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The Delis-Kaplan Executive Function System

A Review

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The Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001a) is a set of standardized tests for comprehensively assessing higher-level cognitive functions, referred to as *executive functions*, in both children and adults (aged 8 to 89). Executive functions draw on the individual's more fundamental or primary cognitive skills (i.e., attention, language, and perception) to generate higher levels of creative and abstract thought.

The D-KEFS is made up of nine tests that measure a wide range of verbal and nonverbal executive functions. Each test is designed to be a stand-alone instrument that can be administered individually or along with other D-KEFS tests, depending on the assessment needs of the specific examinee and/or the time constraints on the examiner.

The nine D-KEFS tests fall into three general categories. Some of the D-KEFS tests are relatively new tests developed by Dr. Dean C. Delis at the University of California in San Diego, Dr. Edith Kaplan at Suffolk University in Boston, and Dr. Joel H. Kramer at the University of California in San Francisco. Some are modifications of tasks that have been used in past experimental studies but not developed into standardized clinical instruments, and some are modifications of existing clinical instruments.

The D-KEFS consists of the D-KEFS Trail Making Test, the D-KEFS Verbal Fluency Test, the D-KEFS Design Fluency Test, the D-KEFS Color-Word Interference Test, the D-KEFS Sorting Test, the D-KEFS Twenty Questions Test, the D-KEFS Word Context Test, the D-KEFS Tower Test and the D-KEFS Proverb Test. The D-KEFS Sorting Test was formerly called the California Card Sorting Test (CCST; Delis, 1988, as cited in Delis, Kaplan, & Kramer, 2001b, p. 1); Delis, Kaplan, & Kramer, 1995a, as cited in Delis et al., 2001b, p. 1). The D-KEFS Proverb Test was previously the California Proverb Test (Delis, Kaplan, & Kramer 1995b, as cited in Delis et al., 2001b, p. 1).

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Purpose and Recommended Use

The nine D-KEFS tests embrace a cognitive-process approach to assess the component functions of higher-level cognitive tasks. Two general types of component processes are isolated and measured by the D-KEFS tests. These processes include more fundamental cognitive skills on which the higher-level executive functions of a particular task depend, as well as multiple higher-level cognitive functions that may contribute to successful performance on a particular test. The D-KEFS was designed to be used in a flexible manner. The examiner can be flexible in terms of administering only some of the D-KEFS tests and in administering only some of the conditions of each D-KEFS test. It is acceptable for the examiner to administer early conditions of a test and omit later conditions; however, the reverse is not true because of alterations in standardized procedures.

The D-KEFS was designed to be used in clinical settings to assess mild brain damage in general and mild frontal-lobe involvement in particular. As well, it was designed for use by school psychologists in school settings. In school settings, one of the goals of the authors of the D-KEFS was to introduce the importance of complementing the assessment of those abilities measured by traditional tests of intelligence and other basic achievement skills with those of higher-level cognitive abilities. Therefore, the D-KEFS tests can be administered and performance interpreted by school psychologists to address questions about a child's capacity for higher-level abstract and creative thinking. However, the authors of the D-KEFS have cautioned that interpretations about the integrity of brain functions based on D-KEFS test results should only be made by psychologists who have had adequate training in neuropsychology.

Major New Features of the D-KEFS

The D-KEFS represents an important development in the measurement of executive functions for a number of reasons. First, it provides a rigorous empirical means for determining whether poor performance on a test is because of deficits in more fundamental cognitive skills or deficits in higher-level executive functions. Use of the D-KEFS with a traditional intelligence test is an excellent way for the school psychologist to compare performance on the traditional intelligence scales and on tasks that require higher-level executive functioning. For example, the D-KEFS tasks are well integrated with the questions and problems presented in the Weschler Intelligence Scale for Children (WISC-IV; Weschler, 2003) and allow for an integration of brain/behavior observations by the school psychologist. In this sense, administration of both the D-KEFS and a traditional intelligence test may indicate damage to executive functioning, which has a negative impact on

traditional intelligence scores and may be reflected in the person's behavior. Likewise, the results of the D-KEFS may indicate that strong executive functioning has a positive impact on traditional intelligence scores, which is also reflected in that individual's behavior.

