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Evidence-based Kernels: Fundamental Units of Behavioral Influence

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Abstract This paper describes evidence-based kernels, fundamental units of behavioral influence that appear to underlie effective prevention and treatment for children, adults, and families. A kernel is a behavior–influence procedure shown through experimental analysis to affect a specific behavior and that is indivisible in the sense that removing any of its components would render it inert. Existing evidence shows that a variety of kernels can influence behavior in context, and some evidence suggests that frequent use or sufficient use of some kernels may produce longer lasting behavioral shifts. The analysis of kernels could contribute to an empirically based theory of behavioral influence, augment existing prevention or treatment efforts, facilitate the dissemination of effective prevention and treatment practices, clarify the active ingredients in existing interventions, and contribute to efficiently developing interventions that are more effective. Kernels involve one or more of the following mechanisms of behavior influence: reinforcement, altering antecedents, changing verbal relational responding, or changing physiological states directly. The paper describes 52 of these kernels, and details practical, theoretical, and research implications, including calling for a national database of kernels that influence human behavior.

Keywords Evidence-based kernels · Public-health benefits · Prevention · Treatment

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This paper presents an analysis of fundamental units of behavioral influence that underlie effective prevention and treatment. We call these units *kernels*. They have two defining features. First, in experimental analysis, researchers have found them to have a reliable effect on one or more specific behaviors. Second, they are fundamental units of behavior influence in the sense that deleting any component of a kernel would render it inert. Understanding kernels could contribute to an empirically based theory of behavioral influence, facilitate dissemination of effective prevention and treatment practices, clarify the active ingredients in existing interventions, and contribute to developing interventions that are more efficient and effective. Subsequent sections of this paper expand on the two essential features of evidence-based kernels, as well as the origins of the idea and terminology.

The ultimate goals of treatment and prevention research are a reduction of the prevalence of the most common and costly problems of behavior and an increase in the prevalence of wellbeing. Current thinking about how to accomplish this assumes that we will identify empirically supported programs and, to a lesser extent, policies, and will disseminate them widely and effectively. Although substantial progress is occurring through this strategy, there are at least four limitations to it that point to the value of kernels as a complementary strategy.

First, it is difficult to implement a program's efficacy widely with fidelity or effectiveness. Ringwalt et al. (2003) surveyed a sample of 1,795 school staff members who were in charge of teaching substance-use prevention programs. Nearly two-thirds reported teaching content that meta-analyses showed was effective. However, only 17% used effective delivery and only 14% used both effective delivery and content. In a second study, Ringwalt et al. (2003) found that about one-fifth of teachers of substance-

use prevention curricula did not use a curriculum guide at all and only 15% reported following one closely. Hallfors and Godette (2002) studied 104 school districts in 12 states. They found that many districts selected evidence-based programs, but only 19% of district coordinators indicated their schools implemented those programs with fidelity. They concluded there was inadequate funding and infrastructural support for implementation. More recently, prevention programs with long-standing efficacy data from more controlled conditions and settings, such as Project Alert or Reconnecting Youth (e.g., Bell et al. 1993; Ellickson et al. 1993), were tested for effectiveness in real-world contexts and conditions. Most often, the obtained effectiveness results do not replicate the efficacy trials (e.g., Hallfors et al. 2006; Sanchez et al. 2007; St. Pierre et al. 2005). Research on how to get programs widely adopted, effectively implemented, and appropriately adapted to different conditions is still in its infancy. However, initial evidence suggests that sole reliance on program dissemination to affect population outcomes will have a limited impact, even with restrictive policies (e.g., Hallfors et al. 2007).

Second, many problems—or behaviors—that affect wellbeing do not require lengthy or complex interventions involving consultations, workshops, training, or support. Consider a few examples. A teacher might improve classroom behavior just by using some non-verbal cues during transitions (Abbott et al. 1998; Krantz and Risley 1977; Rosenkoetter and Fowler 1986) or reduce aggression and bullying on the playground by cooperative games (Murphy et al. 1983). A parent might easily improve a teenager's cooperation with a mystery motivator (Madaus et al. 2003). A principal might reduce disturbing or disruptive behaviors and increase engaged learning with the principal's lottery (Thorpe et al. 1978). A college professor might increase participation of students with response cards instead of the expensive clicker systems (Shabani and Carr 2004). In other words, a simple method of behavior influence might well solve a specific problem, and that was all that was required. The simple solution might actually avoid larger, more unpleasant difficulties or have greater good over time. For example, the response cards used in a classroom increase academic achievement (Gardner et al. 1994) or the use of organized recess might not only reduce aggression on the playground, but also improve the academic performance of children in the classroom with ADHD (Jarrett et al. 1998). Thus, simple solutions might just be sufficient in many cases.

