculated as the standard deviation of interbeat intervals after removing irregular trends in heart rate due to factors such as blood pressure changes and body temperature oscillations.*

2.4.4. *Mood:* In the survey administered before each work period, subjects were instructed to indicate 'how they were feeling right now' (resting mood state). In the survey administered after each work period, subjects were instructed to indicate 'how they were feeling during the work period they had just completed' (work-related mood state). Work-related mood states were not assessed before the microbreak because interrupting the task to administer the survey would have provided a brief rest period.

Both the resting and work-related mood surveys contained the same 18 statements about mood state; for example, 'I am feeling energetic' (resting mood state), which the subject rated on a 1 to 5 scale (1 = hardly at all; 2 = a little; 3 = some; 4 = a lot; 5 = a great deal). Responses to these items were combined additively to produce scale scores for 'tension', 'fatigue', and 'irritation' as shown in table 1. Scores for 'boredom' and 'perceived stress' were based on responses to two single items (I feel bored; I feel stressed). Most of these items were selected from the Profile of Mood States (McNair *et al.* 1971). Cronbach's *alpha* (Cronbach 1951) for the 'tension', 'fatigue', and irritation' scales were 0·83, 0·90, and 0·95, respectively.

2.5. *Analysis*

The natural logarithm of microbreak length in seconds was used in all analyses (i.e., microbreak length in ln-sec). Use of this transformation is consistent with models of rest break effects in which recovery from fatigue is nonlinear in time (Gustafson 1982, Rohmert 1973), with more rapid recovery occurring early in the rest break period. In addition, use of the log transformation helped normalize the distribution of microbreak length in preparation for ANOVA tests.

2.5.1. *Performance decrements over the work period:* Repeated measures ANOVA† was used to test the primary hypothesis that microbreaks prevented fatigue-related

*A special signal processing program to identify unwanted trends was developed using a cubic polynomial moving average (Kendall 1973), 39 samples in width, applied to the record of interbeat intervals sampled at 5 Hz. Removal of these trends was used to help isolate heart arrhythmia resulting from respiratory-linked changes in vagal tone (Bohrer and Porges, 1982).

† Greenhouse–Geisser epsilon was used in all repeated-measures ANOVA analyses to adjust the degrees of freedom in the *F*-tests for within-subjects effects, because the *F*-tests are not robust when the assumption of equal measure-to-measure correlations is violated (Greenhouse and Geisser 1959).

Table 1. Derivation of mood scales.

Fatigue = Fatigued + Energetic* + Tired + Alert + Sluggish + Full of Pep*
Tension = Tense + Relaxed* + On Edge + Calm* + Nervous + At Ease*
Irritation = Impatient + Irritated + Annoyed + Aggravated

Note: *Items reverse scaled.

performance decrements over the 40-min work period. Mean performance scores in the first half of the work period were compared with mean performance scores in the second half of the work period. Separate, one-tailed tests were conducted to determine if, (1) keystroke output had decreased, (2) error rate increased, and, (3) correction rate increased, in the second half of the work period.

2.5.2. *Changes in physiological responses over the work period:* Repeated measures ANOVA was also used to test for changes in heart rate and heart rate variability over the work period. Heart rate measures in the first half of the work period were compared with heart rate measures in the second half of the work period.

2.5.3. *Relationships between microbreak length, performance, physiological responses, and mood states:* Multiple regression was used to explore relationships between the length of worker-terminated microbreaks and the performance, mood, and physiological measures. In each regression analysis, 'dummy' variables corresponding to subjects and work periods were included to adjust for effects of subject differences (e.g., age and data-entry experience) and time-related trends.

Effects of microbreak length. Separate regression analyses were conducted to determine if microbreak length could predict performance and physiological responses in the second half of the 40-min work period.

Determinants of microbreak length. Separate regression analyses tested if performance, physiological responses, and resting mood states predicted microbreak length in the associated work period. Regression analysis was also used to test if microbreak length varied in relation to work-related mood states.

2.5.4. *Within-session changes in performance, physiological responses, mood states, and microbreak length:* Although not central to testing the effectiveness of discretionary-length microbreaks, additional repeated-measures ANOVA tests were conducted to determine if systematic, fatigue-related changes in performance, physiological responses, mood states, and microbreak length occurred over the three work periods of each morning and afternoon session (i.e., within-sessions). For testing within-sessions changes in mood states, the resting and work-related mood scores were combined into a single score for each work period. Tests were also performed on the differences between resting mood states and work-related mood states.