Second, several new switching conditions were designed and added to some of the D-KEFS tests, including the Color-Word Interference Test, the D-KEFS Verbal Fluency Test, and the D-KEFS Design Fluency Test. Furthermore, the classic switching procedure was retained in the D-KEFS Trail Making Test. These switching conditions require switching from one cognitive set of conditions to another. For example, in the Design Fluency Test, the first condition involves connecting filled circles in a certain manner, the second condition requires connecting open circles, and the switching condition requires that the circles be connected in a manner that involves switching from filled to open circles.

Third, capture stimuli were added to several of the test materials to increase the sensitivity of the D-KEFS tests to subtle and mild forms of stimulus-bound behavior. These capture stimuli attract an individual's attention and pull toward answers that are incorrect and need to be ruled out by the person completing the task. D-KEFS tests that include capture stimuli are the Trail Making Test (in which two pairs of capture stimuli are placed strategically in each quadrant of the stimulus page), the Twenty Questions Test (in which salient features added to the stimulus array pull for more concrete initial yes/no questions by the examinee), and the Proverb Test (in which perceptually similar but incorrect alternatives are added to the multiple-choice responses).

Fourth, the processing demands of the D-KEFS tests were increased over those of similar traditional clinical tests to maximize the detection of subtle executive-function deficits.

Fifth, higher ceilings and lower floors were designed for the D-KEFS so that clinically relevant results are provided regardless of whether the examinee is an exceptionally bright individual with subtle cognitive deficits or a person with significant brain damage and functional impairment.

Sixth, several of the D-KEFS tests were designed to appear like games that are fun to play and appealing to both children and adults. Last, the D-KEFS tests do not employ the right/wrong feedback procedures used in the Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay, & Curtiss, 1993, as cited in Delis et al., 2001b, p. 5) and the Category Test (Halstead, 1947, as cited in Delis et al., 2001b, p. 9) as some individuals, and particularly children, are easily discouraged by repeated negative feedback.

The D-KEFS includes tests that measure executive functions either in the verbal modality or in the nonverbal modality. The standardized scores of these tests can be directly compared, because all of the tests were normed on the same national reference group. As well, the D-KEFS provides alternate forms with normative data for

three of the tests that are most susceptible to practice effects, including the D-KEFS Sorting Test, the D-KEFS Twenty Questions Test, and the D-KEFS Verbal Fluency Test.

Dimensions Measured: Descriptions of the D-KEFS Tests

New Tests

D-KEFS Word Context Test. The D-KEFS Word Context Test is a means of evaluating executive functions in the verbal modality and assessing such skills as deductive reasoning, integration of multiple bits of information, hypothesis testing, and flexibility of thinking. At the fundamental level of processing, this test requires the examinee to use basic receptive and expressive language skills to understand the clue sentences and to generate verbal answers. The D-KEFS Word Context Test complements the Similarities subtest of the WISC for children and adults because it also requires verbal abstract thinking. However, the D-KEFS Word Context Test measures deductive reasoning skills, whereas the Wechsler Similarities subtest measures inductive reasoning abilities. Dr. Edith Kaplan originally developed the Word Context Test in collaboration with Dr. Heinz Werner (Werner & Kaplan, 1952 as cited in Delis et al., 2001b, p. 17) as a means of studying the nature of the acquisition of word meanings in children. For the school psychologist, this test is valuable as a supplemental assessment of receptive and expressive language as well as a measure of inductive reasoning abilities and flexibility of thinking at the level of executive functioning.

D-KEFS Sorting Test. The D-KEFS Sorting Test measures a number of important component processes of executive functions, including initiation of problem-solving behavior, concept-formation skills, modality-specific problem-solving skills (verbal versus nonverbal), the ability to explain sorting concepts abstractly, the ability to transfer sorting concepts into action, the ability to inhibit previous sorting responses to engage in flexibility of behavior, and the ability to inhibit previous description responses to engage in flexibility of thinking. The D-KEFS Sorting Test was formerly called the CCST and was developed by Dr. Dean Delis in the late 1980s (Delis et al., 2001b). The school psychologist will find information gained from administration of this test regarding the ability to inhibit previous responses particularly useful when trying to determine whether a student is able to control impulsive behaviors in problem solving. Moreover, this test measures a student's ability to explain sorting concepts abstractly and looks at whether a student can clearly explain why the cards were sorted in a particular manner.