Third, program dissemination is unlikely to affect practices or problems that fall outside the scope of a program. Teachers, clinicians, parents, healthcare providers, coworkers, supervisors, and many others are constantly trying to have a beneficial influence on others' behavior. Existing formal programs address only a small range of situations and behaviors they seek to influence. For example, parents may complain to a teacher, principal, nurse, or doctor how hard it is to get their young child moving in the morning. Alone, such a complaint does not merit implementing parenting skills training. However, a simple behavior change strategy, such as the *Beat the Timer* game (Adams and Drabman 1995), in which the child receives a reward for completing a behavior before the timer goes off, could solve the problem, and prevent parent–child conflict. Even in situations where an effective program exists, the program dissemination strategy will fail to affect *any* practices of those who choose not to adopt the program. A related issue is that that many problems have no evidence-based programs on published approved lists. For example, bipolar disorder is increasingly common among younger children, yet there are no listed programs for teachers with such children. Thus, given current evidence, it is likely that for now most daily practices that influence human development will fall outside the scope of existing programs. Failing to improve those practices is a missed opportunity.

Cost is a fourth limitation of depending solely on program dissemination to affect public health. The National Registry of Effective Programs and Practices provides cost information (see http://modelprograms.samhsa.gov/template.cfm?page=nrepbutton). Direct costs for program developers include material production, training, licensing, ongoing consultation of adopters, results monitoring, and program improvement. There are also hidden costs, such as venues, staff training, temporary staff replacement to cover duties, and administrative costs. For example, a model universal program that reduced observed aggression on the playground by about 10% (Grossman et al. 1997) requires 17.5 h of direct instruction per pupil, plus indirect costs for material and training of teachers. Thus, a school with 25 teachers may spend $12,000–15,000 for materials, training, staff timing, and (possibly) substitute teachers. A cost of $500 per teacher per universal program is unexceptional for listed programs. Therapeutic model programs (e.g., Ogden and Halliday-Boykins 2004; Szapocznik and Williams 2000) can cost between $80,000 and 200,000 depending on the nature of licensing needs, training, materials, supervision, monitoring, and staffing. If multiple evidence-based programs are required, costs per problem (e.g., tobacco, alcohol, violence, bullying, or mental illness) can bring the total to hundreds of thousands of dollars in direct and indirect costs per setting. These funds are not typically available to schools, human service agencies, groups, and others charged with prevention and treatment. There is no reason to expect a surge in such funds at a local, state, or federal level anytime soon. Clearly, if program adoption is the only avenue to large population

effects, progress will be slow and costly. It would be very useful from a public health and safety perspective if there were low-cost prevention, intervention, and treatment strategies to deploy easily—reducing the need for more expensive strategies that might not be possible to field where money and resources are scarce.

A fifth concern is that existing programs have limited effectiveness, modest effect sizes, scalability concerns, weak generalization, difficulty with maintenance or sustainability, and even iatrogenic effects (e.g., Hallfors et al. 2006; St. Pierre et al. 2005; Sanchez et al. 2007). This is not to diminish the enormous progress of prevention science in the past 30 years (Biglan 2004). However, inspection of recent meta-analyses of interventions (e.g., Bledsoe 2003; Derzon et al. 2005, 2006; Ennett et al. 2003; Lősel and Beelmann 2003; Lipsey et al. 2006; Scheckner et al. 2004; Tobler et al. 2000) finds plenty of room for improving the effectiveness of our programs.