3. Results

Mean microbreak length was 3·31 ln-sec (27·4 s). As shown in figure 2, the distribution of microbreak length in seconds (before transformation to ln-sec) was skewed. Descriptive statistics for microbreak length, and the performance and physiological response measures, are provided in table 2. Examination of scatterplots showed that

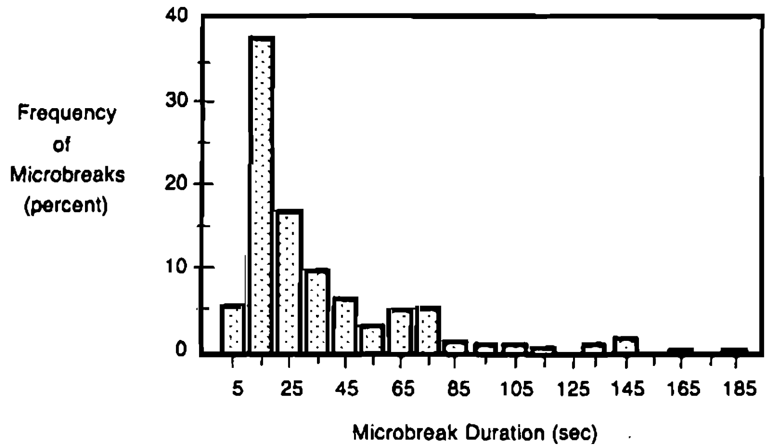

Figure 2. Frequency histogram of microbreak length (s).

Table 2. Descriptive statistics for the research measures.

Variable	Mean	S.D.	Min	Max
Microbreak Length (s)	37·0	33·1	8	184
Microbreak Length (ln-sec)	3·31	0·744	2·1	5·2
Total Keystrokes/20-min	2647	544	905	5370
Error Rate (per cent)	5·19	4·06	·18	23·3
Correction Rate (per cent)	7·56	4·26	·76	28·7
Mean IBI* (ms)	751	91·9	569	1065
IBI Variability (ms)	22·4	11·5	5·1	85·9

Note: * Interbeat interval.

performance measures (keystroke output, error rate, and correction rate) varied independently from each other.

3.1. *Performance decrements over the 40-min work period*

Total keystroke output was significantly less in the second half than in the first half of the work period ($F(1, 4) = 10·13$, $p = 0·02$). The mean for the second half of the work period was 53 keystrokes less than in the first half of the work period. Correction rate was significantly greater in the second half than in the first half of the work period ($F(1, 3) = 7·81$, $p = 0·04$). The correction rate for the second half of the work period was ½% greater than the first half of the work period. No significant increase in error rate was found between the first and second halves of the work period.

3.2. *Changes in physiological responses over the 40-min work period*

No significant change in the mean interbeat interval or heart rate variability was found between the first and second halves of the work period.

3.3. *Relationships between microbreak length, performance, physiological responses, and mood states*

3.3.1. *Effects of microbreak length:* Regression tests revealed that microbreak length was predictive of changes in one performance measure and one physiological response measure following the microbreak. Low correction rate in the second half of the work period was predicted by long microbreaks (t (169) = −2·32, p = 0·02). Long microbreaks were predictive of a longer mean interbeat interval (i.e., lower heart rate) in the second half of the work period (t (176) = 2·16, p = 0·03).

3.3.2. *Determinants of microbreak length:* Regression tests indicated that only one premicrobreak performance measure was predictive of microbreak length: an inverse relationship was found between correction rate in the first half of the work period and microbreak length (t (171) = −2·01, p = 0·05).

A high level of work-related 'fatigue' was associated with long microbreaks (t (158) = 2·39, p = 0·02). Similarly, long microbreaks were associated with a high level of work-related 'boredom' (t (158) = 2·14, p = 0·03).

Physiological response measures in the first half of the work period were not predictive of microbreak length. In addition, no significant relationship between resting mood state and microbreak length was found. Line length was not a significant predictor of microbreak length.

3.4. *Within-session changes in microbreak length, performance, physiological responses, and mood states*

3.4.1. *Microbreak length:* Microbreak length (in ln-sec) varied significantly within sessions (F (2, 12) = 7·91, p = 0·02). Inspection of plots showed a decline averaging 5 s from period 1 to period 3 of each session.

3.4.2. *Performance:* No significant within-sessions changes were found for the performance measures.

