INSTRUMENTATION & TECHNIQUES

A program for studies of altered sleep-wake schedules and performance

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Studies of the effects of variations in sleep-wake schedules on human performance tend to run for several days and involve extensive repeated testing in order to take into account time-of-day and cumulative cross-day effects (Broughton & Ogilvie, 1992; Monk, 1991; Webb, 1982). Such research typically addresses issues pertaining to sustained operations and shift work and is often more appropriately conducted in the field. The present paper describes a computer-automated system designed to administer sleep-wake schedules and performance tests, and to store results of such testing in file formats that are easy to access with commercially available statistical packages.

Various sleep-wake schedule protocols have been used to study performance (Carskadon & Dement, 1987; Dinges, 1986; Dinges, Orne, & Orne, 1985; Lavie, Gopher, & Wollman, 1987; Lubin, Hord, Tracy, & Johnson, 1976; Mullaney, Kripke, & Fleck, 1983; Tilley & Wilkinson, 1984; Webb, 1987). Fluctuations in performance levels, like those associated with emergency and sustained operations, shift work, jet lag, and disorders of excessive sleepiness, are a function of both time-of-day and sleep-wake patterns. In order to assess the alteration of sleep-wake schedules properly, performance testing must be frequent throughout the waking period.

Continuous testing paradigms often involve schedules that span days or weeks. When several subjects are involved, a tradeoff exists between capacity for subject supervision and total running time of the experiment. If

subjects are run concurrently, increased supervision is required, whereas, if subjects are run sequentially, the total experimental time can become excessive. Computer administration of sleep schedules and performance test sessions has the advantage of reducing the amount of individual supervision needed, thus allowing more subjects to be studied in less time.

The long protocols common in establishing altered sleep-wake schedules often involve some discomfort for subjects, owing to sleep deprivation, or sleep fragmentation. As a result, personality factors may affect subjects' performance significantly by influencing their moods or attitudes toward the study. In these situations, administration by computer can be beneficial by enforcing the protocol while permitting time for the maintenance of good rapport between subjects and experimenters.

The maintenance of precise timing becomes difficult in the establishment of sleep-wake schedules during multiple days, yet it is essential for the investigation of both sleep and chronobiological phenomena. In the measurement of sleep inertia, it is critical to control test time after awakening and to ensure that subjects do not fall asleep during test sessions (Dinges et al., 1985). Accurate description of time-of-day effects requires the precise temporal placement of bed periods and execution of test sessions.

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The traditional administration of performance and self-evaluation batteries involves data collection from a variety of sources, such as pen and paper or the audio recording of oral responses. These methods necessitate the later transcription of data to the computer for analysis. This has led a number of investigators to develop computer software to directly acquire and analyze performance test data (Angus & Heslegrave, 1985; Bittner, Smith, Kennedy, Staley, & Harbeson, 1985; Brand & Houx, 1992; Bremer, 1989; Kaplan, 1982; Mullaney, Fleck, Okudaira, & Kripke, 1985; Popper, Dragsbaek, Siegel, & Hirsch, 1988; Ryman, Naitoh, & Englund, 1984). When a computer collects the data, transcription is no longer necessary, errors are minimized, and time is saved. In addition, data contamination is reduced by the use of standardized computer instructions and by minimizing the experimenter-subject social contact in the testing environment.

We describe here an automated schedule execution program (ASEP) developed to alleviate some of the preceding difficulties, by both providing subjects with a sleep-wake protocol to be followed and administering performance tests and sleep quality and self-evaluation questions. To our knowledge this is the first program to combine sleep-wake scheduling with performance tasks chosen to be sensitive to such manipulations.

PROGRAM OPERATION

The ASEP program can be run on any IBM-PC-compatible computer equipped with a hard disk and a math coprocessor. It was developed with C and assembly languages and requires approximately 110K of DOS memory while running. Timing is based on the standard timer that maintains the DOS clock and therefore operates independently of processor speed. In our studies, subjects used a notebook computer running the ASEP software driven by a preprogrammed personalized schedule (see Figure 1, here a Compaq LTE). Each system was equipped with a serial four-choice reaction time device. An additional numeric keypad (not necessary for program operation) was also provided, simplifying the method of data entry on the notebook computers that we used. For all tests, subjects are seated in a cubical area on a comfortable chair; the notebook computer is on a desk, with the screen some 40–45 cm from the eyes. The screen intensity was self-adjusted for comfort.

