D-KEFS™

Delis–Kaplan Executive Function System™

Advanced

MANUAL

Dean C. Delis

Edith Kaplan

With the collaboration of Miles L. Delis

Pearson

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Chapter 1. Overview of the D-KEFS Advanced

Introduction

Executive functions are distinct processes of cognition that are vital for performing new, complex, and dynamic tasks. These cognitive abilities draw upon fundamental, lower level, and overlearned cognitive skills (e.g., attention, language, visuospatial abilities, processing speed, and acquired knowledge) to generate higher levels of cognition including working memory, inhibition, cognitive shifting, abstract thinking, problem-solving, creativity, planning, organization, fluent thinking, and rapid decision-making. The Delis-Kaplan Executive Function System™ (D-KEFS™) Advanced provides six new, fully digital, performance-based measures of executive functions. The tests are designed for children and adults ages 8–90 years and were normed on a nationally stratified sample of over 1,200 individuals.

Direct, performance-based measures of executive functioning provide unique information on cognitive functioning. They are essential to include in a larger assessment battery because research shows that other cognitive tests, including IQ subtests and memory measures, do not adequately assess executive functions. For example, in child and adult clinical groups, executive functions can be selectively impaired with intact performance in other cognitive domains including attention, verbal abilities, visuospatial skills, and learning and memory. Further, IQ subtests and memory measures have relatively low correlations with tests of executive functioning (Delis et al., 2001; Delis et al., 2007; Wechsler, 2009). Moreover, other tests often load on separate factors in factor-analytic studies (Bilder et al., 2023; Schneider & McGrew, 2018). Results from structural and functional neuroimaging studies have found that, compared to other cognitive domains, executive functions have greater dependency on the integrity of distinct brain systems particularly in the frontal lobes (Yuan & Raz, 2014). Performance-based measures of executive functioning are often used along with rating scales of executive function behaviors (e.g., the Behavior Rating Inventory of Executive Function® [2nd ed.; BRIEF®2; Gioia et al., 2015], the Delis Rating of Executive Functions [D-REF] for children [Delis, 2012], and the D-REF Adult [Delis, 2021]); however, because rating scales rely on self-report or collateral report of executive functioning, they tend to have low correlations with results from performance-based tests of executive functioning (Biederman et al., 2008; Soto et al., 2020; Toplak et al., 2013). These low correlations indicate that subjectively based rating scales may be inadequate for assessing certain aspects of executive functioning. Delis (2021) notes that rating scales are better suited for assessing hot executive functions (e.g., emotional or behavioral dyscontrol), whereas performance-based tests, like the D-KEFS Advanced, are better suited for assessing cold executive functions (i.e., the higher level cognitive abilities noted previously). For these reasons, performance-based tests of executive functioning are essential instruments in the assessment of neurocognitive development in children and decline in adults.

The D-KEFS Advanced does not replace but rather complements and expands on the original D–KEFS (Delis et al., 2001). The original D–KEFS was the first nationally normed set of performance-based cognitive tests designed specifically for the assessment of executive functioning in children and adults (ages 8–89 years). Since its publication in 2001, the D–KEFS has been used or cited in thousands of published studies, articles, and books. Surveys show that the D–KEFS tests are among the top executive function assessment instruments used in the United States and Canada (Benson et al., 2019; Rabin et al., 2016). The original D–KEFS will

continue to be available for use with the D-KEFS Advanced, and examiners can selectively use tests from both instruments depending on the assessment needs of each examinee.

The D-KEFS Advanced consists of six, all-digital, performance-based tests of executive functioning, three of which have multiple conditions. The tests and the conditions within the assessment include:

- Trail Making Test (TMT)
    - Condition 1: Number Sequencing (NS)
    - Condition 2: Letter Sequencing (LS)
    - Condition 3: Number–Letter Switching (SW)
    - Condition 4: Switching–Distraction (SWD)
    - Condition 5: Switching–Working Memory (SWM)
- Verbal Fluency Test (VFT)
    - Condition 1: Letter Fluency (LF)
    - Condition 2: Category Fluency (CF)
    - Condition 3: Switching Fluency (SW)
        - Category–Letter Switching (CLS)
        - Letter–Category–Letter Switching (LCLS)
- Color–Word Interference Test (CWIT)
    - Condition 1: Color Identification (CI)
    - Condition 2: Word Identification (WI)
    - Condition 3: Inhibition (IN)
    - Condition 4: Inhibition/Switching (SW)
- Tower Test (TWR)
- Social Sorting Test (SST)
- Risk–Reward Decision Test (RISK)

Table 1.1 provides a brief description of the D-KEFS Advanced tests. Detailed information on the development of each test can be found in Chapter 3 along with reliability and validity information. Each test has a separate chapter devoted to describing the administration, scoring, and interpretation of that test.