Modifications of Existing Tasks

D-KEFS Twenty Questions Test. This test measures the ability to perceive various categories and subcategories, the ability to formulate abstract, yes/no questions that eliminate the maximum number of objects regardless of the examiner's answer, and the ability to incorporate the examiner's feedback to formulate more efficient yes/no questions. It requires visual attention and perception, object recognition, and object naming. As well, the D-KEFS Twenty Questions Test measures the process of categorization. It assesses the ability to perceive verbal or visual features that are common to a subset of objects among the universe of objects depicted on the stimulus page, and the ability to form a higher-level concept that captures the defining properties of that subgroup, thereby mentally subsuming those objects in an efficient, systematic manner with as few questions as possible. This test was first adapted for use in experimental studies of the development of concept-formation skills in normally functioning children (Mosher & Hornsby, 1966 as cited in Delis et al., 2001b, p. 19). When school psychologists use this test, information is gleaned about the ability of a student to develop abstract concepts and use abstract categorizations. As well, visual attentiveness and deliberation are required, allowing the school psychologist to determine if the student is able to focus on visual details when problem solving.

D-KEFS Tower Test. The D-KEFS Tower Test is a means of assessing several key executive functions, including spatial planning, rule learning, inhibition of impulsive and perseverative responding, and the ability to establish and maintain instructional set. Key fundamental abilities assessed by this task include visual attention and visual-spatial skills. Executive functions tapped by the D-KEFS Tower Test include spatial planning, rule learning, inhibition, and establishing and maintaining cognitive set. Tower tests have been adapted for use in experimental studies of planning and problem-solving abilities in patients with frontal lobe involvement (e.g., Levin et al, 1994, as cited in Delis et al., 2001b, p. 20). For the school psychologist, the D-KEFS Tower Test is a measure not only of an examinee's planning and spatial problem-solving abilities but also of ability to inhibit perseverative and unplanned, impulsive responses within a visual nonverbal modality.

D-KEFS Color-Word Interference Test. This test primarily measures the ability to inhibit an overlearned verbal response (i.e., reading the printed words) to generate the conflicting response of naming the dissonant ink colors in which the words are printed. As well, an inhibition/switching condition evaluates both inhibition and cognitive flexibility. Stroop (1935, as cited in Delis et al., 2001b, p. 21) developed this procedure for studying verbal interference effects. The D-KEFS Color-Word Interference Test can be used by the school psychologist to evaluate both cognitive flexibility and a student's ability to inhibit perseverative and unplanned, impulsive

responses within the verbal modality. It is complimentary to the D-KEFS Tower Test when one is looking at a student's ability to control impulsivity in both verbal and nonverbal problem solving.

D-KEFS Verbal Fluency Test. The D-KEFS Verbal Fluency Test measures the ability to generate words fluently in an effortful phonemic format (letter fluency), from overlearned concepts (category fluency), and simultaneously shifting between overlearned concepts (category switching). Letter and verbal fluency tests were first developed in the 1930s and have been used in neuropsychology in both research studies and clinical practice. The school psychologist can gain supplemental information about language skills and processing since the ability to fluently generate words and to shift between different verbal conceptual categories is required when a student completes the D-KEFS Verbal Fluency Test.

D-KEFS Design Fluency Test. The D-KEFS Design Fluency Test measures the ability to draw as many different designs as possible in 60 seconds. Condition 1 provides a basic test of design fluency, Condition 2 measures both design fluency and response inhibition, and Condition 3 measures design fluency and cognitive flexibility. This test is a nonverbal analog of the D-KEFS Verbal Fluency Test and taps basic visual attention, motor speed, visual-perceptual skills, and constructional skills. The executive functions required include initiation of problem-solving behavior, fluency in generating visual patterns, creativity in drawing new designs, simultaneous processing in drawing the designs while observing the rules and restrictions of the task, and inhibiting previously drawn responses. The first version of this test was developed as a nonverbal analogue to verbal fluency procedures (Jones-Gotman & Milner, 1977 as cited in Delis et al., 2001b, p. 22). This test is useful for the school psychologist because it provides supplemental information about visual-motor processing and integration in a complete psycho-educational assessment.