The program uses three system files in order to run: a *configuration*, a *status*, and a *schedule* file. All three are text files that can be viewed and modified with a text editor.

The configuration file *as.cfg* provides subject information. This information includes the subject name and identification number, the data file prefix, the start date of the experiment and a schedule file name. A typical configuration file is shown below.

```
as.cfg
name:DD
```

```
number:1
start date:03/5/1991
data file:DD
schedule file:DD.SCH
```

The status file *as.sts* is created and used by ASEP to record its running status when operation is to be suspended. It can be used to resume or begin execution at any point in the sleep-wake schedule defined by the schedule file specified in *as.cfg*.

The schedule file specified in *as.cfg* defines the sleep-wake schedule and testing protocol for ASEP. The schedule file contains a list of tasks that initiate sleep periods and test sessions. A typical schedule file is shown below.

```
DAY 3          ; March 17
23:41:49 G    ;
;Short Nap Condition. (TEST DAY)
DAY 4          ; March 18
00:01:49 B    ;
06:20:54 A    ;
06:37:54 G    ;
07:07:54 G    ;
;Breakfast
08:07:54 G    ;
08:42:41 G    ;
09:02:41 B    ;
09:30:45 A    ;
09:47:45 G    ;
10:17:45 G    ;
10:57:45 G    ;
11:40:00 G    ;
12:00:00 B    ;
12:28:04 A    ;
12:45:04 G    ;
13:15:04 G    ;
;Lunch
14:40:19 G    ;
15:00:19 B    ;
15:25:23 A    ;
15:42:23 G    ;
```

Tasks before sleep periods are indicated by the B (before-sleep episode session) following a specified time, and test-session tasks are indicated by the letters G (general session) and A (after-sleep episode session). Each line of the schedule file provides either a target task plus its corresponding time or an experimental day number. Tasks for different days are separated by DAY specifiers, and the tasks following are initiated on that experimental day. Day and target entries must be listed in chronological order. Semicolons denote a trailing comment enabling the file to be documented.

As is implied by the previous sample schedule file, our investigations involved the definition of three separate schedulable task sessions for ASEP to perform: a preparation session before a scheduled nocturnal sleep or nap bed period (B), a test session after a bed period (A), and a general test session (G) for sessions presented

at other times between scheduled sleep periods. Each task is defined by the set of subtasks listed below:

B Session Tasks

1. two-part warning of upcoming sleep period
2. instructions for synchronizing the computer with external devices
3. instruction to turn out lights and go to sleep

A Session Tasks

1. alarm clock signal to wake subject from sleep period
2. instructions for synchronizing the computer with external devices
3. sleep and mood questions prior to performance testing
4. the Descending Subtraction Test
5. the Grammatical Transformation Test
6. the Four-Choice Reaction Time Test
7. the Grip Strength Test
8. the Subjective Estimation Report Questions
9. oral temperature reading
10. sleep and mood questions after performance testing
11. report of mental experience for previous sleep period
12. Stanford Sleepiness Scale

G Session Tasks

1. two-part warning of upcoming test session

2. instructions for synchronizing the computer with external devices
3. the Descending Subtraction Test
4. the Grammatical Transformation Test
5. the Four-Choice Reaction Time Test
6. the Grip Strength Test
7. the Subjective Estimation Report Questions
8. oral temperature reading
9. Stanford Sleepiness Scale

The B session task involves instructions to guide the subject through the preparations for a scheduled sleep period with the responsibility for subject compliance remaining with the experimenter. In our own applications involving various nap schedules, concurrent ambulatory physiological sleep-wake monitoring has been performed (Medilog 9000 recorders, Oxford Medical Systems). An alternative approach might be wrist actigraphy, the patterns of which concord over 90% with the sleep-wake state (Kripke, Mullaney, Messin, & Wyborne, 1978; Mullaney, Kripke, & Messin, 1980; Sadeh, Alster, Urbach, & Lavie, 1989). Execution of each scheduled sleep period begins by presenting the subject with a two-part warning, one 3 min prior to lights out and the other warning 1.5 min prior to lights out. The subjects are instructed to set event markers for synchronizing the computer with external devices and then to turn out their lights and go to sleep. The onset and offset times of each scheduled sleep period can be preset to an accuracy of 1 sec. Any series of schedules of alterations of sleep length and timing (sleep reduction, sleep extension, changes in cir-

Figure 1. The portable notebook computer running the ASEP program assists subjects in maintaining sleep-wake schedules and administers performance tests. Also shown are a serial four-choice reaction time interface and external numeric keypad.

cadian sleep placement, various polyphasic sleep patterns) can be programmed.