Table 1.1 Description of the D-KEFS Advanced Tests

Test	Description
Trail Making Test (TMT)	The TMT uses a visuomotor format to assess basic to complex multitasking. Two new switching conditions were developed to assist in assessing the contribution of cognitive shifting, response inhibition to distracting stimuli, and working memory to multitasking skills. There are five conditions: two baseline sequencing tasks that require the examinee to connect circles either in numerical or alphabetical order, and three switching tasks that require the examinee to shift between connecting numbers and letters under different executive function demands.
Verbal Fluency Test (VFT)	The VFT measures the ability to rapidly generate verbal responses according to either phonemic rules (i.e., initial letter) or semantic rules (i.e., superordinate category) and to perform verbal multitasking by switching between the phonemic and semantic rules. There are seven trials in which the examinee says as many words as possible in 60 seconds either according to an initial letter, a semantic category, or switching between the phonemic and semantic rules.
Color–Word Interference Test (CWIT)	The CWIT assesses the ability to inhibit a prepotent (i.e., overlearned or automatic) verbal response to generate a more difficult, conflicting response (i.e., the Stroop effect) and to engage in multitasking by switching between the automatic and more difficult verbal responses. There are four conditions: two baseline tasks that assess the fundamental skills of rapid color or word identification (which measure basic verbal processing speed), a test of verbal inhibition in which the examinee must inhibit the prepotent response of identifying the printed word (i.e., the name of a color) to identify the conflicting color of the word's letters, and a test of verbal multitasking in which the examinee must switch between the automatic and more difficult response.
Tower Test (TWR)	The TWR assesses spatial planning; rule learning; inhibition of impulsive, trial-and-error responses; and the ability to establish, maintain, and quickly switch between instructional sets. The examinee moves chips across three tables on the bottom of the stimulus to replicate the chip placements shown at the top of the stimulus while following several rules. The rules are to (a) use the fewest number of moves possible; (b) move only one chip at a time; (c) never place a larger chip on top of a smaller chip for solid chips; (d) never place a smaller chip on top of a larger chip for striped chips; and (e) complete the task within a liberal time frame rather than as quickly as possible, thereby placing greater emphasis on planning and accuracy over speed.
Social Sorting Test (SST)	Modeled after the Wisconsin Card Sorting Test® (WCST®), which was developed by Grant and Berg (1948) and later normed by Heaton et al. (1993), the SST uses ecologically valid stimuli (i.e., photos of people with different emotional expressions and clothing) to measure problem-solving that requires facial and affect recognition, concept identification, use of feedback, conceptual flexibility, and inhibition of perseverative responses. The examinee is shown four key cards and a stack of sorting cards and then matches each of the sorting cards to a key card according to preestablished rules that are unknown to them. After each sort, the examinee is given correct/incorrect visual feedback according to these predefined rules. The rules change throughout the test without warning to the examinee, and the examinee must rely only on the feedback after each response to guide their next sorting response. For some sorts, two or three rules are simultaneously reinforced, which requires the examinee to adhere to the current conceptual rule despite the ambiguity in the feedback and the pull to be derailed to the other reinforced sorting rules. For other sorts, there is unambiguous feedback that a current sorting rule must be abandoned, which requires inhibition of perseverative responses and conceptual flexibility to implement a different sorting rule.
Risk–Reward Decision Test (RISK; ages 19–90 years only)	The RISK measures the hot executive function of risky decision-making in the context of a problem-solving task involving a horse-racing game. For each of 60 races, the examinee must pick one of three horses that vary in terms of their odds of winning and their payout. These parameters are well defined at the onset of the test, so the examinee does not have to learn them by trial and error like on other risk-taking tests. The examinee must choose between a horse that has the lowest chance of winning but pays the most money, a horse that is most likely to win but pays the least money, and a middle-odds horse that pays a middle-range amount. Money is earned or lost based on a predetermined outcome, and the examinee must use the win/loss feedback to adjust their level of risk-taking to maximize their winnings.

D-KEFS Advanced Development Goals

Five overarching goals drove the development of the D-KEFS Advanced:

- Provide a fully digital assessment
- Expand construct coverage
- Expand the process approach
- Enhance reliability, validity, and clinical sensitivity
- Reduce examiner burden and measurement error

Provide a Fully Digital Assessment

The D-KEFS Advanced is not a revision of the original D–KEFS; it represents a new paradigm for assessing cognition in general and executive functions in particular. This new paradigm was achieved by designing the D-KEFS Advanced from its inception to be administered and scored only on a digital platform. The D-KEFS Advanced requires no test equipment, record forms, or stimuli booklets beyond two iPad®s (one for the examinee [Client Device] and one for the examiner [Practitioner Device]) and a stylus for the examinee. All administration and scoring for the D-KEFS Advanced were developed for Q-interactive® (the digital platform) without the constraint of needing equivalent print (paper-pencil) versions of the same tests. This all-digital approach provided freedom to harness the processing capabilities of modern digital devices to develop highly dynamic, more complex tests and to capture test responses at a more precise level. These goals could not have been achieved if equivalent print versions of the tests were also required. For example, on the D-KEFS Advanced Trail Making Test, two new, more complex switching conditions were developed (i.e., Switching–Distraction and Switching–Working Memory) in which precisely timed stimuli rapidly appear and disappear on the Client Device. In addition, the primary measure of the new TMT is the mean time to make individual connections measured in 0.1 seconds rather than the time to complete all the connections. This finer dissection of test performance at the individual response level was found to improve reliability, validity, and sensitivity in identifying executive function deficits in child and adult clinical groups (see Chapter 3).

This microanalysis of test responses also provided the opportunity to develop numerous new process scores including new measures that assess speed–accuracy tradeoffs. These tradeoff measures capture a unique aspect of executive functioning by assessing how examinees modulate their response speed relative to their accuracy rate to optimize performance on complex timed tasks. Using the digital interface to reduce examiner burden was also a primary focus. For example, for five of the six tests, all raw and standardized scores including error types and other process measures are captured and scored automatically by the digital interface. Only the Verbal Fluency Test requires the examiner to record and classify the examinee's responses, after which the raw and standardized scores are generated automatically. In addition, for five of the six tests, examiner prompts are provided automatically on the Practitioner Device to inform the examiner of precisely when to provide a prompt and what to say, significantly reducing measurement error across all tests. Numerous other steps were taken to reduce examiner burden and measurement error. For example, on the CWIT, because the items are presented individually, it is impossible for examinees to skip items or rows, which occasionally occurs on print versions of all current Stroop tasks and leads to greater measurement error. As another example, on the new Trail Making Test, examinees receive instant visual feedback on the Client Device when they make an incorrect connection, and they are not allowed to impulsively make rapid additional connections from their last incorrect circle (rather only from their last correct connection). By reducing measurement error, the tests gain greater reliability and validity in measuring executive functioning.

Administration and discontinue times were shortened to decrease frustration in examinees with significant impairment. This was accomplished by measuring performance at the individual response level (e.g., the time taken to make individual connections on the Trail Making Test), which allowed for shorter time limits on individual conditions compared to the print versions of the test. In addition, core scaled scores for select conditions are instantly displayed on the Practitioner Device upon completion of those tasks to help examiners determine, in real time, whether to administer additional, more difficult conditions. For some tests, examinees are allowed to repeat demonstration/sample items to ensure that they understand the tasks, which reduces frustration and improves the floors of the tests. The motor demands of several tests were reduced to provide a better assessment of the higher order skills evaluated by those tasks. New global performance measures were developed to improve discrimination of levels of performance in the below average range. At the same time, the ceilings of the tests were also raised to provide greater sensitivity in detecting subtle declines in individuals with high, premorbid executive functions. This was accomplished by developing more complex, cognitively demanding tasks, many of which could only be developed using an all-digital approach. In summary, the goals of the D-KEFS Advanced were analogous to the development of new generations of MRI brain scans that harness digital technology to provide greater detail and clarity in detecting subtle to severe changes in brain structure and function.