3.4.3. *Physiological responses:* The mean interbeat interval varied significantly within sessions (F (2, 8) = 7·14, p = 0·04). Inspection of plots showed a decrease in heart rate (longer interbeat intervals) over each session. Heart rate variability did not vary significantly within sessions.

3.4.4. *Mood State:* 'Fatigue' (F (2, 12) = 4·38, p = 0·05) and 'boredom' (F (2, 12) = 5·63, p = 0·04) varied within sessions. Inspection of plots indicated that both 'fatigue' and 'boredom' increased over each morning and afternoon session. Significant differences between resting mood states and work-related mood states were found. Work related 'tension' (F (1, 6) = 64·25, p < 0·001), 'fatigue' (F (1, 6) = 25·67, p < 0·01), and 'irritation' (F (1, 6) = 11·11, p = 0·02) were significantly elevated above resting levels.

4. Discussion

The data show that microbreak length varied in relation to work-related mood states ('fatigue', 'boredom') and, in turn, was predictive of performance and physiological response following the break (correction rate, heart rate). There was also evidence, however, of an accumulation of fatigue over the 40-min work period. Lower keystroke output and increased correction rate in the second half of the work period suggested that the worker-terminated microbreaks were not completely effective in controlling fatigue. These findings are consistent with earlier research reporting the ineffectiveness of discretionary breaks (Sundelin *et al.* 1986, Henning 1986, Janaro and Bechtold 1985, Pulket and Kogi 1984).

Since heart rate recovered in proportion to break length, lengthening the microbreak would be expected to overcome tension-related increases in heart rate. This may not be true, however, for keystroke performance since break length was not predictive of keystroke output in the second half of the work period. The lack of a significant relationship between microbreak length and keystroke output is probably due to subjects (who were professional data entry operators) striving to keep keystroke output high irrespective of the degree of recovery which occurred during the microbreak. Such compensatory effort would effectively uncouple keystroke performance from microbreak length. This compensatory effort to maintain work output, also evidenced by a constant error rate over the work period, would be expected since performance evaluation in professional data entry work emphasizes keystroke output and error rate. Correction rate, in contrast, is not used as a performance standard and is not likely to be closely monitored by data entry workers. This may explain why correction rate was the only performance measure which reflected recovery proportional to break length.

The fact that keystroke output declined and correction rate increased over the 40-min work period suggests that a single 'microbreak' may not provide sufficient time to allow adequate recovery from the stresses affecting keying performance. In contrast, keystroke output did not significantly decline nor did correction rate significantly increase over the morning or afternoon sessions, indicating that a longer break (which included time away from the workstation) resulted in more complete recovery.

The question remains as to why the subjects did not extend the discretionary breaks to allow more complete recovery. One possibility is that they returned to work prematurely to avoid loss of adaptation to the task. According to Rohmert (1973), loss of 'adaptation to work' during a rest break can lower work output in the subsequent work period because a warm-up period is required when work is resumed. Experienced data entry operators are likely to be sensitive to the tradeoff between recovery and loss of adaptation to work, and may terminate microbreaks early to maintain their efficiency. This tradeoff also may explain why breaks became shorter as the morning and afternoon sessions progressed even though 'fatigue' had accumulated (i.e., the rationale might have been 'If I stop too long now, I'll never get going again').

In summary, the results suggest that while frequent, discretionary-length microbreaks are beneficial, they are not utilized effectively by data entry workers. There is a tendency for workers to terminate microbreaks before performance recovery is complete. Such an effect may be exacerbated in the presence of additional pressures to perform (for example, working under incentive pay conditions; Schleifer and Amick 1989). Therefore, for workers to receive the full benefits of scheduled microbreaks, microbreak length may need to be more closely controlled to assure complete recovery.

5. Conclusion

The results of this study indicate that data entry workers tend to prolong microbreaks in relation to their perception of fatigue, and that microbreaks are instrumental in reducing fatigue and associated performance decrements. The data also suggest, however, that scheduled microbreaks of discretionary length may be of limited effectiveness in combatting fatigue.