The scheduled wake-up time for the subjects is marked by the execution of an A session task. Rather than the two-part warning, this task begins with an "alarm clock" signal consisting of tone bursts of 3-sec duration followed by 3 sec of silence. Consecutive tone bursts get increasingly louder until a maximum volume of 75 dB is reached.¹ The subject has only to hit any key on the computer keyboard to shut off the alarm, and the reaction time to the key hit is measured. A battery of sleep and self-evaluation questions as well as selected performance tests is then administered.

Between the completion of the A session task and the next B session sleep period, ASEP collects data by administering G session tasks at scheduled intervals. A G session task begins with a two-part warning identical to that of a B session. The subject is then guided through a set of self-evaluation questions and performance tests similar to those for the A session but including no sleep-related questions. All input from the subjects is timed, and the subjects are warned via the computer's buzzer when more than 30 sec of inactivity have elapsed. This aids the subjects in maintaining wakefulness during test sessions, and it ensures a timely completion of each test-session task. ASEP records the actual start time and duration of each session task performed, as well as the start times and durations of all subtasks within a session.

PERFORMANCE TASKS

At present, four performance tests have been chosen and implemented because of their sensitivity to altered sleep-wake schedules, relatively low learning effects, and overall reliability. They are: the Descending Subtraction Test (DST; Evans & Orne, 1975), Baddeley's Grammatical Transformation Test (GTT; Baddeley, 1968), the Four-Choice Reaction Time Test (FCRT; Wilkinson & Houghton, 1975), and a Grip Strength Test (GRIP; Aschoff, Giedke, Poppel, & Wever, 1972).

The DST measures information processing ability through repeated subtractions with decrementing subtrahends. Each occurrence of the test presents the subject with a randomly generated root number in the range of 500 to 999, from which he/she must subtract the number 9. From the difference, 8 is subtracted, resulting in a new difference from which 7 is subtracted. This continues until a subtrahend of 2 has been used to generate a difference and then the process repeats by using 9 as the subtrahend. Responses are entered with the numeric keys on the keyboard, and the subject's previous difference response is continually displayed on the screen. The test runs to a maximum of 2 min or 150 responses. The responses are used to calculate the total correct, the errors, and the percentage correct.² All three values are saved.

Baddeley's GTT provides a measure of logical reasoning ability requiring the subject to make true or false responses to logical relational statements such as "A pre-

Figure 2. The four-choice reaction time device. Panel a shows the circuit schematic for one of the four stimulus-response elements in the reaction time device; panel b shows the pin connections between the computer's parallel printer port and the four stimulus-response elements in the reaction time device.

cedes B-BA." A total of 64 relational statements is used, with the order of presentation generated randomly for each occurrence of the test. Test items are displayed one at a time. The test's duration is set to a maximum of 2 min, with total responses, total correct, errors, and percentage correct computed at test completion.

The FCRT measures a combination of attentional capacity and response speed. It uses a box external to the computer that contains four stimulus lights and four response buttons each in a square formation (see Figure 1). The computer controls and randomly generates the stimuli and monitors responses through the parallel printer

port, which is used to connect the box to the computer. Figure 2a illustrates the stimulus-response circuit for a single reaction time element. Four separate stimulus-response circuit elements are present in the reaction time device. Figure 2b identifies the pin interface for connecting the reaction time device to the computer's parallel printer port. ASEP uses the computer's internal clock for timing but reprograms the clock to attain greater than millisecond resolution. The reaction time responses are measured to millisecond accuracy. The ASEP version of the FCRT test was developed at the University of Ottawa's Human Neuroscience Research Unit, but its specifications are derived from those outlined in Wilkinson and Houghton (1975). The start times of each trial's stimulus are recorded for intratest analysis. The test runs for a maximum of 5 min or 800 responses, with the total number of trials, the total correct, errors, and percentage correct computed at test termination.