D-KEFS Trail Making Test. The D-KEFS Trail Making Test consists of a visual cancellation task and a series of connect-the-circle tasks. The primary executive-function task is Condition 4 (number-letter switching), which is a means of assessing flexibility of thinking on a visual-motor sequencing task. The other four conditions of this test allow the examiner to quantify and derive normative data for several key component processes necessary for performing the switching task, including visual scanning, number sequencing, letter sequencing, and motor speed. This test is a modification of the classic test originally developed by Partington (Brown & Partington, 1942, as cited in Delis et al., 2001b, p. 5), and later selected and popularized as a neuropsychological test in the Halstead-Reitan Neuropsychological Battery (HRNB; Reitan & Wolfson, 1993, as cited in Delis et al., 2001b, p. 3). The D-KEFS Trail Making Test provides the

school psychologist with excellent information about visual motor processing and speed. As well, it gives additional information about impulsivity and flexibility of thinking in nonverbal problem solving.

D-KEFS Proverb Test. The D-KEFS Proverb Test consists of eight sayings that are presented in two conditions, free inquiry and multiple choice. The test consists of both common and uncommon proverbs, the latter of which tend to place greater demands on novel abstraction skills. Multiple process and contrast measures are provided for the two conditions of the test, which can be useful for identifying the neurocognitive mechanisms underlying poor performance on this verbal abstraction task. The D-KEFS Proverb Test was designed for adolescents and adults aged 16 to 89 years, unlike the other eight tests of the D-KEFS, which were designed for use with children and adults aged 8 to 89. The D-KEFS Proverb Test was formerly called the California Proverb Test and was developed in the late 1980s. It was generally modeled after Gorham's formal proverb test (Gorham, 1956, as cited in Delis et al., 2001b, p. 24) in which examinees are asked to write their interpretations of proverbs. The school psychologist will gain additional information about an older student's ability to form novel verbal abstractions when this test is administered.

Administration

The *D-KEFS Examiner's Manual* (Delis et al., 2001b) provides detailed and clear descriptions of how to administer and score the nine D-KEFS tests. To facilitate administration of the D-KEFS tests, the task instructions and prompts are provided in the stimulus booklet itself (or in the record form, for the D-KEFS Twenty Questions Test and D-KEFS Color-Word Interference Test). The D-KEFS tests incorporate standardized discontinue rules and time limits to minimize frustration in some individuals. The examiner prompts, discontinue rules, and time limits are clearly displayed to examiners in the stimulus booklet and/or record form. During administration of the D-KEFS, the school psychologist needs to be adept at simultaneously scoring and timing the student's performance and should be comfortable with the test materials before administration begins.

Types of Scores Available

For most of the measures provided by the D-KEFS tests, raw scores are converted to scaled scores, with a mean of 10 and a standard deviation of 3. However, for some process measures, the raw scores are converted to cumulative percentile ranks. A key feature of the D-KEFS is the use of contrast measures that either directly quantify relative performance on a baseline task and a higher-level task or quantify performance on one higher-level condition relative to performance on another condition.

Contrast measures are interpreted differently from most other scaled scores. That is, for a contrast measure, either low- or high-scaled scores may reflect different types of cognitive problems. As well as scaled scores and contrast measures, it is possible to calculate a combined scale score that reflects the examinee's ability on similar cognitive functions under somewhat different conditions.

The D-KEFS provides primary scaled scores and, in some instances, processing measures in percentile ranks. In addition, optional scores are available, the neurocognitive mechanisms underlying poor performance on a task are elucidated, and each examinee's profile of effective and impaired executive functions is documented. The primary measures provide global scores for characterizing overall performance on a particular task or process scores for key components or aspects of the task. Optional measures are provided to offer a more comprehensive assessment of executive functions. For example, on the D-KEFS Color-Word Interference Test, optional contrast measures include an error analysis for each of the four conditions of this test as well as an analysis of completion times for the inhibition/switching condition versus the color naming and word reading conditions of the test. Alternate forms were developed for three of the D-KEFS tests: the D-KEFS Sorting Test, the D-KEFS Twenty Questions Test, and the D-KEFS Verbal Fluency Test.

Given the wide variety of scores offered by the D-KEFS, it is recommended that the D-KEFS Scoring Assistant Software be used to automatically compute the standardized scores for both the primary and optional measures of the standard and alternate forms of the D-KEFS. This greatly enhances the efficiency with which the D-KEFS can be used in clinical practice and/or in school psychology.