Develop New Speed–Accuracy Tradeoff Scores

The processing capacity of the human mind is limited, which gives rise to the speed–accuracy tradeoff in solving complex, timed cognitive tasks. That is, for many complex tasks, an inverse relationship can exist between the speed and accuracy with which they are solved. Placing too much emphasis on speed when solving a task can result in a high error rate (i.e., sacrificing accuracy), whereas placing too much emphasis on accuracy can result in an overly prolonged completion time (i.e., sacrificing speed). For tasks like this, a balance must be achieved between allocating cognitive resources toward speed versus accuracy for optimal performance. The digital interface allows for data to be collected on both speed and accuracy without adding more administration and scoring burden to the examiner.

To date, few cognitive tests have incorporated measures that capture speed–accuracy tradeoff performance in their scoring systems. Two possible reasons for this are (a) many existing timed neuropsychological tests do not provide standardized scores for error rates (e.g., the Coding and Symbol Search subtests [e.g., Wechsler, 2024], the traditional Trails A and B test [Reitan, 1955]), thereby precluding their ability to measure the accuracy side of the speed–accuracy tradeoff, and (b) even for existing tests that do provide standardized scores for errors (e.g., the original D–KEFS Trail Making Test), those tests often do not elicit enough error responses in the normative sample to provide psychometrically adequate measures of accuracy (i.e., the error measures do not have sufficient range and adequate distribution). However, in developing the D-KEFS Advanced, one of the main objectives was to design the tests to be more cognitively demanding, in part to elicit increased error rates in the normative sample. For example, the new Trail Making Test has three switching conditions instead of one; two of the conditions have greater cognitive demands that resulted in higher overall error rates. The resulting error score has a larger range and distribution in the normative sample. As another example, the new Tower Test requires cognitive shifting in that examinees must switch between a different problem-solving rule (i.e., never place a larger chip on a smaller chip or vice versa) depending on the item type (i.e., items with solid chips versus striped chips). This switching requirement increased the complexity of the task and yielded a wide range and distribution of error rates (i.e., unproductive moves, rule violation errors). With the improved psychometric properties of the error rates on the D-KEFS Advanced, it was psychometrically feasible to develop new measures of speed–accuracy tradeoff for the Trail Making Test, the Color–Word Interference Test, and the Tower Test.

Lower the Floor and Decrease Examinee Frustration

Executive function tests are inherently difficult and can be especially frustrating for individuals with significant neurocognitive impairments. In designing the D-KEFS Advanced, steps were taken and numerous pilot studies were conducted to identify ways to modify the tests to lower the floor, reduce administration times, and decrease frustration in individuals with significant developmental or acquired neurocognitive impairments.

The digital interface was designed with ease of examinee responding as a central tenant. For example, on the Trail Making Test, pilot studies revealed that it was more difficult for examinees to draw the connecting lines on the Client Device compared to touching the circles in the correct order with the connecting lines automatically and instantly generated on the Client Device. For many individuals with motor deficits, performing the trail making task using the touch-the-circle method was easier and faster for them than using the draw-the-line method. By minimizing the motor demands of the tasks, the touch-the-circle method on the Client Device was less frustrating and afforded a more accurate assessment of true executive function strengths and weaknesses by reducing the confounding effects of motor difficulties.

Similarly, on the new Color–Word Interference Test, the examinee no longer needs to articulate the color names on any of the conditions and instead uses the stylus to touch the correct response on the Client Device. For many individuals with speech articulation or word-finding problems, this touch response method is easier for them than saying each response aloud as required by other Stroop tasks (including the original D–KEFS print version). Thus, the new response mode on the fully digital CWIT (i.e., touch the correct response rather than say words) can bypass articulation and word-finding problems and provide a more accurate assessment of an examinee's executive function strengths and weaknesses by reducing the confounding effects caused by these problems.

The fully digital format of the D-KEFS Advanced also created an opportunity to lessen the frustration that individuals experience when taking executive function tests by significantly reducing time limits. For example, on existing versions of the trail making task (e.g., Trails A and B, the original D–KEFS), the discontinuation times are relatively long (e.g., 300 s for the traditional Trails B test and 240 s for the original D–KEFS Trail Making Test Number–Letter Switching condition). For examinees who experience difficulty completing this task, the long discontinuation times can be highly frustrating and the final couple of minutes of the task typically do not provide additional useful clinical information. However, on the Number–Letter Switching condition of the D-KEFS Advanced, the time limit is significantly shorter (i.e., 150 s), which helps to decrease the frustration that some individuals experience when taking the test. As noted previously, using the all-digital format in which the primary measure is the mean time to make individual connections rather than the total time to make all connections enabled the development of shorter test times.

Another way that the all-digital D-KEFS Advanced tests can reduce examinees' frustration is by providing the examiner with the core scaled score after the examinee completes select conditions of a test. For example, the new Trail Making Test now includes three switching conditions rather than one; the two new switching conditions are more cognitively demanding than the traditional number–letter switching task. After completing the new TMT Number–Letter Switching condition, the examinee's core scaled score for that condition is instantly provided, which can inform the examiner's decision on whether to administer the two remaining, more demanding switching conditions.