The GRIP test instructs the subject to perform three grip strength trials on a commercial hand-held dynamometer and prompts the subject to key in the results of each trial. Each value entered is checked to ensure that it lies in the valid range for the dynamometer. From the three trials, the mean, standard deviation, and variance are computed for consistency of data treatment.

SELF-EVALUATION QUESTIONS

Self-evaluation questions are used to collect data concerning the subjects' emotional and mental states and quality of sleep in the preceding bed period. Subjective evaluation subtasks are presented as visual analog lines, numeric input scales, or multiple-choice questions. The visual analog scale is used to measure how subjects rate themselves with respect to a descriptive statement. The scale is presented as a horizontal line whose center, they are instructed, represents the value of how they would usually rate themselves; toward the right is a greater value than usual, while to the left is less than usual. For example, for the variable *sleepiness*, the extreme right represents the most intense sleepiness ever encountered; the center, average sleepiness; and the extreme left, the maximum alertness ever experienced. Responses are given by moving a cursor along the visual analog line, which contains 38 discrete levels. Cursor movement is controlled by the keyboard's horizontal arrow keys, and a selection is made by pressing the enter key.

The subjective evaluation tasks include a subjective estimation report (SER) inventory, which is a modified version of Thayer's Adjective Checklist (Thayer, 1967, 1978). It consists of 34 adjectives selected for known sensitivity to the multidimensional nature of sleepiness, which are scored on a visual analog basis. The Stanford Sleepiness Scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) is also administered. Seven levels of sleepiness are described and identified by the numeric value assigned to them. The subject indicates

the appropriate level by selecting the corresponding number key.

OUTPUT

A total of 19 files are used to store the data resulting from the execution of targets, with each test session generating just over 12,000 bytes of data. Variables are grouped according to subtask and to function and then stored in separate subtest files. Raw data files are binary, whereas processed data are stored in text format. Data file names are derived from the subject's data file prefix and subject number; and the extension reflects the task or the type of data contained in the file.

Text files containing processed data are created for all results of performance and self-evaluation tasks. These files are written in matrix format, with each column representing a unique variable and each line containing data for a single test session. The first five fields of a text data file line contain test-session identification information. This consists of the subject identification number, session identification (type of test session), start time of target taken from the schedule file, actual start time of the target (useful in identifying delayed sessions), and a subtest identification number. The data variables occupy all remaining fields. This format was adopted for accessibility of data by commercially available statistical software packages such as BMDP and SPSS and for spreadsheet packages such as Lotus 1-2-3, Borland's Quattro, and Microsoft's Excel. The sample data file below contains results from the DST. The first column shows that this data belongs to Subject 6. Next is the type of session in which these data were collected, where a general G session is denoted by 0, an A session by a 1 and a B session by a 2. The next two columns are the scheduled start time and actual start time of the session in seconds from the beginning of the study, and the fifth column shows the DST's subtask ID of 1. The remaining four columns are the total number of responses, the number of correct responses, the number of incorrect responses, and the percentage correct in that order.

sn	ses	sched	actual	tsk	n	c	e	%
6	0	298065	298065	1	17	16	1	94.1
6	0	301200	301200	1	17	16	1	94.1
6	1	304084	304084	1	12	11	1	91.7
6	0	305104	305104	1	13	12	1	92.3
6	0	306904	306904	1	18	17	1	94.4
6	0	312019	312019	1	16	16	0	100.0

Three of the performance tests—the Baddeley GTT, the DST, and the FCRT test—all generate the same four processed variables: the total number of responses, the number of correct responses, the number of incorrect responses, and the percent correct. The redundancy was introduced for the ease of further analysis. Processed variables from each GRIP test are also stored. Visual analog self-evaluation results are transformed from 38 discrete levels into a value between 1 and 100, while

multiple choice and numeric inputs (such as the Stanford Sleepiness Scale) are stored in their immediate form.

Binary files are used to store raw performance test data as well as seed values used in random number generation. The seed values used to initialize the random number generator are saved so that specific task runs can be reproduced. The actual DST and GTT responses for each session are saved so that the pattern of errors can be examined. Raw data from each FCRT stimulus-response trial, consisting of the particular stimulus light, the actual response button depressed, the stimulus-response reaction time, and the trial start time are saved. These data are used for off-line analyses of individual reaction times and patterns of response errors.