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On a étudié les effets des pauses brèves sur les performances et le bien-être d'opérateurs effectuant une tâche de saisie de données, hautement répétitive. Des opérateurs entraînés (N = 20) ont effectué la tâche au cours d'une expérience de deux jours, en situation simulée de bureaux. Chaque jour a été subdivisé en 6 périodes de 40 minutes de travail. Les sujets avaient une courte pause (micro-pause) sur leur poste, au milieu de chaque période de travail. Ils avaient la consigne d'interrompre cette pause lorsqu-ils se sentaient prêts à poursuivre leur travail. Pendant chaque moitié de la période de travail, on a enregistré la cadence de frappe du clavier, le taux d'erreurs, le taux de correction des erreurs, la fréquence cardiaque et la variabilité de la fréquence cardiaque. En outre, on a relevé leur état de forme subjective avant et pendant la période de travail. La durée moyenne des micro-pauses était de 27,4 s. Une cote élevée pour la fatigue et l'ennui, pendant la période de travail, était associée à des micro-pauses plus longues; ce qui suggère que la pause était auto-ajustée en fonction de l'état de la forme. Par ailleurs, les taux de corrections et la fréquence cardiaque étaient plus bas après les micro-pauses longues, ce qui implique que le degré de récupération dépendait de la longueur de la micro-pause. Cependant la comparaison des performances de frappe et du taux de corrections avant et après la micro-pause, a révélé que la performance se détériorait après la micro-pause, ce qui suggère que les sujets interrompaient leur micro-pause avant la récupération complète.

Die Wirkung von kurzen Erholungspausen auf Leistung und Wohlfühlen wurden für eine hoch repetitive Dateneingabe-Tätigkeit ausgewertet. Erfahrene Dateneingabe-Operateure (N = 20) führten die Tätigkeit in einem zwei-Tage Experiment in einer simulierten Büroumgebung durch. Jeder Tag wurde in sechs, 40 Minuten dauernde Arbeitsperioden eingeteilt. Die Versuchspersonen nahmen eine kurze Erholungspause an der Arbeitsstation (Mikrounterbrechung) in der Mitte jeder Arbeitsperiode. Die Versuchsperson wurde angewiesen, diese Mikrounterbrechung zu beenden, wenn sie bereit war, die Arbeit wieder aufzunehmen. Die Rate der Tastendrucke, die Fehlerrate, die Korrekturrate, die Herzschlagfrequenz und die Variabilität des Herzschlags wurden für beide Hälften der Arbeitsperiode aufgenommen. Zusätzlich wurden die Zustände der Stimmung vor und während der Arbeitsperiode bewertet. Es wurde gefunden, daß die Dauer der Mikrounterbrechungen im Durchschnitt 27,4 s betrug. Hohe Raten der Ermüdung und der Langeweile während der Arbeitsperiode waren mit längeren Mikrounterbrechungen verbunden, was darauf hindeutet, daß die Unterbrechungsperiode in Beziehung zum Stimmungszustand von den Versuchspersonen selbst angepaßt wurde. Zusätzlich waren die Korrekturrate und die Herzschlagfrequenz nach einer langen Mikrounterbrechung niedriger. Daraus ergibt sich, daß der Grad der Erholung mit der Länge der Mikrounterbrechung verknüpft war. Ein Vergleich der Tastendruck-Ausgabe und der Korrekturrate vor und nach der Mikrounterbrechung läßt jedoch erkennen, daß die Leistung sich nach der Mikrounterbrechung verschlechterte, was darauf hindeutet, daß die Versuchspersonen die Mikrounterbrechung beendeten, bevor vollständige Erholung eintreten konnte.

成績と健康に及ぼす微小休憩の影響を繰返頻度の高いデータ入力作業で評価した。経験のあるデータ入力オペレータ（N＝20）がこの作業を2日間の実験で模擬事務所環境下で実施した。1日を60の40分作業時間に分けた。被験者は各作業時間の中間でワークステーションで微小休憩を取った。被験者は作業を続ける用意ができたときに微小休憩を終了するようにと指示された。キーストローク率、誤り率、修正率、心拍数、心拍数ばらつきを作業時間の半分毎に評価した。さらに、作業時間前と作業時間中の気分の状態も評価した。微小休憩は平均して27.4秒の長さであった。作業時間中の疲労と退屈の高い評点は長い微小休憩と相関しており、休憩時間が気分の状態に従って自己調整されることを示唆した。さらに、修正率と心拍数は長い微小休憩の後では低く、回復程度が微小休憩の長さに関係していることを示した。微小休憩前後のキーストローク率と修正率を比較すると、しかし、成績は微小休憩の後に悪化し、これは被験者が完全に回復する前に微小休憩を終了することを示した。