Expand Construct Coverage

Since the publication of the original D–KEFS, research on executive functioning has increased along with the need to evaluate multiple aspects of executive functions. The original D–KEFS has been used in many

research studies and has proved to be a valuable tool. The D-KEFS Advanced provides new measures that can be used to complement the original D–KEFS and not replace it. The original, print D–KEFS tests will continue to be available for use with the new, all-digital D-KEFS Advanced tests. However, as noted previously, several new tests and conditions were developed for the D-KEFS Advanced to assess skills not measured in the original D–KEFS including a new test that incorporates affect recognition in the evaluation of executive functions (i.e., the Social Sorting Test) and a new, performance-based test that incorporates the assessment of hot executive functions (e.g., emotional restraint) in the context of decision-making (i.e., the Risk–Reward Decision Test). Finally, focus was put on increasing the ecological validity of the tests to better simulate real-world situations (e.g., assessing the effects of systematic distraction on multitasking skills as evaluated by the new TMT Switching–Distraction condition). The combination of the original D–KEFS and the D-KEFS Advanced now provides 15 tests that measure a wide spectrum of verbal and nonverbal executive functions. Each test is designed to be a stand-alone instrument that can be administered individually or with other original D–KEFS and D-KEFS Advanced tests (e.g., the Proverb, Word Context, and Sorting Tests from the original D–KEFS offer additional verbal measures of executive functioning). Further, the Design Fluency Test from the original D–KEFS provides a visuomotor fluency measure to complement the D-KEFS Advanced measures.

Four tests on the D-KEFS Advanced overlap with the print versions in the original D–KEFS. To decide which version to administer to a particular examinee, it is important to understand the different administration, item presentation, response requirements, and scores across the two versions. In general, the D-KEFS Advanced versions are recommended because of the enhanced tasks, richer set of core and process scores, and newer normative data; however, the original D–KEFS may be the appropriate choice for a specific setting or examinee. For example, the verbal fluency tasks across the two editions are similar but there are differences that may make one version more appropriate for different examinees. On the original D–KEFS Verbal Fluency Test, the switching condition involves cognitive shifting in retrieving words from two semantic categories. This version can be more sensitive to subtle declines in preclinical Alzheimer's disease in which a breakdown in semantic memory from mesial temporal involvement is often an early cognitive marker (Salmon & Bondi, 2009; Wright et al., 2023). In contrast, the switching condition of the D-KEFS Advanced Verbal Fluency Test involves cognitive shifting in retrieving words from a semantic category and words that start with a specified letter. For most examinees, this new version is cognitively more demanding because it requires switching between distinct retrieval search strategies (i.e., semantic versus phonemic rules). This newer version may be preferred to assess examinees with possible or suspected frontal involvement given its greater demands on cognitive shifting. As another example, the original D–KEFS Trail Making Test includes conditions for assessing the visual-scanning and motor-speed component processes required to perform the number sequencing, letter sequencing, and cognitive shifting aspects of the test. To help streamline the test for most examinees (who often perform well on those tasks), those two tasks were not included in the D-KEFS Advanced TMT. However, if an examinee struggles on the new Number and/or Letter Sequencing conditions, the examiner can administer the original D–KEFS Trail Making Test Visual Scanning or Motor Speed conditions to assess whether the examinee's sequencing difficulties may be related, at least in part, to an impairment in these fundamental skills.

Incorporate the Assessment of Social Cognition and Affect Recognition in the Evaluation of Executive Functioning

Social cognition, including facial and affect recognition, involves highly complex processes. These skills require fundamental cognitive abilities (e.g., perception of facial features) and higher level executive functions (e.g., deciphering the emotional meaning and significance of facial expressions). Because the Social Sorting Test parallels the WCST, it can serve as an alternate form of the WCST. The SST was also designed to assess social and affect recognition in the context of a test of concept identification, conceptual flexibility, and problem-solving.

Incorporate the Assessment of Hot Executive Functions

An exciting area of research in neuropsychology focuses on the distinction between hot and cold executive functions (Bechara et al., 1999; Colautti et al., 2022; Diamond, 2013; Fernández García et al., 2021; Zelazo, 2020). Hot executive functions refer to the ability to regulate behavior and emotions; problems in this area can lead to emotional dyscontrol, behavioral impulsivity, and risk-taking tendencies. In contrast, cold executive functions refer to classic higher level cognitive abilities including working memory, response inhibition, cognitive shifting, abstract thinking, creativity, planning, organization, and problem-solving. Importantly, hot and cold executive functions are not isolated abilities; rather, they must work in harmony for successful performance especially under conditions of uncertainty, pressure, and stress. For example, behavioral inhibition is needed to prevent stimulus-bound responding which frees the individual from enticements in the immediate environment to engage in higher level problem-solving. Although hot and cold executive functions tap into overlapping processes, research has found that different brain regions play more prominent roles in the mediation of these two aspects of executive functioning: Hot executive functions are especially dependent on ventromedial prefrontal regions, whereas cold executive functions are highly dependent on dorsolateral and mesial frontal regions (Obeso et al., 2021; Salehinejad et al., 2021; Spaniol et al., 2019).

Problems with hot executive functions, including emotional dyscontrol and impulsivity, are best assessed with behavioral rating scales (e.g., the D-REF, the BRIEF2), whereas deficits in cold executive functions are best assessed with performance-based tests (e.g., the WCST, the D-KEFS Advanced [see Delis, 2021]). As noted earlier in this chapter, practitioners are cautioned against using only behavioral rating scales to evaluate cold executive function abilities given their low correlations with performance-based tests of these higher level cognitive skills (Biederman et al., 2008; Soto et al., 2020; Toplak et al., 2013). That is, self-report or collateral-report ratings of higher level cognitive abilities (e.g., working memory, response inhibition, cognitive shifting) tend to have low correlations with performance-based tests of those skills. Rating scales can provide helpful information about whether examinees subjectively believe or have insight into possible problems in cold executive function abilities but performance-based tests are needed to assess whether an individual has genuine deficits in those areas (see Delis, 2021).

The D-KEFS Advanced includes a new, performance-based test, the Risk–Reward Decision Test, that incorporates the assessment of hot executive functions, specifically risky decision-making, in the context of a problem-solving task. Unlike the other D-KEFS Advanced tests that are administered to children and adults (ages 8–90 years), the RISK is administered only to adults (ages 19–90 years). Research from the D-KEFS Advanced standardization study revealed that individuals with TBI had significant difficulties in risk-raking and problem-solving as assessed by the RISK (see Chapter 3).

Embrace Ecological Validity

One of the criticisms of cognitive assessments in children and adults is that they occur in a highly structured, quiet, controlled (i.e., one-on-one) setting and therefore fail to assess the individual's ability to perform various cognitive skills in common real-world situations that are often dynamically changing, unpredictable, and replete with distracting stimuli. Using an all-digital format for the D-KEFS Advanced provided an invaluable opportunity to create new tests and conditions that simulate these distracting and changing environments and thus have greater ecological validity. For example, the systematic auditory and visual distracting stimuli presented in the new TMT Switching–Distraction condition simulates the examinee's ability to perform multitasking in an environment that is closer to common, real-world settings that are often noisy and distracting.