APPLICATIONS

ASEP has gone through three versions. The first operated solely as a sleep-wake and performance schedule administration program, alerting experimenters and subjects about upcoming test sessions. It was used in our laboratory's studies of the efficacy of different daytime nap schedules following 4 h of anchor sleep (Stampi, Broughton, Mullington, & Campos, 1990a, 1990b; Stampi, Mullington, Rivers, Campos, & Broughton, 1990). Although the DST, GTT, FCRT test, and subjective evaluation subtests were included, they were not administered by computer, but were carried out by means of written and taped oral responses. Data were later transcribed for analysis and compared with prior and concomitant sleep-wake states objectified by ambulatory physiological monitoring.

The next version of ASEP was used in a polynap study of 60-min "days" in which subjects slept for 20 min at a time followed by 40 min of wakefulness (unpublished data). During the 40 min of wakefulness, subjects were required to do performance testing immediately upon waking and 20 min after waking, continuously around the clock for several consecutive days. The physiological monitoring and performance tests were the same as those listed above, with the exception that the FCRT test had not yet been implemented into the ASEP, and there were fewer subjective estimation items. Four subjects were run simultaneously in this protocol.

The current third version of the software was developed for use in a study of the efficacy of scheduled naps in the management of excessive daytime sleepiness in narcolepsy-cataplexy (Mullington & Broughton, 1994, *in press*). This study had three experimental conditions. In one condition, subjects received their full habitual total sleep time per 24 h (as determined by sleep logs kept for five stimulant-free days just prior to entry into the study) in one major bed period. In the other two conditions, 25% of habitual total sleep time per 24 h was given as either a single long nap in the middle of the waking period or five short naps spread equidistantly throughout the day. Eight subjects were run through the experimental conditions in two groups of 4 subjects. Scheduling was complicated by the fact that the sub-

jects had differing prestudy total sleep times, which needed to be divided into percentages for the protocols. Thus, every subject was on an individually tailored sleep-wake and performance testing schedule.

In all studies, learning sessions were programmed prior to experimental manipulations of the sleep-wake schedule. Typically, it has taken four to eight sessions on the DST and GTT tasks and three to five on the FCRT test for learning to be complete. This is similar to the tests done manually. Subjects have not sensed any significant differences between approaches, and post-learning session baseline data in rested normals have been similar. There is no doubt, however, that computerization has increased efficiency of data gathering. All the protocols described above would have been exceedingly difficult to conduct in a completely manual environment.

DISCUSSION

A number of available software programs for performance testing have been developed for nonportable computers that are unusable in the field (Bittner et al., 1985; Brand & Houx, 1992; Mullaney et al., 1985; Ryman et al., 1984) and are restricted to applications in the laboratory. Those developed for portable or pocket computers (Bremer, 1989; Popper et al., 1988) have generally not included tests for their sensitivity to sleep-wake manipulations and do not have software for scheduling of sleep-wake status or timing of performance tests. Other software packages can only be run on less common hardware (Bremer, 1989). Unlike other software, the ASEP program was developed specifically for computer-controlled sleep-wake and performance test scheduling using performance tasks selected for sensitivity to sleep-wake manipulations with a format usable on virtually all DOS-based PC-compatible portable and notebook computers.

ASEP's utility has increased with each successive version of the program. The progression has been toward increased automation and decreased demands on direct experimenter supervision of the sleep-wake schedule and associated test sessions. The benefits of this reduced interaction between experimenter and subject are threefold. First, the use of computers enables the standardization of instructions and test administration conditions. Second, and related to this, the reduction of personal contact in the testing process minimizes the influence of the experimenter's personality and mood fluctuations on performance results via their effects on the subject's mood and motivation. Third, the experimenter becomes free to attend to other duties involved in running the experiment.

The automatic storage of results enables more economical data processing. In the first version of this program, subjects were awakened by telephone, given their DST number, and required to perform the test aurally over the phone. The responses were tape recorded and later transcribed for computer. On the average, transcription took twice the time it took to perform the test.

With protocols having DST lengths of 5 min and averaging 25 tests per day, transcription involved over 4 h of analysis time per experimental day per subject. For tests such as the GTT and subjective estimation reports, the automated data storage protected against loss of test sheets or possible alteration of results by subjects after the allotted test time had passed.

