Divided into two volumes, *Handbook of Special Education Research* provides a comprehensive overview of critical issues in special education research. This first volume addresses key topics in theory, methods, and development, exploring how these three domains interconnect to build effective special education research. Each chapter features considerations for future research and implications for fostering continuous improvement and innovation. Essential reading for researchers and students of special education, this handbook brings together diverse and complementary perspectives to help move the field forward.

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This volume and our companion volume (Handbook of Special Education Research, Volume II: Research-Based Practices and Intervention Innovations) grew out of numerous discussions and activities of the Division for Research (DR) of The Council for Exceptional Children. We felt a need to take stock of where the field has been, where it currently is, and potential avenues for the future. These discussions continue regularly among members of the DR executive committee. It seemed fruitful to share these ideas and conversations with the entire membership of the division and the field more broadly. In many respects, the purpose of this volume is to help chart the future, but not as a map or set of guideposts. Rather, our goal is to cultivate a fertile landscape from which emerging scholars, personnel preparation program leaders, and other stakeholders in special education can develop and nurture their own ideas and pathways forward as they move toward currently unknown frontiers.

We would like to thank Chris Lemons, Sarah Powell, Kathleen Lane, and Tisa Aceves, the editors of the companion volume. We started out thinking that we would have just one volume. However, as we began to identify potential topics and authors, the number of chapters ballooned to over 50. Fortunately, Chris, Sarah, Kathleen, and Tisa agreed to step forward to lead a second volume.

We would also like to thank all the members of the executive committee of DR for the past seven years. Through their hard work, their conversations in committee meetings, and their own research activities and experiences, they collectively created the impetus and foundation for this volume.

In addition, we would like to thank the Hammill Institute, sponsors of DR’s Doctoral Student Seminars in Special Education Research. This online seminar and discussion series involves a revolving network of doctoral students in special education from universities across the world who collaboratively work to address the question, “What makes for excellence in special education research?” The work this group does annually reminds us of the importance of the next generation of scholars and strengthens our commitment to building for the future. The Doctoral Student Seminars began in 2008, and many of the contributors in this volume have linkages to this program. We would also like to thank the faculty leaders of the Doctoral Student Seminars: Dr. Jean B. Crockett (University of Florida), Dr. Mary Theresa Kiely (Queens College, The City University of New York), and Dr. Kristen M. O’Brien (George Mason University).

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SECTION 1

Theoretical Foundations of Special Education Research
From time to time, it is instructive for a scientific discipline to step back, reflect on its progress, consider the impact the field is having on constituent stakeholders and society more broadly, and contemplate next steps forward. In the past few decades, the world has changed in many ways that affect the lives of children with exceptionalities and their families. From increasing diversity, enhanced technology, innovations in communications and social media, and changing educational and work structures, the landscape for working with and supporting individuals with exceptionalities has become more complex and also potentially more powerful as we have more resources and opportunities to make a difference. Likewise, for children and youth with exceptionalities, the increased complexity in their developmental experiences and circumstances means they have to negotiate new challenges that also present new possibilities in their learning, growth, and outcomes.

With the backdrop of the recent pandemic; forced adaptations; and inequities compounded as different groups and communities were differentially affected by the resulting health, social, economic, and political turmoil, we are now positioned to better see the adversity experienced by the youth we serve. On one hand, there is more innovation and promise than ever to support the unique needs of students with exceptionalities. On the other hand, disparities in resources and experiences and constraints in opportunities and services are reflected in growing gaps in educational performance and outcomes of youth from different backgrounds (Fuchs et al., 2018; NCES, 2019; Spencer, 2019).

As the Council for Exceptional Children, Division for Research (CEC-DR), it is important to elucidate, disseminate, and build upon advances in the field. It is equally critical to illuminate imbalances and disproportionate challenges experienced by subgroups of students and identify needed intervention and service delivery adaptations to respond to the differential needs of each child and the families, communities, and cultures that are central to their learning and growth. Accordingly, the goal of this two-volume handbook on special education research is to summarize advances in research while simultaneously addressing critical issues and needs in our efforts to support each student with exceptionalities across different abilities, backgrounds, cultures, and ecologies.

In the first volume, our aim is to meet this goal in three complementary ways. First, we provide an overview of key concepts and theories that undergird research in special education and the intervention and service delivery strategies we use to support students with exceptionalities and the ecological systems (e.g., families, peer groups, classrooms, schools, neighborhoods, cultures,
sociopolitical structures) in which they live and that shape their opportunities and development. Second, we present methodological and analytical approaches that are used in special education research to clarify information; answer theoretical and conceptual questions; make inferences from data; evaluate programs and services; aggregate and distill information across studies; and utilize the evidence base to guide efforts to tailor interventions to students, teachers, schools, and communities. Third, we examine a variety of developmental processes and ecological factors that differentially influence the opportunities and experiences of students with exceptionalities and the special education services they need.

In the second volume, the authors highlight critical areas of special education research and outline what we currently know about effective systems, interventions, assessments, and efforts to support educators. They also provide ideas about where special education researchers should go next to enhance the effectiveness of our efforts. Topics span academic, behavioral, and social interventions; assessment; tiered systems of support; the educator workforce; technology; and the needs of our most vulnerable populations. Our hope is that these chapters inspire the next generation of special education researchers to push the field forward in new and innovative ways.

**Foundations of Research in Special Education**

By its very nature, special education grew out of the understanding that all children have different characteristics and abilities, and each student can learn and develop skills to contribute to their own self-determined pathways, careers, and lifestyles when they are provided educational supports and related services that are responsive to their own strengths, needs, and ecological circumstances. Although students with exceptionalities differ somewhat from the majority of their same-age classmates in terms of their characteristics, development, and learning needs, their capacity to grow, adapt, and be successful in school and life can be nurtured and enhanced when supports are centered on what they need rather than on what works for others who are different from them. The following three foundational concepts of special education are central to conducting research to create effective interventions and service delivery frameworks that are responsive to students with exceptionalities with diverse needs.

**Individualized**

First, it is critical to individualize strategies and supports for youth with exceptionalities. Special education recognizes that what works for others is likely to not work in the same way for the students we serve. Students with exceptionalities can be highly successful. It is incumbent upon researchers to realize that teachers and other service providers will need to tailor strategies and supports to specific students, circumstances, and contexts. Youth with exceptionalities, like all youth, are dynamic in their growth and functioning. This means a strategy that works now may not work tomorrow or that additional factors may need to be considered to foster the success for a specific child. Therefore, as we conduct research, we need to develop frameworks that provide interventionists (e.g., teachers, other related service providers) with conceptual guides, data use tools, and decision trees to monitor each student’s progress and to make ongoing adaptations in the supports and strategies they use for individual students.

**Interdisciplinary**

Second, special education is necessarily interdisciplinary. Across the various special education categories, individual characteristics and needs vary broadly across physical or sensory factors; cognitive and learning processes; emotional, social, and behavioral functioning and adjustment; and health
and developmental adaptation. Therefore, as a field, special education involves an array of specialties and specialists. But the need for different disciplines working together extends beyond services for different categories of exceptionalities. Rather, individual children, themselves, develop as an integrated whole (Farmer et al., 2016). Although a child may be identified for services for a particular exceptionality classification (autism spectrum disorder, deaf-blindness, deafness, early childhood, emotional disturbance, giftedness, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech or language impairment, visual impairment including blindness), many of these classifications may be comorbid, and students may need services in other related domains. As children develop, their functioning in one domain is likely to influence and be influenced by their functioning in other domains (Darling-Hammond et al., 2020; Sameroff, 2020). Therefore, it is necessary to provide services and supports that extend beyond the primary area of exceptionality and include a focus on the other domains that may affect or be affected by the child’s exceptionality. That is why we have mandates for multidisciplinary teams and services in our special education policy. As we conduct research in special education, we need to ensure that we are considering the whole child and the interplay of an array of services and supports they need rather than focusing exclusively on a discrete domain or skill in isolation.