Efforts were made to enhance the ecological validity of the D-KEFS Advanced tests in other ways as well. On the new D-KEFS Advanced Social Sorting Test, the key sorting concepts of the task were designed to be real-world stimuli including the faces of people, their emotional expressions, and details of their clothing. This test assesses the ability to use correct/incorrect feedback to quickly isolate important categories in real-world stimuli and to flexibly use those rules or concepts to solve problems. Another new measure, the Risk–Reward Decision Test, assesses risky decision-making in the context of a horse-racing game with galloping sounds and chimes when money is won. Many examinees become very animated when taking this test, including cheering for their selected horses to win, which parallels several real-world scenarios where individuals make decisions involving risks and rewards (e.g., gaming machines). The new D-KEFS Advanced tests, including the TMT Switching–Distraction condition and the RISK, elicit an array of different behavioral responses not usually seen in print versions of tests, which highlights another advantage of the fully digital approach.

Expand the Process Approach

The original D–KEFS was among the first set of tests to embrace the process approach to the assessment of executive functioning (Kaplan, 1988). Each test yields several scores that reflect not only the overall performance on the test but also the strategies, errors, and processes that examinees display in solving the executive function tasks. The D-KEFS Advanced all-digital format allowed for the development of new, more dynamic tests and conditions, and it further elevated the process approach to cognitive assessment.

Elevate the Process Approach to Cognitive Assessment

The all-digital interface of the D-KEFS Advanced tests takes the process approach to a new level by automatically scoring considerably more process measures. Across all six tests, core scores are provided to capture global performance within a condition or across an entire test, and process scores capture data on speed, accuracy (through both error and correct responses), and strategies used that contribute to the overall scores. For example, the D-KEFS Advanced Tower Test not only provides a more sensitive global performance score that has a higher ceiling and lower floor than the original D–KEFS Tower Test, but it also provides numerous process scores that help elucidate underlying reasons for impaired performance. For instance, the Tower Test provides scores that reflect unproductive responses (i.e., chip moves that do not bring the examinee's chip arrangement closer to the target solution) and new measures that directly reflect levels of trial-and-error responding, including 0-back responses (i.e., lifting a chip and placing it back on its original table), 1-back responses (i.e., moving a chip to a different table and then returning it to its original table), and 2-back responses (i.e., moving a chip to two different tables and then returning it to its original table). On the Social Sorting Test, a new process measure was developed that reflects derailment errors in which an examinee is correctly sorting to one category, receives ambiguous correct feedback that simultaneously reinforces two or three categories, and is then derailed and starts sorting to a different category that was just reinforced but is incorrect. These new process measures provide valuable insights into the underlying mechanism of an examinee's executive function deficits.

Identify the Mechanism of Impaired Multitasking

Multitasking requires several executive function components for successful performance. For example, the standard switching condition of the trail making task requires (a) inhibition of responding to the next prepotent (i.e., automatic or overlearned) stimulus after each new number or letter response has been made (i.e., inhibiting number-to-number or letter-to-letter connections), (b) working memory to remember the place in the sequence while switching between numbers and letters and visually searching for the next correct circle to connect, and (c) cognitive shifting to be able to fluently abandon one response mode for another. The D-KEFS Advanced TMT provides new measures that aid in assessing whether a breakdown in complex multitasking is related to problems in response inhibition, working memory, and/or cognitive

shifting. For example, the Switching–Distraction condition, a new measure of complex multitasking, involves systematic auditory and visual distracting stimuli that are precisely presented to magnify the next prepotent response that must be inhibited after the examinee makes each correct response. If an examinee performs at the expected level on the TMT Number–Letter Switching condition but exhibits impairment on the new TMT Switching–Distraction condition (which places greater demands on inhibitory skills), then the mechanism of the examinee's multitasking impairment may be with response inhibition (see Chapter 4). As another example, if an examinee performs within the expected level on both the Number–Letter Switching and Switching–Distraction conditions but is impaired on the new Switching–Working Memory condition (in which the demands on working memory are magnified), then the mechanism of this examinee's impaired multitasking performance may be with working memory.

Enhance Reliability, Validity, and Clinical Sensitivity

Demonstration of the clinical utility of assessment instruments is critical for their validity and use. A key goal in the release of the D-KEFS Advanced was to demonstrate its improved sensitivity in detecting executive function deficits in common child and adult clinical groups. Results are provided for using the D-KEFS Advanced in several clinical groups including attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and math disorders (specific learning disorder-mathematics [SLD-Math]) in children and adolescents, and traumatic brain injury (TBI) and mild cognitive impairment (MCI) in adults (see Chapter 3). The results revealed improved sensitivity (i.e., higher effect sizes) compared to findings from past studies using other executive function tests, including the original D–KEFS. For example, the new D-KEFS Advanced Color–Word Interference Test yielded large effect sizes and the TMT and the SST yielded moderate effect sizes in identifying executive function deficits in children and adolescents with ADHD (see Chapter 3), which has historically been an elusive finding for a cognitive instrument in this population. In addition, five of the six new D-KEFS Advanced tests (i.e., the TMT, the VFT, the CWIT, the TWR, the SST) yielded large effect sizes and the RISK yielded a moderate effect size in identifying executive function deficits in adults with TBI (see Chapter 3).

To ensure the new tests measure what they are designed to measure, several concurrent validity studies were conducted as part of the final standardization study. The largest study was conducted by comparing performance on the original D–KEFS and the D-KEFS Advanced. Given the large body of research supporting the original D–KEFS as a measure of executive functioning and the close similarities of four of the D-KEFS Advanced tests, the significant correlations among corresponding tests in this study provide support for the clinical utility of the D-KEFS Advanced tests as measures of executive functioning. In addition, studies were conducted in which performance on select tests of the D-KEFS Advanced was compared with performance on the WCST, the Iowa Gambling Task™ (2nd ed.; IGT™2; Bechara, 2016), the Wechsler Individual Achievement Test® (4th ed.; WIAT®-4; NCS Pearson, 2020), the Wechsler Adult Intelligence Scale® (5th ed.; WAIS®-5; Wechsler, 2024), and ratings on the D-REF.