A sixth concern is that current evidence-based programs do not easily meet the diffusion criteria (Rogers 1995). For instance, individuals who might be early adopters of proven and tested prevention strategies can often gain access to these strategies only through institutions such as schools or state agencies. If a school or agency lags, thousands of individuals or families in geographic areas cannot avail themselves of strategies that might prevent school failure, substance abuse, mental illness, delinquency, or other ills. Individual teachers also cannot adopt science-based strategies, as almost all evidence-based prevention programs require school or district adoptions. For example, it is easier for a parent or teacher to gain access to a prescription drug to treat ADHD or depression than to obtain evidence-based strategies that might similarly affect behavior (e.g., Ridgway et al. 2003; Schilling et al. 2003; Larun et al. 2006).

Each limitation points to the value of identifying and making available kernels of behavior influence. We do not suggest that kernels replace tested, proven programs; we propose that kernels supplement or strengthen programs, help to create new programs more efficiently, or make effective behavior–influence techniques available in situations where programs are unavailable, impractical, or just unnecessary based on the simplicity of the problem addressed.

Kernel Definition, Derivation, and Examples

We designate as evidence-based *kernels* any indivisible procedure shown through experimental evaluation to produce reliable effects on behavior (Embry 2004). The derivation of the term "kernels" arose in Embry's (2004) paper describing the active ingredients in evidenced-based prevention or treatment behavior-change programs, distinct from the earlier nebulous concepts of "principles of effectiveness." The perceived need for a taxonomy and nomenclature for these active ingredients emerged from a yearlong series of meetings organized by the second author, involving some 20 leading prevention, scientific, and policy leaders. Some of the scientists at the meetings were Richard Catalano, Harold Holder, Brian Flay, and the authors of this paper. These scientists had created and tested many prevention and treatment programs and had used some common ingredients to make those programs work. The scientists, however, had never denominated those ingredients or active components in ways that each other understood or that others might easily perceive for new invention or systematic replications.

Other disciplines do have such taxonomies and nomenclature. For example, medications contain lists of known "active ingredients," which have proven effectiveness separate from effects of the compounded product. For example, aspirin is clearly effective in its own right, and so are enteric coatings. Joined, they result in a product such as "buffered aspirin," composed of two separate active ingredients. One can look up medications' active ingredients in publications like the *Physician's Desk Reference* and look up how to use them in the *Merck Manual*. Nothing similar exists in applied behavioral science.

We chose the term "evidence-based kernel" for several reasons. First, it had the metaphorical resonance of something organic that influenced life or behavior. Second, the metaphor was about something very compact, although obviously in quantity or through blending, it could become something bigger or more productive. Third, the term was novel, which would confer the ability to track its use and make its meaning clear and crisp compared to words or phrases in past use such as "principles of effectiveness."

The unit of a kernel is indivisible in the sense that it would be ineffective if one eliminated any of its components. Experimental evaluations of kernels may involve randomized controlled trials (RCTs) or interrupted time-series experiments (Flay et al. 2004). Examples of kernels include timeout, written praise notes, self-monitoring, framing relations among stimuli to affect the value of a given stimulus, and physiological strategies such as nasal breathing when upset or increasing omega-3 fatty acids in the diet in order to influence behavior. The description of a kernel as an indivisible procedure merits discussion by metaphor and example.

First, a kernel is like a seed that contains central information for growth or change. Second, a kernel also evokes the idea of an implicit human technology to effect change from the earliest use of agriculture to the use of core routines in modern computers. A broken seed will not grow, and a broken core computer routine ("kernel panic") will

cause the machine to be inoperative. One of the oldest prepared foods by humans, dating to the Neolithic era—bread, further illustrates the point of indivisibility. Bread consists of flour and water. Bread may be leavened or unleavened. Even unleavened, bread can be quite varied: lavashes, tortilla, chapatis, rotis, naans, etc. Bread is simple and irreductable: remove the flour or liquid, there is no bread. The example of bread also illustrates the nearly infinite ways additions to it can make it sweet, spicy, bitter, fattening, medicinal, or celebratory. Of course other preparations of meat, legumes, fruits, or vegetables can be served with bread to form daily meals or diet—a culinary equivalent of a program.

Second, an evidence-based kernel has core components that cannot be removed and be effective. Consider some examples: (1) *Timeout* must be a brief removal from whatever is reinforcing the undesirable behavior, followed by intensive reinforcement for engaging in the desired behavior upon return; (2) a Home-Note from school must cue high rates of positive reinforcement from home adults, not emphasize the bad behavior at school; (3) beat the timer requires some kind of mechanical device to keep track of time, set for a brief time, and with a signal that cues reinforcement for the target behavior when the time elapses; and (4) nasal breathing must involve breathing through the nose and not the through the mouth, when upset, for the physiological and behavior benefits to happen.