Standardization of the D-KEFS

The D-KEFS standardization sample consisted of 1,750 children, adolescents, and adults aged 8 to 89 years. Stratification was based on age, sex, race/ethnicity, years of education, and geographic region. The 2000 U.S. Census figures (as cited in Delis, Kaplan, & Kramer, 2001c, pp.1-132) were used as target values for the composition of the D-KEFS normative sample. Specifically, each sample contained: 75 children from 8 to 11 years; 100 children and/or adolescents in each of the age 12 to 15 groups; 175 adolescents and/or adults in the age 16 to 19 and 20 to 29 samples; 150 adults in the 30 to 39 group; 100 adults in each of the 40 to 49, 50 to 59, and 80 to 89 samples; and 125 adults in each of the 60 to 69 and 70 to 79 groups.

The D-KEFS sample consisted of roughly equal proportions of men and women at each age group, with the exception of the older age groups, which had more women than men, consistent with the 2000 U.S. Census data. For each age group in the standardization sample, the proportions of African American, Hispanic, White, and other racial and ethnic groups sampled were stratified to approximate the 2000 U.S. Census population estimates. The D-KEFS sample was divided into the five

major educational groups used by the U.S. Census: less than or equal to 8 years of education, 9 to 11 years, 12 years, 13 to 15 years, and 16 years or more of education. For examinees aged 8 to 19 years, the mean parent education level was substituted for the examinee's education level. The United States was divided into four major geographical areas as specified by the U.S. Census data: Northeast, North Central, South, and West. The D-KEFS Technical Manual (Delis et al., 2001c) gives the age effects for each of the nine tests in the D-KEFS and comprehensively outlines the development of the norms for the D-KEFS.

Technical Characteristics

Reliability. The *D-KEFS Technical Manual* (Delis et al., 2001c) presents information with regard to the reliability of scores derived from the D-KEFS. It was acknowledged that the range and variability of the different D-KEFS tests have a bearing on the nature and outcome of the reliability analyses performed on the instruments. For this reason, the internal consistency, test-retest reliability, and standard errors of measurement and confidence intervals were examined in considerable detail for each separate D-KEFS test. Given the complex nature of examining reliability for each of the D-KEFS tests, the reader is referred to the *Technical Manual* for discussion of this matter. However, with only a few exceptions, the D-KEFS tests tend to display moderately good internal consistency coefficients and good test-retest reliability. On some of the D-KEFS tests (i.e., D-KEFS Design Fluency Test), item interdependence precluded the use of internal consistency procedures, and reliability was investigated with test-retest procedures.

Validity. Evidence for the validity of the D-KEFS is reported in the *Technical Manual* (Delis et al., 2001c). The D-KEFS tests are either relatively new or modifications of long-standing clinical or experimental tests. The validity of D-KEFS instruments that are modified tests (i.e., the Stroop procedure, Trail Making Test, Verbal and Design Fluency tests, Tower Tasks, the Twenty-Questions procedure, and Proverb interpretations) has been demonstrated in numerous neuropsychological studies conducted during the past 50 years or more. The reader is referred to Lezak (1995, as cited in Delis et al., 2001c, p. 47) and Spreen and Strauss (1998, as cited in Delis et al., 2001c, p. 47) for reviews of these studies. The validity of one of the relatively new tests, the D-KEFS Sorting Test, has also been investigated in several neuropsychological studies using an early version of that instrument called the CCST (Delis, 1988, as cited in Delis et al., 2001b, p. 1). These studies are reviewed in the *Technical Manual*. Several studies of the standardization version of the D-KEFS tests have been conducted since 1999 and are also reviewed in the *D-KEFS Technical Manual*.

The intercorrelations of measures provided by each of the nine D-KEFS tests were investigated using variables that are converted to scaled scores. The directionality of

the scaled scores on the D-KEFS was set in the traditional manner, with better performance associated with higher scaled-score values. For each of the nine D-KEFS tests, correlation tables showed positive correlations for both accuracy and error measures that indicate that better performance on one variable is associated with better performance on the other. The correlations for each test are presented in the following broad age bands: 8 to 19 years, 20 to 49 years, and 50 to 89 years.