Improve Utility in Child and Adolescent Evaluations

Executive function skills continue to develop well into adulthood with rapid growth in childhood and adolescence. In addition, executive function abilities develop at different rates and peak at different ages. They are among the most important cognitive skills for successfully navigating the demands of life, school, socializing, and career and among the most vulnerable because of the protracted development of the frontal lobes. Because fundamental skills (e.g., language acquisition, reading) also develop at different rates in children and adolescents, it is important to have executive function tests that parse out the relative integrity of fundamental skills versus higher level abilities.

As previously noted, a major goal of the D-KEFS Advanced was to lower the floors to yield higher quality results among younger children and individuals with serious developmental or acquired impairments. Examples of how this goal was achieved include adding the option to readminister demonstration/sample items to ensure that the examinee understands the task (i.e., on the TMT, the CWIT, and the TWR), minimizing motor or articulation demands (i.e., on the TMT, the CWIT, and the TWR), and adding multiple easy-to-build towers on the Tower Test. Finally, a greater proportion of children are growing up in a world that is saturated with digital devices with the incorporation of tablets into the classroom and rise of remote learning. It may be the case that interactive tests administered using a digital platform elicit a more accurate depiction of cognitive skills than traditional print tests.

It is important to note that the D-KEFS Advanced norms span critical ages in childhood, adolescence, and young adulthood to assess the extended development of executive function skills over the first third of the lifespan. Smaller age bands are used in these ages to capture the rapid development and variability of executive functioning. This allows tracking of an individual's progress longitudinally in comparison to their same-age peers to determine whether they follow an expected developmental trajectory. It also facilitates tracking the efficacy of interventions designed to ameliorate executive dysfunctions that a child or adolescent may experience.

Improve Interpretation

Interpreting performance on the original D–KEFS and the D-KEFS Advanced can be daunting for new users and those unfamiliar with the process approach to cognitive assessment. Interpreting multiple scores can be confusing, particularly when analysis of one score is dependent on other scores. This Manual provides detailed guidance on interpretation of each test, and the Score Report includes flowcharts and graphs to aid in the interpretation process. For example, interpretation of the Trail Making Test begins with an examination of the component processes needed to perform the two baseline sequencing tasks, and each subsequent condition is analyzed after factoring in the results from the proceeding conditions. Placing the individual scores within this broader hierarchy of cognitive skills helps users learn how to interpret the numerous measures provided by the D-KEFS Advanced. All scores, including standard scores, scaled scores, and base rates, are adjusted for age. Examiners also have the option of deriving core scores for adults that are adjusted for age and education level. All core and process scores are included in the report; however, additional report options can be selected (i.e., age/education-referenced scores for ages 20–90 years, raw scores, item responses) that provide different configurations of results depending on the level of interpretation needed for a particular setting. Graphs and flowcharts are also included in the Score Report to aid interpretation.

In addition to improvements in the interpretation guidance and reports, a subsample of the national normative group was given both the D-KEFS Advanced and the D-REF child version to objectively capture these reports of behavior, which provides a more integrated assessment of hot and cold executive functions.

Reduce Examiner Burden and Measurement Error

The digital interface provided an opportunity to reduce examiner burden across the administration, scoring, and interpretation of the D-KEFS Advanced. Features were included on the Practitioner and Client Devices with the goal of making the tests as effortless as possible to administer and score with most scoring done automatically. This directly reduces measurement error, as well as administration and scoring time, while freeing the examiner to observe the examinee's test-taking behavior. Score Reports are generated immediately after administration and provide schematic flowcharts and graphs to assist clinicians in interpreting the wealth of core and process measures provided.

Ease of Administration and Automatic Scoring

Print versions of executive function tests can be among the most cognitively difficult tasks for examiners to administer. For example, on the original D–KEFS Tower Test, the examiner must (1) record the time for the examinee to make the first chip move, (2) count each chip move the examinee makes (which can occur very rapidly for some examinees), (3) catch and stop the examinee from making any rule violation errors and record those errors, (4) remember when to administer various prompts and what to say, (5) keep track of the stopwatch, and (6) monitor and remember the different time limits for different items. In addition, the original D–KEFS Tower Test requires the examiner to juggle several pieces of equipment when administering the test including the wooden tower base, the five wooden discs, the Stimulus Booklet with instructions, the Record Form, a pencil/pen for recording responses, and a stopwatch or other timing device.

On the fully digital D-KEFS Advanced, the administration and scoring of the various executive function tests are a simplified, seamless process. For example, on the new Tower Test, each chip move and the time to make that move are automatically captured and scored; each type of rule violation error is automatically captured and scored, and corrective feedback is automatically provided to the examinee in the form of a red X that flashes on the stimulus with a brief shaking of the chip; examiner prompt notifications with the exact wording of what to say are automatically displayed on the Practitioner Device at the precise moment they should be read to the examinee; numerous new process measures are automatically scored (e.g., 0-Back, 1-Back, and 2-Back Moves that reflect levels of trial-and-error responses); and administration of each item of the test automatically stops when the time limit is reached.

The streamlined administration and automatic scoring provided on the D-KEFS Advanced tests significantly reduces examiner administration and scoring mistakes, thereby decreasing measurement error, and allows the examiner to focus on one of the most important aspects of the assessment process: observing the behaviors and emotions exhibited by the examinee while taking the tests. Table 1.2 lists improvements made to address ease of administration and scoring for several of the D-KEFS Advanced tests.