Contextualized

Third, it is necessary to understand and support the student in context. In addition to focusing on the whole child and how different domains operate together as a dynamic system, we must consider how the various settings in which children are embedded contribute to their functioning and growth (Bronfenbrenner, 1996). Children learn and develop, in large part, by how they engage with multilayered ecologies (e.g., families, peer groups, classroom, schools, neighborhoods, cultures, sociopolitical structures) that collectively shape their experiences (Bronfenbrenner, 1977; Smith & Thelen, 2003). This means that development is experiential, as opposed to universal, and involves continuous adaptation between the characteristics of the child and the affordances and constraints of their ecological systems (Bronfenbrenner, 1996; Cairns, 2000; Nasir, 2018). Two children who are together in the same classroom may experience the context very differently both because of their different characteristics and because of different ecological factors that they experience in their daily living (Cairns & Cairns, 1994; Farmer et al., 2016; Sameroff, 2020).

For example, consider a setting in which the school district mandates a 20-minute silent reading activity in middle school with everyone reading the same assigned book in homeroom each day. This activity is an evidence-based universal program required by the district as an opportunity to foster independent leisure reading skills while helping students transition into a learning mindset to start the school day. Two students who are from the same neighborhood and the same general background experience this activity in very different ways. One student is a strong reader, enjoys the content of the assigned books, has been reading books with a parent at home, and finds this activity to be a relaxing way to transition into the start of instructional activities. The second student has dyslexia, struggles to read independently, and reads at home with parents with books that are adapted to their reading needs. During this activity, the student is not sure they are even on the correct page and spends the time acting like they are reading and hoping to go unnoticed by classmates. At the completion of this routine morning activity, one student is emotionally and behaviorally prepared to succeed throughout the day while the other receives no adaptive supports, struggles with their disability, and starts the day acutely aware of their reading difficulties and feeling socially vulnerable and thinking they do not belong in class.

When children experience difficulties, it is helpful to view problems as not resting in the student or the ecology, but in the transactions between the two (Hobbs, 1966). This means that when
teachers and other specialists intervene with a student, it is necessary to not only focus on the characteristics of the child that needs support but also to clarify how both proximal and more distal ecological factors are contributing to the child’s functioning and how they can be addressed or leveraged in intervention. In addition to investigations that control for context to say whether an intervention works, we need research that clarifies how to respond to multilevel contexts that contribute to students’ functioning and growth. This requires a different set of research questions that center on understanding how to be responsive to multilayered ecologies and how to use them as an ally in the intervention process.

The Present Role and Circumstances of Special Education Research

The Individuals with Disabilities Education Act (IDEA, 2004) mandates services that are individualized and responsive to the unique strengths and needs of each child we serve. Thus, special education research, by its very nature, centers on idiographic considerations (Maggin et al., 2016). We use research techniques such as single-case designs and data-driven intervention approaches because the students with whom special educators work are, by definition, likely to have needs that are expressed and manifested differently from the general population of students. Therefore, while it is possible to use larger population data sets and group designs to help clarify whether an intervention shows promise with a particular group of students with exceptionalities (e.g., students with learning disabilities, students with intellectual disabilities, students with emotional and behavioral disorders), our mission is not so much to say whether an intervention works generally as it is to clarify the assessment considerations, strategy selection, and adaptive parameters for going about the process of supporting the successful learning and social and behavioral adjustment of individual youth who have needs and circumstances that are different from others (Danielson & Rosenquist, 2014; Fuchs & Fuchs, 2015; Kern & Wehby, 2014; Roberts et al., 2021).

As we work to produce and support the use of evidence-based intervention by teachers and other related service providers, we must distinguish what that means for a field in which development is not universal, our students’ needs are typically outside the parameters of the supports that work for the general population, and their needs are often influenced by the contributions of multiple factors that make a singular approach ineffective (Chen et al., 2021; Lemons et al., 2014; Sutherland et al., 2018). We must temper the common expectation that scripted, manualized programs can be developed that will be effective for all children if they are implemented with fidelity. We are working with highly individualized, dynamic phenomena where day-to-day monitoring of students’ performance and corresponding adaptation of strategies and supports are essential. For some special education issues or needs, it may be possible to develop programs that have this individualized and dynamic component built within them. But in many cases, we are necessarily dealing with moving targets that require complex, multifactored, and tailored approaches that are student and context specific. Therefore, we need research designs that can help guide practice on the ground that is consistent with special education mandates and that recognize that generalizable, one-size-fits-all approaches are illusory for our field.

The Centrality of Diversity in the Mission of Special Education Research

A key premise in special education is that all children can learn and be successful if we center our efforts on their strengths and needs and we provide supports that minimize the impact of their differences on their daily functioning and adaptation. Because they in some ways learn and function differently from other children, the developmental trajectories to success for youth with exceptionalities are likely to be different. Metrics of flourishing growth and corresponding supports to foster sustained positive adaptation for students with exceptionalities are likely to be different as well. That
is the beauty of human development. There are diverse pathways to positive outcomes, and children
do not need to follow the same developmental sequence or have the same abilities, characteristics,
and experiences of others to achieve success that is meaningful within their worlds. They need
opportunities and supports that are relevant to them.

This developmental diversity is critical for special education research. In some ways, population-
based research centered on the general linear model presupposes universal developmental pathways
and sameness in the experiences and needs of all children. The expectation that interventions can
be created that are generally effective for all children and implemented in the same way across dif-
ferent individuals, contexts, circumstances, and cultures ignores developmental diversity and is likely
to result in inadequate supports for children who are represented in the tails of the normal curve on
common learning and developmental factors. Children with exceptionalities can learn and grow.
However, the predominant population-centered research paradigm in education and the resulting
programs, interventions, and policies are not necessarily designed to align with their needs, nor their
pathways to success.

This is where special education research is critical. Our very mission is to be responsive to dif-
ferences in ability, functioning, and adaptation. Rather than expecting that all children can get to
the same outcome in the same way, we recognize the need to adapt learning strategies and environ-
ments to the individual and to the diverse characteristics, strengths, and needs that are relevant to
their development and success. We also recognize that self-determination is a critical component of
the development of children with exceptionalities, and we cannot presuppose the outcomes that are
meaningful to them. Therefore, at its very core, special education research is centered on individual
persons as opposed to the general population. Our goal is to establish systematic approaches to build
from our knowledge of diversity in development and to use data in ways that tailor supports to the
student, the circumstances, and the ecology.

This means that our research must extend beyond focusing on identifying intervention programs
or strategies that generally work. We need to ensure that our research includes an emphasis on the
diversity of persons and the diverse, multilevel contexts they experience and navigate across the
lifecourse. The lenses of social justice, equity, antiracism, inclusion, and belonging must also be
central to our efforts, and we must focus on diversity in preparing the next generation of special
education researchers. We have a strong foundation of research that is centered on individuals and
the use of data to adapt strategies to their diverse strengths and needs. This work is systematic and
rigorous, though it necessarily may not be generalizable. Instead, the metrics of the impact of our
field must include our responsiveness to diversity and our capacity and effectiveness in fostering the
self-determined success of each individual person we serve.