Programs, however, are rarely irreductable. Programs contain many components or kernels, and the loss of a single one enables the program still to have some effect in most cases. For example, evidence-based reading programs like Direct Instruction or Success for All have kernels such as choral responding or peer-assisted learning among many other active ingredients. The loss or omission of a single program component may reduce results but will not obliterate results typically.

Naturally, some may ask about the cultural competence of evidence-based kernels. Anthropologists or evolutionary theorists (e.g., Wilson and Wilson 2007) posit human evolution and advancement are significantly based on our ability to influence each other for group benefit. We suggest that the idea of evidence-based kernels has deep roots in anthropology. Humans have a long history of creating ways to influence each other, and noticing the effects of their inventions to do so. While we hold fast to the notion that an evidence-based kernel must have peer-reviewed publication showing experimentally proven results, we are not blind to the fact that many kernels listed in this publication have more than chance analogue in the wisdom traditions of cultures to influence the behavior of relatives, mates, and neighbors. Many of the kernels herein are not just found in evidence-based programs or scientific journals; they can be found, too, in old culturally selected practices. For example, choral responding is a scientifically proven practice described herein (e.g., Godfrey et al. 2003), yet it can be found as a cultural practice from cultures as environmentally diverse as Polynesians to Arctic peoples; scientists funded by the National Institute of Health have recently experimentally demonstrated the efficacy of the omega-3 fatty acid on influencing many types of human behavior (e.g., Freeman et al. 2006a, b), while grandmothers several hundred years ago made sure that everybody had their daily dose of cod liver oil; and while legions of behavioral scientists since the 1960s may have demonstrated the effects of praise (e.g., Leblanc et al. 2005), the Yup'ik peoples of Alaska apparently applied the principle a long time before European contact.

Humans—be they parents, teachers, leaders, business people, or even scientists—attempt to influence behavior, which begs the question of what influence might mean. Thus, a kernel may increase the frequency or duration of a behavior or may make a behavior less likely. The change in frequency or duration of behavior is observable in real time. The mechanism of influence might be a function of an antecedent to channel behavior, a consequence following the behavior, a set of words about the behavior, or direct manipulation of physiology. These possible mechanisms or pathways of how kernels can influence the acquisition, rate, or duration of behavior will be discussed subsequently. Some examples of kernels now merit attention.

The Example of Timeout

Timeout was one of the first kernels of behavior–influence technology (Wolf et al. 1964). Dicky was a 3-year-old boy with autism who had undergone surgery for cataracts. He lived in a psychiatric hospital and had frequent tantrums resulting in self-injury. In tribute to the late Montrose Wolf, Risley described this landmark study (Risley 2005):

> After having just discovered the power of adult attention for young children, and realizing that the staff could not simply ignore temper tantrums, especially violent ones with mild self-abuse, Wolf decided to prescribe a response to tantrums that would minimize any social reinforcing effect of the necessary attention and counterbalance that reinforcement with a period of social isolation. The prescription for tantrums was to place Dicky, calmly and without comment, in his room until the tantrum ceased and at least 10 minutes had passed. When tantrums were under control and after wearing glasses had been hand shaped, Dicky began to throw his

glasses occasionally. When the social isolation prescription was applied, glasses throwing decreased from about twice per day to zero. But the hospital staff doubted that it was due to the procedure, because Dicky didn't seem to mind being taken to his room; he just rocked in his rocking chair and hummed to himself. Because throwing glasses was both less serious and more reliably measured than tantrums, Wolf agreed to discontinue the procedure—and glasses throwing soon increased to the previous level. The social isolation procedure was reinstated, and glasses throwing decreased again to zero. (pp. 281–282)

Thus was born *timeout*, shown since in hundreds of studies to reduce the frequency of a vast range of behaviors. It is a staple of nearly every evidence-based prevention program for parenting (e.g., Incredible Years [Webster-Stratton and Reid 2007]; Triple P [Sanders and Markie-Dadds 1996]; Parent Management Training [Forgatch et al. 2005a, b]). It is also part of popular culture. Shows like *Nanny 911* display its use; websites with advice to parents describe it (e.g., http://www.thelaboroflove.com/forum/quality/timeout.html). Although there is no population-based data on the prevalence of families and schools using timeout, it seems that in many areas, timeout is the normative replacement for harsh methods of discipline.