As well as improving efficient use of human resources, the automated system has helped to improve data collection and ensure accurate timing of test sessions and bed periods. This is of considerable importance for the quality of data gathered in studies of sleep inertia and circadian (and ultradian) rhythms in performance. The timing information stored in the files is useful in the investigation of phase relationships between performance and such physiological measures as EEG and temperature. It also enables the experimenter to verify that tests were done at the prescribed times and to pinpoint any unusual delays between individual subtests within a test session. The system records time in seconds from the beginning of the study and so can be used to analyze performance on "days" different from 24 h (i.e., ultrashort "days" or extended "days" lasting more than 24 h), or of length specified by the scheduled protocol.

There are limitations to any computer system in such studies, and experimenters need to be aware of them. For example, subjects can unplug a component (such as the four-choice box or the numeric keypad) or turn the computer off in an act of automatic behavior brought on by extreme sleepiness. This occurred during the third study in which the program was used. A narcoleptic subject turned the computer off in response to a "press any key" prompt made by the computer. Luckily the experimenter was standing close by and was able to reenter the program at the right time in order to continue the scheduled test with minimal time loss.

Another limitation is that the computer can do nothing beyond beeping at a subject who is unable to wake up or, as can occur in pathological sleepiness, who has fallen asleep on the computer keyboard. A human experimenter is able to shake the subject and call his/her name repeatedly to force an arousal. It is extremely useful to have both experimenters and subjects keep a careful record of the occurrence and timing of anything that goes wrong. With the experimenter replaced by the computer, there is otherwise no way of knowing when an error has been made that the subject is unable to correct, or when the subject has stopped performing in the middle of a test for reasons other than being asleep. Using computers to administer tests makes it all the more important for subjects and experimenters to keep records of human and technical factors that create difficulties.

It might be thought that computer-presented performance tasks would be inherently less motivating than manual tasks. This has not proved to be the case in the laboratory. In both approaches, even after the test has been learned fully, the experimenter remains nearby the subject. In field testing outside the laboratory and without such direct supervision, this might pose a problem,

although there is no inherent reason why reduction of motivation under such conditions would be greater than it would be for manual tasks.

This use of computers has been received very well by subjects participating in experiments conducted with ASEP. More and more, computers are becoming an indispensable everyday tool for the general population, and their increasing portability makes them a real asset for field research. If the experimenter is aware of the limitations of the technology, it will facilitate increased productivity and developments in areas of research requiring repeated testing and altered sleep-wake schedules.

To run the ASEP program, it is necessary to use an IBM-AT-compatible computer with at least a 12-MHz 286 processor, 640K of conventional memory, a 287 math coprocessor, a 40-Mb hard disk, and DOS Version 4.0 or greater. Persons interested in obtaining a copy of ASEP can do so for a nominal fee to recapture development costs by contacting R. Broughton, Division of Neurology, Ottawa General Hospital, 501 Smyth Rd., Ottawa, ON, Canada K1H 8L6.

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NOTES

1. Since the PC's speaker sounds with different intensities at different frequencies, a sound pressure meter was used to measure intensity at a distance of 3 ft for different frequencies for each computer. The alarm signal was constructed by presenting different frequencies in an order that resulted in increasing volume.

2. Subjects were given standard instructions for performing the DST. They were also instructed that in the case of forgetting the subtrahend (the number being subtracted), they were to select one between 2 and 9 and continue with the test. The first step in scoring the DST is to generate a list of differences, D_i , by subtracting consecutive responses (the total number of responses is the maximum value for i). When all responses are correct, the resultant sequence of differences should be: 9 8 7 6 5 4 3 2 9 8 7 6 5 4 3 2 9 8, . . . D_i is scored correct if $D_i + 1 = D_{i-1}$ (or $D_{i-1} = 2$ when $D_i = 9$). When D_i is not in sequence with the D_{i-1} term, it is compared with the sequence starting with the D_{i-2} term. D_i is correct if $D_i + 2 = D_{i-2}$ (or $D_{i-2} = 2$ when $D_i = 8$ or $D_{i-2} = 3$ when $D_i = 9$). If D_i is not correct with respect to the D_{i-1} or D_{i-2} terms, it is similarly compared with the sequence starting with the D_{i-3} term. When the D_i term is not in agreement with the sequence beginning with any of the three previous terms, the response is considered incorrect.

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