**Building for the Future**

As special education research moves forward, we need to continue what we do well, educate others
about the necessary differences between our work and research in general education and allied fields,
and broadly disseminate the impact and contributions that special education makes to education
more generally (Fuchs & Fuchs, 2015; Maggin et al., 2016; Vaughn & Swanson, 2015). Advocating
for our students and their families is also a critical feature of our research. This means uncovering
and bringing to the forefront differences in the experiences and needs of students with exceptionali-
ties in ways that promote equitable practices and opportunities for each child. But helping others
understand our students and what we do is only part of the equation to realize the promise of IDEA.
We must also be introspective, willing to change what needs to be changed, and willing to see what
we do in a new light.

This means that we must be prepared to take bold steps and foster innovations that extend
beyond what we do well and what is familiar or comfortable. We must continually ask ourselves hard
questions. Are we responsive to relevant constituents? Are we engaging all constituents in equitable and impactful ways? Are we asking the right questions? Do we have the tools and supports to fulfill our mission? Should we reframe the interplay between research and practice within our field? Can we better engage allied and adjacent fields?

We did not seek to answer these questions as we set out to develop these two volumes. Our goal was more modest. We aimed to bring together a broad group of scientists in special education representing different areas of interests, reflecting different levels of career backgrounds and experiences, and exemplifying a broad range of disciplinary perspectives and expertise. At one level, the chapters across the two volumes, both individually and collectively, are an accounting of where we have been, where we are, and where we might go in the future. At a second level, they are a conversation. A discussion of what we know, what we need to know, and what is possible. Broadly, research is the generation and application of new knowledge. Yet its impact arguably rests in its interpretation and perceived relevance. On this score, we hope the conversations in these volumes extend beyond authors, scientists, and students and foster new lenses through which to engage with and be responsive to individuals with exceptionalities, their families, and the teachers and other professionals who support them in their daily lives.

**References**


National Center for Educational Statistics (NCES-NAEP) (2019). The great divergence: Growing disparities between the Nation’s highest and lowest achievers in NAEP mathematics and reading between 2009 and
Taking Stock of Special Education Research


This chapter outlines theory, development, and application of behavior analysis as it relates to special education research and practice. One particular branch of behavior analysis, applied behavior analysis (ABA), is embedded in both the history and practice of special education. ABA is a scientific approach to understanding and changing behavior in ways that address problems of social importance (Wolf, 1978). Using a variety of research-based strategies, ABA practitioners and behaviorally oriented educators dedicate their practice to the systematic application of instructional technologies that develop the skills (e.g., academic, behavioral, daily living) most likely to increase quality of life in individuals with and without disabilities.

Theoretical Foundations of ABA

A comprehensive treatment of behaviorism extends beyond the purview of this chapter, and interested readers are referred to various authoritative, book-length treatments of the topic (e.g., Catania, 2013; Michael, 2004; Moore, 2008; Skinner, 1938). However, the scientific by-product of this philosophy, behavior analysis, has facilitated the development of generalizable principles, processes, and concepts of behavior that have proven invaluable to the development of an increasingly robust technology of behavior change often employed in the service of therapeutic outcomes for individuals both with and without developmental disabilities (e.g., intellectual disabilities, autism spectrum disorder [ASD]). Thus, an overview of the theory of knowledge that establishes the behaviorist perspective and justifies its methods of inquiry is warranted.

Behaviorism Versus Mentalism

A historical overview of ABA typically begins with Watson (1924). Prior to Watson’s entry into the field, explanations of human behavior were dominated by fixed, internal attributes such as states of mind. Watson introduced a behaviorist point of view, shifting the focus to observable, measurable behaviors. Thus, perhaps the easiest way to describe behaviorism is to first describe what it is not.
Mentalism attempts to explain behavior by attributing causal status to phenomena that purportedly occur in a domain (e.g., mental, cognitive, conceptual, spiritual, psychic) that differs from the domain in which behavior occurs. More specifically, mentalism infers that (a) entailed in any given organism’s physiological makeup exists a domain beyond the one in which behavior occurs (e.g., consciousness, intelligence, soul); (b) within this domain exists unobservable phenomena that are considered to be the independent contributions of the organism; (c) explanations of behavior necessarily consist of an appeal to these inferred phenomena as causes; and (d) organism and behavior are only in direct contact with the inferred phenomena, not the environment itself. As a result, specification of the causal status of these phenomena serves as the focus of inquiry of mentalistic traditions (e.g., Moore, 2015). By contrast, behaviorists view dualistic (mind/consciousness) explanations of behavior as problematic because they impede the development of an accurate and unified account of nature, due to their tendency to promote circular reasoning (e.g., Billy can solve problems because he is smart. We know Billy is smart because he can solve problems) and (often) because they stall the achievement of the regarded scientific objectives of prediction and control (e.g., if it is assumed that causal variables extend beyond the reach of scientific methods, then causality cannot be known through scientific means).

As an alternative, behaviorists view human behavior as the completely determined product of an interaction between innate endowment and environmental events. By extension, they propose that the study of behavior can be meaningfully construed as a life science and, more specifically, as a branch of biology. From this vantage point, behaviorists assert that it must be possible, at least in principle, to secure a complete account of all human behavior in terms of historically relevant behavioral, physiological, and environmental variables, without appeals to mentalistic dimensions. Thus, for a behaviorist, behavior itself is the appropriate subject matter of all psychological inquiry and should not be considered a mere index of processes that allegedly occur in hypothetical domains (Skinner, 1938).

**Contribution of Cognitive Processes, Genetics, and Physiology to Behavior**

A rejection of mentalism does not suggest that behaviorists also reject the existence (or importance) of higher-order cognitive processes (e.g., language, problem-solving). Rather, behaviorists propose that these processes are themselves instances of behavior and are best understood in relation to current and historical interactions between the relevant organism and its environment, thus making them directly amenable to scientific inquiry.

Related, behaviorists do not reject the contribution of genetic endowment and acknowledge the mediational role of physiology in the development and evolution of behavioral processes. Technically, behavior is the action of an organism’s effector (an organ at the end of an efferent nerve fiber specialized for altering its environment mechanically or chemically [e.g., striped and smooth muscles, duct and ductless glands]). Further, a stimulus is an energy change that affects an organism through a receptor (an organ that converts environmental energy changes into nerve impulses), and energy transformations caused by stimuli are at the root of experiences such as seeing, hearing, smelling, and tasting. Thus, by definition, stimulus-response interactions are a direct product of physiological processes.

Notwithstanding, an intimate understanding of an organism’s physiology is unnecessary for understanding general principles of behavior, and scientific discoveries in physiological domains will only serve to justify, rather than alter, discoveries made at the behavioral level. As a result, from a behaviorist’s perspective, the most thorough explanation for any organism’s current performance can be found by analyzing its history of interactions with the environment.
Contribution of Environmental Contingencies to Behavior

As in biology, the theory of evolution (Darwin, 1859) and the concept of selectionism (repeated cycles of variation, interaction with the environment, and differential replication as a function of that interaction) hold a critical role in behavioral accounts of what an organism does. Specifically, it is useful to analyze the evolution of a repertoire by considering the “fitness” of each of its constituent members. Said differently, behavior persists because of its ability to meet the demands posed by the contingencies of relevant environments, and therefore survive. Thus, the behavior of an organism can be understood to be the joint product of (a) phylogenic selection (contingencies of survival responsible for species-specific repertoires), (b) ontogenic selection (contingencies of reinforcement responsible for the shaping and conditioning of idiosyncratic repertoires across an individual’s lifetime), and (c) cultural selection (contingencies that maintain evolved social environments). Although each topic serves as the focus of different academic disciplines ([a] behavioral genetics and ethology, [b] behavior analysis, [c] social and cultural anthropology), it can be useful to describe their interactions when justifying the behavior-analytic perspective.