Table 1.2 Examples of Ease of Administration and Scoring Improvements Made on the D-KEFS Advanced Compared to Traditional Executive Function Tests

Original D–KEFS Trail Making Test	D-KEFS Advanced Trail Making Test

• Materials:
  • Stimulus Booklet to read instructions
  • Five paper response forms
  • Paper Record Form to record completion times and errors
  • Pencil/pen for the examiner and the examinee
  • Stopwatch
	• Materials:
	  • Practitioner Device
	  • Client Device
	  • Stylus

• On practice items, the examiner must:
  • Immediately identify incorrect connections
  • Stop the examinee from continuing to make connections
  • Remember the type of corrective feedback to give depending on the type of error made
	• On sample items, incorrect connections are automatically detected and marked on the Client Device:
	  • The incorrect circle and connecting line turn red, a white X temporarily displays on the red circle, and the circle remains red
	  • The Client Device darkens, and the examinee is not allowed to continue connecting additional circles
	  • A notification immediately appears on the Practitioner Device and provides the examiner with the exact prompt to read aloud that explains the error type
	  • The examiner touches the OK button, which brightens the Client Device and allows the examinee to complete the sample item

• During test items, the examiner:
  • Reads the instructions from the Stimulus Booklet
  • Starts and attends to the stopwatch
  • Closely monitors each connection made by the examinee
  • Immediately stops the examinee when an incorrect connection is made and before additional connections are made (which is difficult for examinees who impulsively draw rapid lines)
  • Asks the examinee to return to the last correct circle
  • Monitors the stopwatch for the discontinue time
  • Attends to the discontinue times for the different conditions
  • Records the total time to complete the condition
  • Records the number and types of errors (e.g., sequencing, set-loss, time discontinuation)
  • Looks up the scaled scores in the Manual or manually enters the raw scores in the software scoring program
	• During test items, the examiner:
	  • Reads the instructions displayed on the Practitioner Device and touches the timer button to activate the Client Device and allow the examinee to start responding
	• All other administration/scoring tasks are performed automatically by the digital interface including:
	  • Marking incorrect connections on the Client Device
	  • The incorrect circle and connecting line turn red, a white X temporarily displays on the red circle, and the circle remains red
	  • Allowing the examinee to continue only from the last correct circle and not from the last incorrect circle
	  • Preventing further responses by the examinee at the discontinue times
	  • Computing all core and process raw scores
	  • Generating and providing all age-referenced and optional age/education-referenced standardized scores in the Score Report along with a speed–accuracy tradeoff graph and a schematic flowchart to aid interpretation

Table 1.2 Examples of Ease of Administration and Scoring Improvements Made on the D-KEFS Advanced Compared to Traditional Executive Function Tests (*continued*)

Original D–KEFS Color–Word Interference Test	D-KEFS Advanced Color–Word Interference Test

• Materials:
  • Stimulus Booklet
  • Paper Record Form to record responses
  • Pencil/pen to record responses
  • Stopwatch
	• Materials:
	  • Practitioner Device
	  • Client Device
	  • Stylus

• On practice items, the examiner must:
  • Identify incorrect responses immediately
  • Stop the examinee from continuing
  • Remember the type of corrective feedback to give depending on the type of error made and provide the corrective feedback
	• On sample items:
	  • Incorrect responses are automatically detected
	  • The Client Device darkens and does not allow further responding
	  • A notification immediately appears on the Practitioner Device and provides the examiner with the exact prompt to read aloud that explains the error type
	  • The examiner touches the OK button, which brightens the Client Device and allows the examinee to continue responding

• During test items, the examiner:
  • Reads the instructions from the Record Form
  • Starts and attends to the stopwatch
  • Closely monitors each response and records errors on the items when they occur
  • Tries to ensure that the examinee does not skip items or rows (which, when it occurs, is difficult to detect and prevent)
  • Monitors the stopwatch for the discontinue time
  • Attends to the discontinue times
  • Records the total time to complete the task
  • Records the number and types of errors
  • Looks up the scaled scores in the Manual or manually enters the raw scores in the software scoring program
	• During test items, the examiner:
	  • Reads the instructions displayed on the Practitioner Device and touches the timer button to activate the Client Device and allow the examinee to start responding
	  • Because items are presented individually, it is impossible for the examinee to skip items or rows
	• All other administration/scoring tasks are performed automatically including:
	  • Coding and scoring correct and incorrect responses
	  • Preventing further responses by the examinee at the discontinue times
	  • Computing all core and process raw scores
	  • Generating and providing all age-referenced and optional age/education-referenced standardized scores in the Score Report along with a speed–accuracy tradeoff graph and a schematic flowchart to aid interpretation

Table 1.2 Examples of Ease of Administration and Scoring Improvements Made on the D-KEFS Advanced Compared to Traditional Executive Function Tests (*continued*)

Original D–KEFS Tower Test	D-KEFS Advanced Tower Test

• Materials:
  • Wooden tower base with three pegs
  • Five discs
  • Stimulus Booklet with instructions
  • Paper Record Form to record times, number of moves, and errors
  • Pencil/pen to record responses
  • Stopwatch
	• Materials:
	  • Practitioner Device
	  • Client Device
	  • Stylus

• For each item, the examiner:
  • Places the chips on the pegs in the correct starting position
  • Reads the instructions from the Stimulus Booklet
  • Makes sure the examinee does not start early
  • Starts the stopwatch
  • Records the first move time
  • Rapidly counts each chip move made (which is difficult for examinees using a rapid trial-and-error approach)
  • Closely monitors for rule violation errors
  • Stops the examinee each time a rule violation occurs
  • Attends to which prompt to give the first time each rule violation occurs
  • Returns the chip to its last peg each time a rule violation occurs
  • Records the total number of rule violations made
  • Keeps track of the different discontinuation times across items
  • Stops the examinee when the time limit is reached
  • Sums the achievement and process scores
  • Looks up the scaled scores in the Manual or manually enters the raw scores in the software scoring program
	• For each item:
	  • The chips are automatically displayed in the correct starting position at the bottom of the stimulus and the target chip placement is shown at the top
	  • The examiner reads the instructions displayed on the Practitioner Device and touches the timer button to allow the examinee to start responding
	  • The examiner reads aloud any prompt notifications that automatically appear on the Practitioner Device the first time the examinee makes each type of rule violation
	• All other administration/scoring tasks are performed automatically including:
	  • Capturing/scoring each type of chip move and the time to make that move
	  • Providing visual corrective feedback for each rule violation error made using a red X and a brief shaking of the chip
	  • Returning the incorrectly placed chip to its last location
	  • Scoring each rule violation type
	  • Ending each item and preventing further responses by the examinee when the specific time or move limit is reached
	  • Computing all core and process raw scores
	  • Generating and providing all age-referenced and optional age/education-referenced standardized scores in the Score Report along with a speed–accuracy tradeoff graph to aid interpretation