The Example of Nasal Breathing or "Doing Turtle"

Humans are amazing at noticing the effects of small physiological interventions that influence human behavior. Grandmothers and experienced teachers, for example, often tell children who are emotionally overwrought and hyperventilating to close their mouths and breathe through the nose while exhaling through the mouth. This strategy is taught formally in such evidence-based prevention programs as the Incredible Years and PATHS (Positive Alternative Thinking Skills), and even has a child-friendly name and story of "doing turtle" (Robin et al. 1976). The strategy is based in empirical observations of the relationship among breathing patterns, physiological measures, behavior, and children's emotional states (McDonnell and Bowden 1989; Naveen et al. 1997; Perna et al. 2002; Pine et al. 1998; Telles et al. 1997; Zaichkowsky et al. 1986). This kernel also illustrates how a simple strategy might be independently discovered and tested from very different theoretical perspectives (e.g., pediatric medical practice, basic research, child psychology, prevention, parenting, and even alternative bodywork such as yoga). Like most kernels, it can be used and proven on its own, or incorporated in programmatic efforts.

Theoretical Taxonomy of Kernels

Although simple enumeration of kernels may support effective practice, their contribution may be more substantial if we organize them within a theoretical framework to delineate the key influences on behavior. Such a framework would facilitate generating new kernels and could point to overlooked procedures for influencing behavior.

Kernels are understandable in terms of the operant behavior of biological organisms, viewed within a developmental and evolutionary perspective. Human behavior—including verbal, cognitive, and emotional functioning—has developed over time as a function of the biological capacities of the organism and the consequences to behavior. Human behavioral tendencies are adaptive functions of current situations and a history of consequences for behaving in similar situations (e.g., Biglan 1995).

Kernels involve one of four primary processes. Many involve consequation of behavior—the presentation or removal of reinforcing or aversive consequences (Biglan 1995, Chap. 3). Others involve an antecedent stimulus affecting motivation to behave due to a history of consequences for responding to that stimulus (e.g., teachers' use of standard signals to prompt students to sit down; Jason, Neal, and Marinakis 1985; Wasserman 1977). A third type primarily involves altering the relations that people derive among verbal stimuli in ways that affect motivation. For example, to elicit a public commitment to engage in a behavior (Chassin et al. 1990), a person feels prompted to associate a network of consequences (such as others' approval) with engaging in the behavior and other consequences with not engaging in the behavior (e.g., disapproval). Each of these three types of kernels involves ways in which a person's social environment affects his or her behavior. In a sense, kernels provide prescriptions for how the social environment can show more support of human development.

A fourth type of kernel alters a biological function of the organisms in ways that affect behavior. An example is supplementation of diets with omega-3 fatty acid (Haag 2003). Indeed, any pharmacological agent that affects behavior would fall into this category, although we stress the importance of distinguishing prescription medications from non-prescription, scientifically proven kernels that individuals or organizations might choose to use without a prescription.

Table 1 presents a list of kernels organized according to this theoretical framework. We categorize each kernel in terms of the primary mechanism by which it affects behavior, although clearly many kernels involve more than one process. Space precludes a complete review of the empirical evidence for each kernel, but we cite all experimental evaluations done for each kernel along with the types of experimental evaluations that have occurred. In