Behavior of the Species: Phylogeny

At this level, behavioral science is concerned with the evolutionary history of the innate behavior of an entire species (e.g., reflex, kinesis, taxis, fixed action patterns). Theoretically, these behaviors are selected because they have facilitated differential success in accessing or avoiding contact with environmental events that are critical to survival (e.g., access to life-sustaining resources and mates, avoidance of predators). Organisms without these innate repertoires do not survive, and therefore do not reproduce. Organisms who do possess them propagate their lines of descent. Environmental contingencies determine the functional utility of responses (e.g., it is only adaptive to blink if damage to an eyeball disadvantages the relevant organism and jeopardizes its ability to survive and reproduce). Thus, it is the environment (not the individual) that selects innate repertoires.

Given the volatility of most environmental contingencies, an important development in human evolution was its inheritance of a genetic endowment that allowed organisms of the lineage to be changed idiosyncratically, and semi-permanently, by their interactions with the environment—that is, to “learn.”

Behavior of the Individual: Ontogeny

At this level, science is concerned with the evolution of individual repertoires across a single lifetime. Specifically, ontogeny is concerned with the ways in which learned behavior evolves to promote and propagate the survival of individuals. Theoretically, the temporary diminishing impact of frequent and repeated exposure to eliciting stimuli (habituation), the conditioning of reflex responses to occur in the presence of novel stimuli (respondent conditioning), and the temporal and topographical sensitivities of general repertoires to their impact on the environment (operant conditioning) collectively allow an organism to maximize contact with life-sustaining events and minimize contact with events that jeopardize survival (for detailed explanations of these terms and concepts, see Catania, 2013; Michael, 2004). Thus, in discussions of ontogenic selection, specific stimulus-response relations metaphorically “survive” when they enhance effective action in novel environments and do not survive (or are “extinguished”) when they do not.

As is the case at the level of phylogeny, environmental contingencies (the circumstances under which neutral stimuli come into contact with unconditioned and conditioned stimuli and unconditioned and conditioned behavior) determine what relations are conditioned at any given moment across an organism’s lifetime. For example, certain four-legged furry animals are paired with the
sound “dog” in the United States, but the sound “cachorro” (Ka-show-ho), in Brazil. Thus, it is again the environment (not the individual) that selects learned repertoires and the circumstances under which they manifest.

**The Behavior of Cultures**

Loosely defined, cultural practice describes a phenomenon in which, through shared experience, individual members of a group come to do the same things, for the same reasons, under similar sets of circumstances (Hayes & Toarmino, 1995). “Culture,” then, refers to a population of cultural practices, as well as the artifacts involved in their replication (Skinner, 1938, 1981, 1987).

Technically, cultural practices are specific instances of operant behavior, and controlling variables that propagate them can easily be found in the history of the individual. However, when certain practices are coordinated with the actions of others, their collective impact on the environment is greater than the sum of their constituent parts (e.g., certain hunting or agricultural practices, warfare). Theoretically, the synergistic qualities of coordinated action are so effective at amplifying the impact of an individual’s behavior on the environment that the act of coordinating action itself becomes reinforcing. As a result, members of certain groups learn to attend to the behavior of others and to mediate contingencies of reinforcement and punishment that shape and maintain important cultural practices. Language (itself a cultural practice) is a particularly important medium through which these practices are transmitted.

At the level of cultural selection then, behavioral science is concerned with analysis of the contingencies (often interlocking and socially mediated) responsible for shaping and transmitting cultural practices among group members across the “lifetime” of a culture. Cultural practices that provide solutions to problems related to a group’s welfare (e.g., how resources are acquired and consumed, how waste is managed, rules of logic and reasoning) purportedly “survive.” Practices that do not benefit the group purportedly do not. As is the case at the levels of phylogeny and ontogeny, environmental contingencies (not members of a group) select and maintain cultural practices.

**Scientific Objectives of Behavior Analysis**

The objective of behavior analytic inquiry is to understand how an organism is affected by the environment by exploring its unlearned and learned response mechanisms through analysis of contingencies found in nature. Although contemporary behavior analysis is not atheoretical, its historical roots are embedded in operationism (i.e., the meaning of a scientific concept is synonymous with the operations by which it is measured) and a healthy skepticism of theory-driven experimentation (cf. Skinner, 1950). From a behaviorist perspective, science is a process through which empirically based rules or laws of nature can be formulated and improved. The purpose of this process is no different from that of any other functional behavior; namely, to maximize contact with reinforcement and to minimize contact with punishment for anyone who encounters it (Skinner, 1957). Science based on theories that do not promote effective action is unnecessarily wasteful. Thus, to a behaviorist, a theory is only valuable to the extent to which it promotes effective action.

In this quest for actionable knowledge, searches for order and lawfulness are pragmatic, conservative in scope, and guided by inductive logic. The paradigm begins with a description of simple cases and facts: for example, statements such as “it is consistently demonstrated that the future frequency of certain classes of behavior are sensitive to the consequences which follow them.” From those facts emerge general, abstract, and functionally defined conceptual taxonomies (e.g., antecedents, consequences, reinforcers, punishers, discriminative stimuli, etc.), which can then be used for interpretive analysis and experimentation.
From a foundation of basic conceptual principles, inquiry advances to analysis of larger systematic arrangements of these principles so that they can be qualified or expanded upon. For example, when exploring parameters of reinforcement, basic scientists learned that the effect of reinforcement on behavior was relative, rather than absolute. Specifically, when multiple contingencies of reinforcement are concurrently available, the amount of responding allocated toward any one contingency is directly proportional to the amount of reinforcement provided by that contingency, relative to the reinforcement provided by all currently operating contingencies. This principle, known as the generalized matching law (Baum, 1974), qualifies the impact that a single contingency of reinforcement has on behavior and has held substantial explanatory power in the decades since its initial discovery.

Each step toward complexity increases the depth and precision of behavioral concepts, thereby increasing the circumstances under which prediction and control can be accomplished. Because principles are not deduced, but rather emerge as the inductive product of empirical facts, negative outcomes (i.e., null effects) are as valuable as positive ones and the field advances each time the results of a well-controlled experiment are reported (Tincani & Travers, 2018).

Scientific Methods in Behavior Analysis: Single-Case Design

Because behavior is a continuous phenomenon that occurs at the individual level (Cooper et al., 2020), behaviorists are skeptical of conclusions drawn from aggregated summaries of data collected at single points in time (Sidman, 1960). As a result, they have developed and continue to refine an experimental methodology—single-case design—which allows scientists to establish control (i.e., unambiguous evidence of a functional relation between behavior and relevant environmental variables) at the individual level, using time series (repeated) measurement systems. Single-case design, then, is the methodology used by behavior analysts to examine and show evidence of changes in behavior resulting from changes in environmental conditions. For an in-depth treatment of single-case methods, see Chapter 9 of this volume.

A variety of single-case designs have been developed that demonstrate functional or causal relations between independent (introduced by the experimenter) and dependent (behavior targeted for change) variables. Regardless of the specific type of single-case design, single-case methods always include an operationally defined target behavior that is measured in a consistent and systematic manner over time and across varying conditions to determine how conditions (e.g., interventions) affect the target behavior. Effects of the independent variable on the dependent variable must be replicated across time and/or individuals to verify that a functional relation exists between the two variables.

Single-case design initially developed from experimental studies of animal behavioral models but has become one of the most effective methodologies for identifying evidence-based practices in special education (Horner et al., 2005). A number of features of single-case design make it well suited to research (and practice) in special education. Primary among them is that single-case design analyzes the behavior of an individual over time and only requires one case to demonstrate causal relationships. Because individuals with disabilities are fewer in number and present more unique characteristics than the general population, single-case design can be used to conduct rigorous research with very low-incidence populations. In addition, single-case graphs allow researchers and practitioners to visually examine changes in individual behavior over time and provide a decision-making aid regarding intensifying or changing interventions and supports—a process that has led to important knowledge production in research and implementation of effective learning and behavior support strategies in practice.