Table 1.2 Examples of Ease of Administration and Scoring Improvements Made on the D-KEFS Advanced Compared to Traditional Executive Function Tests (*continued*)

WCST (print version, which was used for the norms)	D-KEFS Advanced Social Sorting Test

• Materials:
  • Two decks of cards (64 cards each)
  • Four key cards
  • Manual with instructions
  • Paper Record Booklet to record sort type and correct/incorrect sorts
  • Pencil/pen to record responses
	• Materials:
	  • Practitioner Device
	  • Client Device
	  • Stylus

• The examiner places the four key cards in the correct position and hands the first deck of cards to the examinee. The examiner must ensure the 64 cards in each deck are in their correct order and that the examinee does not accidentally knock over the deck or sort two or three cards stuck together.	• The Client Device displays the four key cards at the top of the stimulus and a virtual deck of cards on the bottom. The examinee uses a stylus to drag the top card in the deck to a designated space below one of the four key cards. Cards cannot be accidentally misordered.

• The examiner:
  • Reads the instructions from the Manual
  • Closely monitors each sort made
  • Remembers the active sorting category to reinforce and says the correct/incorrect feedback for each sort
  • Tells the examinee to slow down if they are rapidly sorting
  • Monitors the number of consecutive correct sorts made
  • Switches the sorting rule in the specified order after 10 consecutive correct sorts
  • Remembers which category to reinforce next
  • Stops the test after six correct series of category sorts
  • Manually calculates the scores or enters each sorting response in the software program to derive the raw and age-corrected and age- and education-corrected standard scores
	• The examiner:
	  • Reads aloud the instructions displayed on the Practitioner Device and touches the timer button to activate the Client Device and allow the examinee to start sorting
	  • Reads aloud any prompt notifications that automatically appear on the Practitioner Device
	• Corrective feedback is automatically provided on the Client Device after each sort (i.e., a green overlay with a checkmark in the upper corner appears over correctly sorted cards and a red overlay with an X in the upper corner appears over incorrectly sorted cards)
	• All other administration/scoring tasks are performed automatically including:
	  • Reinforcing 10 consecutive correct sorts for the first category
	  • Switching to the next sorting category
	  • Cycling through the series of six category sorts
	  • Ending the task either after the sixth series of category sorts has been completed or 128 cards have been sorted
	  • Computing all core and process raw scores
	  • Generating and providing all age-referenced and optional age/education-referenced standardized scores in the Score Report

Theoretical Considerations

Over the years, models or theories of executive functioning have been proposed, which are helpful for conceptualizing the differences between frontal versus posterior cortical functions (Baddeley, 1986; Fuster, 2008; Luria, 1980; Petrides, 2000; Shallice & Burgess, 1996; Stuss & Knight, 2013; Suchy, 2015). However, these models also have limitations in that they often address only certain aspects of executive functioning (e.g., working memory), and the models are continually changing and evolving over time. In developing the original D–KEFS and the D-KEFS Advanced, the emphasis was not on trying to design tests that adhere to a specific model or theory of frontal lobe functioning, especially given the limitations inherent in those models. Rather, the emphasis was on developing tests that are sensitive to the detection of subtle problems in a wide range of executive functions across different modalities and to include conditions and process measures that allow the examiner to isolate and distinguish between deficits in fundamental versus higher level cognitive skills and different components of executive functioning (e.g., inhibition, cognitive shifting, working memory).

Stages of Development of the D-KEFS Advanced

The research and development of the D-KEFS Advanced spanned a period of over 16 years and experimented with multiple digital platforms because of evolving technology. The different stages of development included (1) the initial proof of concept (2009–2010), (2) nearly 20 early research studies evaluating the performance of typically functioning examinees (especially children ages 8–11 years and adults ages 70–90 years) and individuals with brain injuries or other neurological conditions, (3) two larger nationally collected pilot studies, (4) a tryout study that included over 300 children and adults, and (5) the final national standardization study that included 1,280 normative participants. Revisions were made to the tests across all the phases based on the results of the previous studies. Individuals with motor impairments and tremors were included in early studies to ensure that the impact of motor difficulties was minimized when using the digital devices.

Detailed information on both the development and standardization of the D-KEFS Advanced and the reliability and validity of the tests (including concurrent validity and clinical validity studies) is provided in Chapter 3. These clinical and concurrent validity studies provide additional support for using the D-KEFS Advanced tests in the assessment of executive functioning.

User Responsibilities and Test Security

In light of the complexities of test administration, diagnosis, and assessment, D-KEFS Advanced users should have training and experience in the administration and interpretation of standardized clinical assessments. They should also have training and/or experience testing individuals whose ages; linguistic background; and clinical, cultural, or educational histories are similar to those of the individual they are evaluating.

In most cases, D-KEFS Advanced users should have completed formal graduate- or professional-level training in psychological assessment. Although a trained technician, research assistant, or student can administer and score the D-KEFS Advanced under supervision, results should be interpreted only by individuals with appropriate training in cognitive assessment. Furthermore, test users should follow the *Standards for Educational and Psychological Testing* (*Standards*; American Educational Research Association [AERA] et al., 2014).

It is the responsibility of the test user to ensure that test materials, including score reports, remain secure and are released only to professionals who will safeguard their proper use. Although review of test results with the examinee, parents and guardians, or other stakeholders (e.g., school personnel) is appropriate when legally and ethically permitted, this review should not include disclosure of test items, instructions, or stimuli

or other test materials that would compromise the security, validity, or value of the D-KEFS Advanced as a measurement tool. Under no circumstances should test materials be resold or displayed in locations where unqualified individuals can purchase or view partial or complete portions of the test. This restriction includes personal and educational internet websites and internet auction sites. Because all test items, norms, and other testing materials are copyrighted, Pearson must approve, in writing, the copying or reproduction of any test materials. This includes the display of any item stimulus in presentations or publications. The only exception to this requirement is the copying of a completed Score Report for the purpose of conveying an individual's records to another qualified professional. These user responsibilities, copyright restrictions, and test security issues are consistent with the guidelines set forth in the *Standards* and are required by the D-KEFS Advanced licensing agreement.