Single-component microcomputer-driven assessment of attention

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The Gordon Diagnostic System (GDS) is a single-component microcomputer-based instrument that can be used to administer 11 psychological tests. The game-like tasks provide objective data for evaluating possible attention-deficit hyperactivity disorder or other conditions that affect a person's ability to sustain attention and exert self-control. The core of the instrument is an integrated circuit with a microprocessor, a random access memory, and an erasable, programmable read-only memory (EPROM). It can be programmed with an IBM PC and an EPROM programmer. The assembly language source is compiled into machine language, which is used to simulate the GDS on the IBM PC or is "burned" into the ROM. The memory is erasable with ultraviolet light, so revisions can be made easily. The GDS illustrates that "custom" programming a ROM is not limited to large industrial concerns, and that it can be done within small research groups.

In this era of ever-increasing microcomputer capacity, it is easy to lose sight of the power that is available in single-component integrated circuits for use in special-purpose applications. This report describes the Gordon Diagnostic System (GDS; Gordon, 1983), a device that uses a single-component microcomputer to test children for attention-deficit hyperactivity disorders (American Psychiatric Association, 1987). The integrated circuit contains a central processing unit, a random access memory (RAM), an erasable, programmable, read-only memory (EPROM), two ports, a data bus, and a few other external connections. These allow it to drive the operation of a moderately complex psychological testing instrument that is contained in a small, portable box (Figure 1).

FUNCTION OF THE INSTRUMENT

The GDS can be used to administer eleven psychological tests (see the Appendix). The administration of the game-like tasks provides the examiner with objective data that is a useful part of an evaluation of a person's ability to sustain attention and exert self-control (Gordon, 1987). The GDS has been standardized on the basis of protocols from over 1,400 normal children and adults, and test-retest reliability has been established (Gordon & Mettelman, 1988). The validity of the device has been examined in terms of its relationship to other neuropsychological instruments (Grant, Ilai, Nussbaum, & Bigler, 1990), behavior-based measures (McClure & Gordon, 1984), and a variety of teacher and parent ratings of attention-deficit hyperactivity disorders (Gordon, Mettelman, Smith, & Irwin, 1990). The general finding is that the GDS scores typically agree with other measures of the presence or absence of attention-deficit hyperactivity disorders. They also contribute unique information that is not available from other sources of data. The device has been used to monitor responses to stimulant medication (Barkley, Fischer, Newby, & Breen, 1988; Brown & Sexson, 1988), as well as in the evaluation of AIDS-related complex (Saykin et al., 1990), closed head injury (Risser & Hamsher, 1990), Fragile X syndrome (Hagerman, Murphy & Wittenberger, 1988), and Alzheimer's disease (Gordon, Beeber, & Mettelman, 1987).

The front panel of the GDS (Figure 1) is intentionally simple. It includes a response button, a three-digit display, a correct-response indicator light, and a game-over light. The rear panel (not shown, and inaccessible to the test subject) includes another three-digit display as well as the buttons and switches necessary to select the tasks to administer and (optionally) the time parameters for each task. The results of the tasks can be viewed on the rear display or transmitted to a printer or computer.

The GDS administers two types of paradigms: delay tasks and vigilance tasks. Delay tasks require the subject to inhibit responding in order to earn points. The subject is instructed to press the response button, wait a while, and then press it again. If the subject refrains from responding for at least 6 sec (in the standard delay task),
a light flashes and the number on the front display is incremented. If the subject responds too soon, there is no reward, and the waiting period is restarted. The number of correct responses and the total responses are recorded by the GDS (Table 1).

Vigilance tasks present to the subject a series of digits on the front display. In the standard vigilance task, the child is told to press the response button every time a "1" is followed by a "9." The GDS records the number of correct responses, missed "1"/"9" combinations, and extraneous responses. In the preschool version, the child is told to respond to a single digit, "1," instead of the pair. A third version of the vigilance task presents pseudo-random distracting digits on either side of the central stimulus digits.

Each task (see the Appendix) is divided into time blocks whose beginning and end are not apparent to the subject being tested. Each block has two time parameters—an interval and a duration. For the delay tasks, the interval is the time that the subject must wait between buttonpresses to get a "point." For the vigilance tasks, the interval is the time between presentation of digits on the display. For both tasks, the duration is the length of time that each block lasts. When the GDS is turned on, there are default time parameters specific to each task. If the examiner wishes to use other parameters, the appropriate values can be entered on the keypad on the rear panel.

**ELECTRONIC COMPONENTS**

The core of the device is the single-component computer shown within the inner rectangle (8749 microprocessor, Figure 2). This integrated circuit (8749H, Intel Corp., Santa Clara, CA) contains an 8-bit microprocessor (CPU) that operates at a frequency of 4 MHz. It also has a 128-byte RAM and a 2,048-byte EPROM. The data bus and two ports are connected to a few accessory integrated circuits and to the switches and displays on the front and rear panels.

The operation of the device is directed by the program stored in the EPROM. Each successive 1- or 2-byte instruction is read from the EPROM into the CPU, which uses the instructions to direct the flow of data among the accumulator, registers, ports, and data bus. When appropriate, the status of the 17 switches on the front and rear panels is examined by the CPU. It also generates the numbers displayed on the front and rear panels and the data transmitted to the serial port and printed by or stored in an external computer.

Between tasks, the CPU monitors the keypad on the rear panel and detects when a number has been pressed to select the task that is to be performed. It begins the task when it detects that the start button on the rear panel has been pressed. During the tasks, the internal timer measures the delay or digit presentation interval and the duration of each of the blocks, using either the default or examiner-specified parameters. The CPU repeatedly tests to determine whether the front-panel response button has been pressed. For the delay tasks, if such a press has occurred long enough after the last press (more time elapsed than the specified interval), then the CPU illuminates the correct indicator light for 1 sec and increments the number of points appearing on the front dis-