Scientific Domains of Behavior Analysis

Currently, behavior analytic scientific endeavors expand across four distinct but interrelated (and ideally communicating) domains: theory, basic science, applied science, and practice.
Theory and Interpretation

Although behaviorists prioritize experimental analysis over theory, data without interpretation are meaningless. For experimental outcomes to be generally useful, some degree of extrapolation is needed. Further, as has been previously stated, behaviorists contend that, at least in principle, it must be possible to appeal to past and present physiological and behavioral principles to secure a complete account of all human behavior. Because the rigors of valid experimentation introduce both practical and ethical barriers to comprehensive empirical analysis across many domains relevant to human functioning, it becomes important to generate plausible (and falsifiable) accounts of behavior in these domains, using conceptual systems and functional taxonomies informed by the findings of decades of experimental analysis.

Thus, the role of this branch of inquiry is interpretation and extrapolation. A nonexhaustive list of topics addressed through behavior analytic theory include the existence and functions of private events (e.g., Skinner, 1957; Palmer, 2009); choice (e.g., Baum, 1974); impulsivity (e.g., Madden & Bickel, 2010; Odum, 2011); persistence (e.g., Nevin & Grace, 2000); relapse (e.g., Shahan, 2020); the functions of verbal behavior (e.g., Skinner, 1957); the functions of rule-governed behavior (e.g., Hayes et al., 1989); problem-solving (e.g., Skinner, 2013); cultural design (e.g., Skinner, 1971); and the roles that arbitrarily applicable derived relational responding (a phenomenon that might be easiest to understand as a special case of generalization) can play in symbolic representation, “understanding,” and emotional pain associated with certain psychopathologies (Hayes et al., 2001; Hayes, 2004; Snyder et al., 2011).

Because these theories are formulated using operationalized taxonomies and functional conceptual units, the validity of their predictions can be subjected to experimental analysis at both basic and applied levels in ways that simultaneously enhance their precision and utility (basic) and the impact of technologies designed for the resolution of socially significant problems (applied). Thus, the degree to which theories guide effective action determines their value and justifies when and how they are modified.

Basic Science

The primary objective of science at this level of inquiry is to develop, refine, and clarify basic and universally applicable principles of behavior. As the theory of evolution establishes a continuity of species, behaviorists are minimally concerned with the identity of subjects who participate in these experiments, provided species-specific traits and tendencies can be controlled for prior to the extrapolation of principle. Basic scientists are in constant contact with theory, as the findings of their empirical work directly inform when and how theory is modified.

Applied Science

The objective of applied science is to leverage conceptual systems provided by basic science and theory in the development and expansion of behavior-change technology appropriate for the resolution of socially important problems. Said differently, the purpose of applied science is to produce clear and unambiguous evidence (or lack thereof) of specific techniques that contribute to a generalizable technology of behavior change that bridges the gap between what is known and what is useful.

To accomplish this, applied scientists must remain aware of developments in theory and basic science, as each clarification of a basic principle of behaviors has the potential to amplify the impact of interventions at the applied level. Likewise, they must stay abreast of challenges encountered by practitioners who deliver behavior analytic services to ensure experimental initiatives remain tethered to clear and socially valid objectives. Because the points of contact between basic laboratory models
and applied scenarios can be vague or otherwise unspecified, a subdomain of applied research (i.e.,
translational research) has grown in popularity.

Translational research describes a scientific tradition in which researchers conduct proof-of-concept studies meant to bridge gaps between basic and applied knowledge for reasons that range from demonstrations of generality to problem-solving (Mace & Critchfield, 2010). Broadly, translational research can be useful because it demonstrates how, specifically, basic laboratory findings might bear relevance to socially significant problems. When successful, these endeavors provide applied scientists with points of contact between applied problems and known mechanisms of change and thus serve as a muse for conceptually systematic problem-solving (e.g., Greer & Shahan, 2019; Wathen & Podlesnik, 2018). Occasionally, they also serve to facilitate identification and/or clarification of behavioral processes uniquely relevant to applied populations (e.g., Sidman, 2000; Dixon et al., 2021).

Although any human problem can be the subject of applied or translational scientific inquiry, robust technologies useful to children with disabilities have included the assessment and treatment of challenging behavior, systematic instruction, and language-based intervention.

**Practice**

Service providers with a behavioral orientation adopt the conceptual systems and technologies developed by basic and applied science to improve the lives of the population(s) of clients for whom said technologies were developed. Occasionally, comprehensive treatment packages have been developed to serve certain populations or problems, including (but not limited to) models of discrete trial instruction (i.e., carefully constructed, concrete opportunities to respond) inspired by work by Ivar Lovaas (e.g., Lovaas, 1977, 1987). More often, practitioners individualize interventions according to their fluency with general principles of systematic instruction (e.g., conditioning through prompting systems and differential reinforcement, shaping, chaining, generalization, and maintenance), and goals are individualized based on the outcomes of functional assessments designed according to conceptual systems developed by the other three branches of inquiry. Functional assessments commonly relevant to children with disabilities include assessments of expressive and receptive communication, from a behavior analytic perspective (e.g., Sundberg, 2008; Partington, 2008), challenging behavior (Bloom et al., 2013; Hanley et al., 2014; Lambert & Houchins-Juárez, 2020), and symbolic representation and generativity (e.g., Rehfeldt & Barnes-Holmes, 2009; Dixon, Belisle et al., 2015; Dixon, Paliulas et al., 2019; Gibbs & Tullis, 2020).

Contemporary practitioners of behavior analysis (i.e., board-certified behavior analysts [BCBAs]) are not distinguished by a specific profession (e.g., psychology, special education) as much as by the nature of their practice and the structure and content of their preservice professional training. Specifically, BCBAs in any profession can be distinguished by their commitment to objective improvements in operationally defined and empirically verifiable goals of social significance through interventions that are individualized based on the results of ongoing and valid formative assessment and that operate on variables found in the natural world (as opposed to a mental one). Although these practitioners prioritize client outcomes and develop data systems that facilitate data-based individualization (rather than experimental control), they are trained in single-case methodology and are capable of conducting applied science within the context of their own practice whenever new knowledge directly relevant to their clientele is needed. That is, they are professionally trained to be scientist-practitioners (e.g., Critchfield, 2015; Dorsey & Harper, 2018). Preservice practitioner graduate programs that embrace the conceptual foundations of behaviorism and mastery of basic and applied methods of inquiry (regardless of profession) can be authorized to deliver coursework that qualifies its graduates to obtain the BCBA credential in addition to whatever professional credentials are valued by the department that houses the program (BACB.com).
Behavior-Analytic Influences in Special Education

ABA has made many critical contributions to special education research and practice. In this section, we outline some of these contributions in terms of their connection to behavioral theory and impact on special education.

Operant Learning Theory

Nearing a century ago, B.F. Skinner (1938) discovered principles of operant conditioning that allowed researchers to systematically shape and establish idiosyncratic behavioral repertoires. These principles were initially studied in labs with nonhuman subjects (e.g., rats or pigeons) and provided the empirical foundation of modern-day, behavior-analytic practices. Through hundreds of lab-based animal experiments, Skinner established the consistent and generalizable effect of basic operant conditioning procedures (e.g., reinforcement, punishment) on behavior. Specifically, Skinner found that behavioral responses followed by improved conditions (e.g., food or water) resulted in increased rates of those behavioral responses. He further found that specific antecedent stimuli could come to occasion these responses when followed by powerful reinforcers, thus formalizing the three-term contingency of discriminative stimulus, behavioral response, and reinforcing stimulus. Using this three-term contingency, also known as operant conditioning, Skinner was able to develop a variety of new behaviors in animal models.