Table 1 Example taxonomy of potential kernels

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Kernels altering consequences for behavior			
Kernels increasing frequency of behavior			
Verbal praise	Person or group receives spoken (or signed) recognition for engagement in target acts, which may be descriptive or simple acknowledgements	Cooperation, social competence, academic engagement/achievement, positive parent–child interactions or marital relations, better sales; reduced disruptive or aggressive behavior; reduced DSM-IV symptoms	Leblanc et al. (2005), Lowe and McLaughlin (1974), Marchant and Young (2001), Marchant et al. (2004), Martens et al. (1997), Matheson and Shriver (2005), Robinson and Robinson (1979), Scott et al. (2001) (All TS)
Peer-to-peer written praise: "Tootle" notes, compliments books/praise notes	A pad or display of decorative notes is posted on a wall, read aloud, or placed in a photo album where peers praise behaviors	Social competence, academic achievement, work performance, violence, aggression, physical health, vandalism	Cabello and Terrell (1994), Embry et al. (1996), Farber and Mayer (1972), Heap and Emerson (1989), Mayer et al. (1983, 1993), Skinner et al. (2000) (TS plus 1 RCT with other kernels)
Beat the timer or beat the buzzer	Reduced time set to complete a task, with access to reward or recognition if task successfully completed before time interval	Parent–child interactions, compliance, physical abuse, child aggression, ADHD, work completion, academic accuracy	Adams and Drabman (1995), Ball and Irwin (1976), Drabman and Creedon (1979), Hudson et al. (1985), Luiselli and Greenidge (1982), McGrath et al. (1987), Wolfe et al. (1981), Wurtele and Drabman (1984) (TS)
Mystery motivators/ grab bag/prize bowl/ game of life	Person draws variable prize of higher and lower values for engaging in targeted behavior	Conduct disorders, oppositional defiance, ADHD, substance abuse, work performance	DeMartini-Scully et al. (2000), Madaus et al. (2003), Moore et al. (1994), Petry et al. (2000, 2001a, b, c, 2004, 2005), Petry and Simcic (2002), Robinson and Sheridan (2000) (TS with children; RCTs with adults)
Public posting (graphing) of feedback of a targeted behavior	Results, products of activity posted for all, may be scores of individuals, teams, or display of work product for all to see	Speeding, academic achievement, conservation, donations, community participation, injury control	Parsons (1982, 1992), Jackson and Mathews (1995), Whyte et al. (1983), Ragnarsson and Bjorgvinsson (1991), Nordstrom et al. (1990), Van Houten and Nau (1981), Nicol and Hantula (2001) (TS)
Principal lottery	Tokens or symbolic rewards for positive behavior result in random rewards from status person (e.g., principal, authority figures) such as positive phone calls home	Academic achievement, disruptive behavior, aggression	Thorpe et al. (1978, 1979) (All TS)
Safety or performance lottery	Tokens or reward tickets given for observed safety or performance behavior, then entered into lottery	Safety behaviors, accident reduction, improved sales or work performance	Geller et al. (1982), Putnam et al. (2003), Roberts and Fanurik (1986), Saari and Latham (1982) (All TS)
Team competition	Groups compete on some task, performance, or game	Improved academic engagement/achievement, reduced disruptive behavior, increased sales, fund raising, and safety; reduced smoking; changed brain chemistry favoring attention and endurance	Beersma et al. (2003); Hoigaard et al. (2006), Kivlighan and Granger (2006), Koffman et al. (1998), Neave and Wolfson (2003) (All TS, and one naturalistic study)