Correlation studies with the D-KEFS Primary Scaled Scores resulted in relatively low positive correlations between D-KEFS tests. This indicates that the instruments are not interchangeable and measure unique aspects of executive functioning with some overlap in variance. Changes in cognitive functioning associated with both the development and decline of abilities across the life span affect the nature of the associations between tests. The various process and efficiency measures provided by the D-KEFS tests also display little correlation across tests. In addition, preferential correlations between verbal with verbal measures or nonverbal with nonverbal measures were not found across tests. Likewise, correlations indicated mostly low or unrelated associations among process/efficiency scores, response initiation measures, and repetition measures, indicating that these scores mean different things depending on the specific D-KEFS test results on which they are calculated. Overall, it is clear that although there is some overlap of executive functions measured by the D-KEFS tests, each individual test should be viewed separately from every other D-KEFS test and interpreted individually.

Performance on the D-KEFS tests was compared with performance on two other assessment instruments: the California Verbal Learning Test–Second Edition (CVLT-II; Delis, Kaplan, Kramer, & Ober, 2000, as cited in Delis et al., 2001c, p. 117) and the Wisconsin Card Sorting Test (WCST; Heaton et al., 1993, as cited in Delis et al., 2001b, p. 5). The correlational study of the D-KEFS and the CVLT-II involved a large sample of 292 subjects. However, the correlational study of the D-KEFS and WCST involved a small sample of 23 subjects and should be considered exploratory in nature. The vast majority of correlations between the CVLT-II and the D-KEFS were not significant, suggesting little overlap between the functions assessed by these two instruments. The low to moderate correlations between the WCST measures and the D-KEFS tests lead to two hypotheses. First, both the WCST and the D-KEFS tests share some degree of variance in measuring higher-level executive functions in general; and second, with only about 16% to 36% of the variance shared among these instruments, each test contributes unique variance in the assessment of different aspects of executive functioning. The results of this exploratory study suggest that further study of the correlation between the WCST and the D-KEFS tests is warranted.

Summary and Conclusions

This review has presented a description of the components, standardization, applications, reliability, and validity of the D-KEFS. It is the reviewer's conclusion

that the D-KEFS is an innovative and promising tool in the measurement of executive functioning in both clinical and nonclinical populations. In clinical populations, the D-KEFS can be used to assess mild brain damage in general and mild frontal-lobe involvement in particular. In school settings, it can be used to complement the assessment of those abilities measured by traditional tests of intelligence and achievement tests with the assessment of higher-level cognitive abilities. This is particularly important in the assessment of learning disabilities, the assessment of attention deficit/hyperactivity disorder (ADHD), and the assessment of gifted students.

In the assessment of learning disabilities, the D-KEFS tests supplement intelligence and achievement testing results and provide valuable information about language processing, visual-motor integration and functioning, attention, concept formation, and planning. In the assessment of ADHD, the D-KEFS can provide valuable information about attention, planning, impulsivity, cognitive switching, inhibition, and flexibility of thinking. In the assessment of gifted students the D-KEFS will be particularly useful in measuring the capacity to engage in creative, abstract thinking. The D-KEFS tests are able to identify those gifted students who struggle in their rote-knowledge skills and thus tend to score lower on traditional intelligence tests but who are extremely creative and talented in their problem-solving and abstract-thinking abilities. These children are often precluded from gifted programs by the scores they obtain on IQ and/or achievement tests. In many cases, however, they could benefit from programs for gifted students that would enhance their capacity for higher-level abstract and creative thought processes.

The *D-KEFS Technical Manual* presents excellent data on the normative sample, reliability, and validity of the D-KEFS tests. In the reviewer's opinion, the technical adequacy and wide application in educational and clinical settings of the D-KEFS make it an excellent choice of instruments for the measurement of executive functioning. The D-KEFS is flexible to use and a strong choice in meeting the evaluative and programming needs of children and adults. Each of the nine D-KEFS tests measures a range of both fundamental cognitive skills and higher-level executive functions and provides primary measure, contrast measure, and optional measure scores. The D-KEFS is a rich assessment battery in terms of the information it provides about executive functioning and is presented in a gamelike format so that most examinees will find it enjoyable to complete and not become discouraged by negative feedback regarding their performance.

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