Fuller (1949) first extended operant conditioning to individuals with disabilities in a study with an institutionalized 18-year-old man with profound developmental disabilities and severely limited mobility. Staff described this young man as incapable of learning; however, when Fuller provided a preferred sugar milk solution following arm raises, the participant soon learned to raise his arm at a rate of three times per minute. This study demonstrated the potential benefit of behavior analysis for individuals with profound disabilities whose ability to learn had previously been dismissed.

Researchers soon moved from targeting simple motor responses to demonstrating that operant conditioning could be used to increase socially important skills and behaviors, as well as decrease challenging behaviors that interfered with quality of life (Wolf, 1978). Lovaas (1977, 1987) began seminal work using operant conditioning to teach social, communication, and academic skills to children with ASD through methods of discrete trial teaching. A number of researchers in ABA have extended this work to embed operant conditioning and discrete trials into play-based and other natural routines to teach critical skills for children with ASD. For example, Brock et al. (2018) used peer-implemented pivotal response training (Koegel & Koegel, 2019), in which typical children were taught to encourage and socially reinforce social play behaviors during recess to increase peer interaction and play in children with ASD. As a result of its empirical support, insurance coverage of ABA-based therapy for children with ASD is now mandated in the majority of the United States. Overall, many evidence-based special education practices are grounded in principles of operant conditioning and ABA (Wong et al., 2014), including the use of (a) direct instruction with rapid opportunities to respond, (b) systematic prompting procedures, and (c) individualized or group-based reinforcement contingencies such as token economies or self-monitoring systems. Further, operant learning theory has led to evidence-based approaches to teacher professional development, such as behavioral skills training, in which a coach provides instructions, modeling, rehearsal/role play, and feedback to teach school staff to implement special education strategies (Kirkpatrick et al., 2019).

Function-Based Approach to Challenging Behavior

Another example of how behavioral science has contributed to instructional technologies that benefit children with disabilities may be found in the development of functional analysis (FA) and
functional behavior assessment (FBA). In a seminal paper, Carr (1977) reviewed previous empirical work to consider why individuals with disabilities might engage in self-injurious behavior (SIB). At this time, challenging behavior in children and adults with disabilities, particularly SIB, was generally viewed as aberrant and maladaptive with purposes that were unknowable and irrelevant to treatment. Therefore, SIB was typically assessed by its form and targeted for reduction using consequence-based procedures like extinction (Lovas et al., 1965), response-cost (Iwata & Bailey, 1974), overcorrection (Foxx & Bechtel, 1983), or differential reinforcement of incompatible behavior (Peterson & Peterson, 1968). Although these procedures were also based on behavior analysis, they were not informed by an understanding of the function, or reinforcement contingencies, maintaining the challenging behavior and often produced mixed results (Bachman, 1972). Carr (1977) concluded that SIB may be maintained by positive, negative, and/or automatic reinforcement in different individuals. Carr went further to identify ways in which knowledge of the motivation for challenging behavior might be used to increase the effectiveness of intervention. He also suggested creating different social conditions in which individuals with SIB could be observed to see which situations were associated with higher rates of SIB, thereby indicating the function of SIB for that person. Iwata et al. (1982), building from Carr’s theoretical work, developed a procedure (a multielement FA) that allowed interventionists to confirm (and rule out) multiple hypotheses of challenging-behavior function across a relatively brief period of time (e.g., a few hours). This procedure has proven critical to decades of intervention research (Beavers et al., 2013; Hanley et al., 2003; Mace, 1994) and practice, as FA and its variations (e.g., trial-based FA; Bloom et al., 2013), as well as FBA (a nonexperimental approach to identifying potential functions of challenging behavior), are commonly used to inform interventions for individuals with challenging behavior.

Thus, theory-driven etiological accounts of challenging behavior eventually led to the development of evidence-based methodologies (FA and FBA), which now play a critical role in the educational programming of many children with disabilities. Applied research has consistently found behavior interventions based on the function of an individual’s challenging behavior to be more effective than behavior interventions not based on function (Jeong & Copeland, 2020). As a result, in 2004, the Individuals with Disabilities Education Act (IDEA) 20 U.S.C § 1415 Procedural Safeguards included provisions mandating an FBA and function-based behavior intervention plan (BIP) for students with disabilities under certain conditions and recommending them for any student with a disability whose behavior interferes with learning. Additionally, FA and FBA procedures have become important tools for caregivers supporting positive behavior at home in their children with disabilities (Fettig & Barton, 2014).

**Data-Based Decision-Making and Individualization**

A final example of ABA’s influence on the field of special education is in the use of ongoing formative assessment to monitor, evaluate, and adjust academic and behavioral interventions for students with disabilities. Such data collection and analysis procedures include curriculum-based measurement (CBM; Deno, 1985), brief experimental analysis (BEA; Daly et al., 1999), progress monitoring (PM; Gesel & Lemons, 2020), data-based decision-making (DBDM; Bruhn et al., 2020), and data-based individualization (DBI; Jung et al., 2018). See Chapter 4 for a more in-depth description of these approaches applied to academic contexts. Although these procedures were developed by researchers both inside (Daly et al., 1999) and outside (Deno & Mirkin, 1977) of ABA, the approach to evaluating the effectiveness of a specific practice for an individual student using systematic, repeated measures highly sensitive to change is rooted in ABA traditions of data collection and analysis (Fuchs, 2017) and can be readily traced back to the work of Dr. Ogden Lindsley (Bruhn et al., 2020).
Lindsley studied behavior analysis with B.F. Skinner and applied the measurement and analysis methods used by Skinner to teaching students with disabilities, an approach known as precision teaching (PT; Lindsley, 1991). Specifically, PT incorporated five principles derived from Skinner's experimental work with animal models: (a) the learner knows best; (b) measure observable behavior; (c) use frequency as the unit of measurement; (d) use a standardized data display; and (e) carefully describe environmental conditions (White, 1986). When combined, these principles involved daily measuring and graphing of student learning on a Standard Celeration Chart and analyzing student progress from initial baseline level to the goal level, or aim, plotted on the graph. If the student was progressing along the aim line, which connected their initial performance to their aim, instruction and monitoring continued as planned; however, if student progress was beneath the aim line, instruction was adjusted or intensified until student progress was on course to reach the aim (Lindsley, 1972). Instructional methods used in PT were based on operant conditioning and when combined with regular evaluation and enhancement of student progress resulted in an extremely effective approach to teaching academic skills to students with disabilities (White, 1986). As a result, PT was federally funded and successfully implemented in a large number of public schools (Beck & Clement, 1991) with such outcomes as fourth-graders in PT schools performing in the 95th percentile on standardized scores of reading achievement compared to fourth-graders in non-PT schools performing at the 71st percentile (Beck, 1979). Building from the work of Lindsley (1972), Deno and Mirkin (1977), Fuchs (Fuchs et al., 1989), and many others, DBI has developed greatly in recent years (Lemons et al., 2017; McMaster et al., 2020), including the federal funding of the National Center on Intensive Intervention (NCII; intensiveintervention.org).

Conclusions and Future Directions for ABA in Special Education

In conclusion, ABA, based on behavioral theory, has positively affected special education research and practice in many crucial areas, including (a) research methodology uniquely suited to identifying evidence-based practices for students with disabilities; (b) effective and systematic instructional methods for students with high- and low-incidence disabilities; (c) theory-driven approaches to assessing and improving challenging behavior in students with and without disabilities; and (d) data-based methods of monitoring, evaluating, and intensifying individualized interventions. Although researchers have used ABA-based methods to develop many evidence-based practices in special education (Wong et al., 2014), an important area of current and future work in ABA lies in creating conditions that facilitate the effective, sustained, and scaled implementation of its practices. Issues of implementation fidelity, maintenance, and generalization are not new to ABA and have been discussed since its inception (Ayllon & Michael, 1959; Baer et al., 1968; Wolf, 1978); however, more recent successes and initiatives in supporting the implementation of effective ABA practices have involved skills-based training, a systems approach, a focus on cultural responsiveness, and methods for fostering “buy-in.”