Table 1 continued

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Contingent music	Music played or stopped in real time, based on observed behavior of the individual or group	Increased weight gain of babies, improved baby development possibly, work performance, academic achievement, attention and focus (ADHD symptoms down); reduced aggression	Allen and Bryant (1985), Barmann and Croyle-Barmann (1980), Barmann et al. (1980), Bellamy and Sontag (1973), Blumenfeld and Eisenfeld (2006), Cevasco and Grant (2005), Cook and Freethy (1973), Cotter (1971), Davis et al. (1980), Dellatan (2003), Deutsch et al. (1976), Eisenstein (1974), Harding and Ballard (1982), Hill et al. (1989), Holloway (1980), Hume and Crossman (1992), Jorgenson (1974), Larson and Ayllon (1990), Madsen (1982), McCarty et al. (1978), McLaughlin and Helm (1993), Standley (1996, 1999), Wilson (1976), Wolfe (1982) (All TS)
Special play	Adult (caregiver or teacher) plays with the child, but lets the child lead in determining what games will be played and how	Improved stress physiology, compliance, and social competence; reduced trauma or depressive symptoms	Bratton et al. (2005) (Meta analysis)
Choral responding	Person(s) chant or sign answer to oral or visual prompt in unison; praise/correction follows	Compared to hand raising, improved academic achievement, disruptive symptoms, retention; reduced behavior problems	Godfrey et al. (2003), Kamps et al. (1994), Taubman et al. (2001), Wolery et al. (1992) (All TS)
Mystery shopper	Unknown individuals make "purchase" or "help request", and target receives praise, reinforcement or corrective feedback	Reduced tobacco sales; improved customer relations; better sales, better compliance by pharmacists, better service from medical personnel or prevention personnel	Bennett et al. (2003), Borfitz (2001), Krevor et al. (2003), Lowndes and Dawes (2001), Moore (1984), Norris (2002), Saunders (2005), Steiner (1986), Sykes and O'Sullivan (2006) (All TS)
Peer-to-peer tutoring	Dyad or triad take turns asking questions, give praise or points and corrective feedback	Improved academics, reduced ADHD/conduct problems, and long-term effects on school engagement decreased special education needs	Allsopp (1997), Delquadri et al. (1983), DuPaul et al. (1998), Fantuzzo and Ginsburg-Block (1998), Greenwood (1991a, b), Maheady et al. (1988a, b), Sideridis et al. (1997) (Both TS and RCT)
Computer action game	Motor response to hit target or get right answer; visual/auditory feedback for correct response, with scoreboard	Increased attention and reduced ADHD like symptoms, which is associated with release of dopamine in the brain	Aase and Sagvolden (2006), Ford et al. (1993), Green and Bavelier (2003), Koepp et al. (1998), Silva (1999) (TS, and TS mixed with randomized conditions)
Correspondence training, "Say-Do"	Symbolic or live models typically represented with a language frame; others elicit what individual says will do and reinforcement follows	Increased rates of targeted behaviors such as academic engagement, disturbing behavior or self-care behaviors	Anderson and Merrett (1997), Luciano et al. (2001), Luciano-Soriano et al. (2000) (TS)
Correspondence training, "Do-Say"	Symbolic or live models typically presented. Cues for behavior and reports by individual to others followed by praise/ reinforcement	Increased rates of targeted behaviors such as academics, self-care or other developmental/ life skill tasks	Merrett and Merrett (1997), Morrison et al. (2002), Roca and Gross (1996) (TS)
Kernels decreasing frequency of behavior			
Time out	Using timer, remove from natural reinforcement for 1 min + 1 min for each year of age	Decreases non-compliance, argumentative behavior and mood outbursts	Fabiano et al. (2004), Kazdin (1980), Wolf et al. (1967) (TS)
Sit and watch, contingent observation or response lock out	Very brief removal from reinforcement (2 min or less), with high-density reinforcement upon reentry for desired behavior	Reduces disruptions in classroom, aggression on playground or during physical education, reduces dangerous behavior	Embry (1982, 1984), Murphy et al. (1983), Porterfield et al. (1976), White and Bailey (1990) (TS)