Each of these implementation factors can be found in School-wide Positive Behavioral Interventions and Supports (PBIS), a framework for delivering school-based behavior supports that is strongly rooted in ABA (Horner & Sugai, 2015). PBIS has experienced great success in its adoption and implementation, with over 25,000 U.S. schools implementing it as of 2018 (pbis.org/about/about). While PBIS incorporates ABA-based approaches to skills training for school staff (Kirkpatrick et al., 2019), it also works at a systems level by focusing on the entire school as the unit of analysis (Horner & Sugai, 2018), thus shaping broader school cultural contingencies to support sustained implementation. More recently, PBIS researchers have been analyzing and developing ways to increase racial equity and cultural responsiveness within the PBIS framework (Gion et al., 2020). In general, as the United States grows more diverse and recognizes the social importance of
addressing racial inequity, behavior analysts will need training and frameworks for implementing culturally responsive interventions (Conners et al., 2019). Finally, PBIS research and practice have devoted considerable energy to understanding and measuring a rather “nonbehavioral” concept: “buy-in,” or personal agreement and investment in the implementation of a practice (Filter et al., 2016). School staff buy-in to PBIS has repeatedly been identified as a critical barrier (and facilitator) to its implementation, and effective methods of fostering buy-in to increase sustained implementation of ABA-based practices may exist (Feuerborn et al., 2016; Robertson, 2020). In sum, research, methods, and practice arising from behavioral theory have greatly affected special education; future efforts to further and broaden acceptance and implementation of ABA-based practices may benefit from an increased focus on understanding the systems, cultures, and people who could use and benefit from ABA in special education.

References


Sidman, M. (1960). *Tactics of scientific research.* Authors Cooperative, Inc.


3

CONTRIBUTIONS OF COGNITIVE SCIENCE TO SPECIAL EDUCATION RESEARCH AND PRACTICE

Historical Context, Current Influences, and Future Directions

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Cognitive science includes cognitive psychology, developmental cognitive psychology, and educational and cognitive neuroscience (see Chapters 7 and 18). In this chapter, we illustrate the contribution of cognitive science to understanding the nature of learning disabilities (LDs) and to intervention design. We discuss historical and current influences of cognitive science, including how (a) academic interventions for LDs were motivated by schema theory and theories of metacognition and metacognitive development; (b) cognitive principles of learning have been applied to academic interventions; and (c) models of reading and mathematical cognition inform understanding of and interventions for dyslexia, reading comprehension disabilities, and math disabilities. We also present some directions for future research.

Human Learning and Memory

In this section we describe three theoretical frameworks broadly situated in the study of human learning and memory and describe their application to LDs. In reality, most interventions are multifaceted, drawing on more than a single theoretical framework or technique from cognitive science. Although we present these frameworks separately given their different historical origins, we make links between them particularly with respect to future research.

Metacognition

History

Metacognition is most strongly associated with the cognitive developmental psychologists John H. Flavell and Ann Brown. They observed that compared to older children, younger children were
remarkably poor at judging how well they could perform a task such as remembering something they learned or realizing when they didn’t understand something (e.g., Flavell et al., 1970). Flavell was interested in describing the development of the ability to understand and reflect on one’s own and other’s cognition, the former making its way into education in terms of cognitive monitoring and self-regulation, and the latter evolving into the field of theory of mind (Baker et al., 2020). Perhaps because developmental differences in metacognition were studied using reading comprehension tasks, it was a short leap to integrate metacognitive theory into academic interventions (Baker et al., 2020), including for students with LDs. For example, in 1992 a special issue of the *Journal of Learning Disabilities* reported interventions using metacognitive principles for children with disabilities in reading, mathematics, and writing (Borkowski, 1992).

**Relations to Academic Skills and Use in Interventions**

The two main components of metacognitive theory that have been applied to academic skills development include *self-monitoring*, an in-the-moment judgment of one’s progress with respect to their task goals, and *self-regulation*, a forward-looking aspect involving cycles of planning, directing one’s attention and effort to the task at hand, evaluation, and revision. Metacognitive approaches are often referred to as dialogue-based. Structured dialogue is used by a teacher (or peer) to model strategies that are applied to content. The student is then guided in their own dialogue-based application of the strategy, often taking the form of “think-alouds” or group discussion (Berkeley & Larsen, 2018). Metacognitive dialogic approaches often involve positive self-talk routines to maintain motivation and address negative attributions (Berkeley & Larsen, 2018). Dialogue-based metacognitive components are also used in reciprocal teaching/peer-mediated learning (Palincsar & Brown, 1984). Metacognitive theory has been influential in the design of strategy-based interventions for LDs. Cognitive strategies need not be *metacognitive* unless they involve self-monitoring or self-regulation components.

In a quantitative synthesis, reading comprehension interventions with an explicit self-regulation component produced large effect sizes (Berkeley & Larsen, 2018). Although these effect sizes were consistent with some previous findings for cognitive strategy instruction, the authors suggested that the self-regulation component was important for transfer and independent strategy use because effects were maintained over time. Metacognitive approaches for students with writing disabilities, such as those found in self-regulated strategy development, are associated with the largest effects on written composition compared to other instructional methods (Gillespie & Graham, 2014). In a meta-analysis across academic domains not disaggregated for LDs, the effect of metacognitive components added to strategy instruction were the highest for writing, then math, then reading (Donker et al., 2014).

Only a few studies of LDs have compared the same intervention with and without the added self-regulatory component. In a study of children with dyslexia, effects on word reading were stronger for a phonologically based intervention with a metacognitive component compared to the phonological approach alone (e.g., Lovett et al., 2000). In a study of third-grade children with math difficulties, Fuchs and colleagues (Fuchs et al., 2021b) compared a fractions intervention with and without a self-regulation + growth-mindset component. There was no added benefit of the metacognitive component, leading the researchers to suggest that, with a strong domain-specific intervention, self-regulation strategies might not be necessary. In a writing intervention study that isolated the self-regulatory component from the cognitive writing strategies component, there was also no added benefit of the self-regulatory component (Graham & Harris, 1989). Metacognitive strategies of goal setting and measuring attainment of that goal were not effective practices when examined individually for children with math disabilities (Gersten et al., 2009).
Issues and Future Directions

Metacognitive approaches have been an important aspect of strategy-based interventions for children with LDs; however, it is unclear whether the addition of metacognitive components leads to better learning than well-designed, domain-specific interventions without such components. This question is best addressed with experimental studies comparing the same domain-specific intervention with and without a metacognitive/self-regulatory component. Given that metacognitive components, when combined with domain-specific instruction, might be particularly relevant for maintenance and transfer, we think this direction is worth pursuing in future studies, which should include maintenance and transfer outcomes. It is also important to determine for whom metacognitive components might be most effective. Sufficient domain knowledge and/or cognitive resources are important for the efficient implementation of metacognitive strategies (Compton et al., 2014), and yet knowledge and cognitive resources are often cited as areas of deficit for individuals with LDs (Swanson et al., 2009). Future research might examine whether domain knowledge and/or cognitive resources moderate effects of interventions with metacognitive components.

Schema Theory

History

Schema theory can be traced to Sir Frederic C. Bartlett (1932), who proposed that one’s previous knowledge primes or sets up expectations for the processing of new information. Although this statement seems uncontroversial, it was at odds with predominant behaviorist theories at the time. Schema theory underlines the importance of prior knowledge for facilitating acquisition of new knowledge and problem-solving.

Relations to Academic Skills and Use in Interventions

Schema theorists have contributed to special education by providing a set of procedures for use in interventions in reading comprehension, mathematics word-problem solving, and written composition. In reading comprehension, a specific use of schema theory has involved teaching different types of text structure, particularly for expository text (e.g., description, cause/effect, compare/contrast, problem/solution, sequence). The idea is that understanding and learning from texts are facilitated when the reader processes the text according to the structure the author has used (Williams, 2018). A meta-analysis of text structure interventions showed substantial effect sizes and larger effects in studies that included instruction in more than one schema for students with or at risk for disabilities (Hebert et al., 2016); however, effects on general measures of reading comprehension were smaller than those on researcher-created measures, without much evidence of maintenance (Hebert et al., 2016). Another technique based on schema theory is activation of topic knowledge prior to processing text (see Hall, 2016 for examples in inference-making interventions for children with reading disabilities).

Schema theory has been applied frequently to math word problems interventions, which have underlying semantic structures (e.g., for additive schema, combine, compare, change problems; for multiplicative schema, equal groups, comparison and proportions or ratio problems; Powell & Fuchs, 2018). These approaches have yielded large effect sizes on math problem-solving in elementary and secondary school students with LDs (Jitendra et al., 2017; Peltier & Vannest, 2017).

Issues and Future Directions

Schema-based approaches can improve reading comprehension, mathematical problem-solving, and writing. We see opportunities for additional research given common findings of fade-out effects (e.g.,
Bailey et al., 2020; Hebert et al., 2016), which suggest that schemas are not consolidated in long-term memory postintervention or are not easily accessible or retrievable during independent learning. Research on cognitive learning principles reviewed later suggests that various techniques that lead to stronger and less context-dependent retention and retrieval of previously learned information might be integrated into schema-based instruction to increase maintenance and transfer of effects.

Another avenue for research relates to intensification that takes children’s general linguistic and cognitive difficulties into account (Fuchs & Fuchs, 2014). For example, children with math disabilities often have co-occurring language difficulties (Morsanyi et al., 2018). In a study of first-graders with significant math difficulties, although schema-based intervention was effective compared to a business-as-usual or number knowledge intervention, word problem and word problem language outcomes were significantly stronger for the group that received the same schema-based intervention plus an embedded language comprehension component compared to all other conditions at posttest (Fuchs et al., 2021a).

**Cognitive Learning Principles**

The term “cognitive learning principles” comprises a theoretical framework for the peculiarities of how human learning and memory work (Bjork et al., 2013). We highlight only a few of these principles from cognitive psychology. See Jordan et al. (2020) for a review of cognitive learning principles with particular reference to children with math disabilities; to the Institute of Education Sciences (IES) practice guide *Organizing Instruction and Study to Improve Student Learning* (Paschler et al., 2007); and to Mayer’s (2008) multimedia principles, which reduce cognitive load in interventions using assistive technology and nonelectronic materials (e.g., text and diagrams).

**History**

The beginnings of the experimental study of human learning and memory, and the discovery of some of the principles, are attributed to a German psychologist, Hermann Ebbinghaus (1885/2013; *Memory: A Contribution to Experimental Psychology*). Ebbinghaus was the sole subject of his experiments in which he used nonsense words to study the conditions under which learning and forgetting occurs. He found that repetition of information across sessions resulted in “savings” and that spacing of learning or distributed practice resulted in stronger retention over time. From the middle of the last century, experimental research in this tradition has been an important subfield of cognitive psychology and has seen something of a renaissance in the past decade or so in its application to education. Most experimental studies of these principles have been conducted with typical college and K to 12 students (e.g., Rittle-Johnson et al., 2020).

**Relations to Academic Skills**

We review a select number of learning principles: (a) practice that is spaced or distributed; (b) interleaving, a type of distributed practice; and (c) contextual variation. Retrieval practice, also called the testing effect (Roediger & Karpicke, 2006), is effective for evaluating one’s own learning and also for learning itself (Dunlosky et al., 2013). We refer to this principle as applicable when discussing practice.

**DISTRIBUTED PRACTICE**

Learning and practice that is spaced—or distributed—over time better consolidates new learning in memory than learning that is massed. This finding holds for a range of knowledge acquisition tasks.
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Despite many studies of the general phenomenon, optimal delays for distributed practice effects (Cepeda et al., 2009) and whether these delays vary for learners at different levels of knowledge or for different types of knowledge are not well understood. In interventions for children with LDs, relevant effects of distributed practice would ideally be measured across much longer time periods than is typical in most cognitive experiments.

In one of the first studies to address educationally relevant practice lags, spacing of greater than one day was associated with better long-term retention (Cepeda et al., 2009). Studies manipulating lag in children are rare; one with typical third-graders showed that spacing math facts practice by three hours resulted in better retention over time than either massed practice or a ten-minute lag between practice sessions (Powell et al., 2020). Distributed practice is often part of intervention study design and is recommended as a best practice (i.e., versus massed practice) for children with LDs in reading (Earle & Sayeski, 2017), writing (Harris et al., 2017), and math (Hughes et al., 2019).

Although experimental cognitive researchers have not frequently manipulated lags in distributed practice, it is actually common in interventions for children with LDs to include a form of distributed practice called cumulative review that occurs over educationally relevant lags. Cumulative review arose from the theory of instruction literature from the 1970s (Engelmann & Carnine, 1982) and has been a critical aspect of interventions for children with LDs since then (personal communication, Russell Gersten, January 29, 2021).

Whereas cognitive studies indicate the superiority of distributed versus massed practice in interventions for children with LDs and cumulative review is a cornerstone of interventions for children with or at risk for LDs, we see several possibilities for additional research: (a) To our knowledge, manipulations of distributed practice to determine optimal lag length have not been conducted for children with LDs; (b) given findings with college students that distributed practice might be differentially effective for learning different types of knowledge (Ebersbach et al., 2020), we suggest that such distinctions may need to be considered and manipulated when applying distributed practice routines to interventions for children with LDs; and (c) we question whether schema-based interventions might benefit from manipulations of spacing, both within the intervention and between posttest and testing of delayed effects, essentially introducing additional practice retrieval opportunities after the end of formal instruction. This suggestion also applies beyond schema-based interventions.

**INTERLEAVED PRACTICE**

Interleaving is a type of distributed practice in which different types of problems or tasks are interleaved during learning and recall rather than focusing on learning of one type (of text, of math problem, and so forth) before moving on to the next. In a classic demonstration, Rohrer and Taylor (2007) provided brief math tutorials followed by practice problems to college students on finding the volumes of geometric solids. Tutorials and practice were either blocked within a single session (learn one solid, practice problems for that type, then learn the next solid) or interleaved (learn all four solids followed by interleaved practice in all four types). Although novel problem-solving accuracy was better for the blocked condition during the tutorial-practice session, it was better for the interleaved condition after a one-week delay. Proposed mechanisms behind the interleaving effect are that (a) comparative learning aids in choosing the correct problem-solving solution when problems are mixed (Dunlosky et al., 2013), as they typically are in real-world situations; (b) interleaving forces retrieval from long-term memory, which is needed to consolidate learning and transfer, whereas blocking simply relies on retrieval from working memory (Dunlosky et al., 2013); and (c) interleaving introduces contextual variation, which is discussed in the next section.

Because interleaving has largely been tested in cognitive studies of short duration, interleaved practice and instruction are essentially the same construct; that is, in these studies, new concepts are