Table 1 continued

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Taxes on consumptive behaviors	Percent of purchase price of goods (cigarettes, alcohol, luxury	Increasing taxation on liquor or tobacco reduces consumption	Biglan et al. (2004) (TS)
Positive note home for inhibition	Adult sends home positive note for inhibition that results in home reward	Reduces disruptive and aggressive behavior and problems at home; increases engagement at school	Gupta et al. (1990), Hutton (1983), Kelley et al. (1988), McCain and Kelley (1993), Taylor et al. (1984) (TS)
Timed rewards for inhibition (DRO)	Using fixed or variable interval, person receives praise and reward for not engaging in a behavior	Reduces ADHD symptoms, conduct problems, accidental attention to negative; increases engagement in prosocial activities	Conyers et al. (2003), Conyers et al. (2004), Hegel and Ferguson (2000) (TS)
Premack principle	The opportunity to engage in a high-probability behavior is made contingent engaging in a targeted behavior or on the inhibition of problematic behavior	Decreases ADHD like behavior, inattention, disruptive behavior, non-compliance	Agathon and Granjus (1976), Andrews (1970), Browder et al. (1984), Ghosh and Chattopadhyay (1993), Gonzalez and Ribes (1975), Harrison and Schaeffer (1975), Homme et al. (1963), Hosie et al. (1974), Knapp (1976), Leclerc and Thurston (2003), Mazur (1975), McMorrow et al. (1978), Van Hevel and Hawkins (1974), Welsh et al. (1992), Williamson (1984) (TS)
Response-cost (point loss)	Small symbolic reward removed or debited, non-emotionally, quickly following targeted behavior	Decreases inattention and disruption; decreases ADHD like behaviors; may if used as a part of teams in first grade decrease substance abuse over lifetime	Conyers et al. (2004), Filcheck et al. (2004), Furr-Holden et al. (2004), Jason et al. (2005), Jorgensen and Pedersen (2005), Kellam and Anthony (1998), Kelley and McCain (1995), McGoey and DuPaul (2000), Storr et al. (2002) (TS and RCT with other embedded kernels)
Low emotion or "private" reprimands	Corrective feedback given without biological cues of threat or intense emotion; short rather than long reprimands are typically of more effective ones	Reduces inattention, disruptions, aggression; reduces emotional responding by adults, including attention to negative behavior	Abramowitz et al. (1987, 1988), Acker and O'Leary (1987), Harris et al. (2003), Houghton et al. (1990), Maglieri et al. (2000), Merrett and Tang (1994), Ostrower and Ziv (1982), Pfiffner et al. (1985), Piazza et al. (1999), Rolider and Van Houten (1984), Scholer et al. (2006), Van Houten et al. (1982) (All TS)
Stop clock	Clock triggered when students misbehave. Lower times on the clock result in access to rewards	Increased academic engagement and reduced disruptions	Cowen et al. (1979) (TS)
Law enforcement fine or citation	Fine or ticket given for relatively minor non-compliant behavior	Reduces tobacco possession, illegal water use, parking in handicap spots	Agras et al. (1980), de Waard and Rooijers (1994), Fletcher (1995), Jason et al. (2000, 2005), Jorgensen and Pedersen (2005), Liberman et al. (1975) (TS and RCT)
Over-correction or positive practice	Person repeats restorative or correct behavior many times	Reduces symptoms of developmental delay; reduces aggression or noncompliance; may reduce accidental attention to negative behavior	Carey and Bucher (1986), Foxx and Jones (1978), Lennox et al. (1988), Maag et al. (1986), Singh (1987), Singh and Singh (1988), Sisson et al. (1993), Sumner et al. (1974), Watson (1993) (All TS)
Buzzer/noise training	A buzzer or noxious noise happens upon some undesired behavior	Reduces non seatbelt use, bedwetting, walking through unauthorized door or driving on shoulder of road	Ankjaer-Jensen and Sejr (1994), Collins (1973), Crisp et al. (1984), Hirasing and Reus (1991), Meadow (1977), Robertson (1975), Robertson and Haddon (1974) (All TS)

Table 1 continued

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Kernels affecting behaviors primarily via antecedents			
Non-verbal transition cues	Visual, kinesthetic and/or auditory cues to single shift attention or task in patterned way, with praise or occasional rewards	Reduces dawdling, increases time on task or engaged learning; gives more time for instruction	Abbott et al. (1998), Embry et al. (1996), Krantz and Risley (1977), Rosenkoetter and Fowler (1986), (TS plus RCT with other embedded kernels)
Stop lights in school settings or traffic settings	Traffic light signals when behavior is appropriate/desirable or inappropriate/ undesirable in real time, and connected to a kind of occasional reinforcement	Decreases noise, off task behavior, or increases stopping in dangerous intersections	Cox et al. (2000), Jason and Liotta (1982), Jason et al. (1985), Lawshe (1940), Medland and Stachnik (1972), Van Houten and Malenfant (1992), Van Houten and Retting (2001), Wasserman (1977) (All TS)
Boundary cues and railings	These may be lines or other cues such as ropes or rails that signal where behavior is safe, acceptable or desired	Decreases dangerous behavior; decreases pushing and shoving; increases waiting behavior in a queue; reduces falls	Carlsson and Lundkvist (1992), Erkal and Safak (2006), Marshall et al. (2005), Nedas et al. (1982), Sorock (1988) (All TS)
Cooperative, structured peer play	Planned activities during children playtime and involve rules, turn taking, social competencies, and cooperation with/ without "soft competition"	Decreases aggression/increases social competence; affects BMI, reduces ADHD symptoms and increases academics after; reduces social rejection in M.S.	Bay-Hinitz et al. (1994), Leff et al. (2004), Mikami et al. (2005), Murphy et al. (1983), Ridgway et al. (2003) (TS and RCT)
Self-modeling	Drawn, photographic, or video model viewer/ listener engaging targeted behavior, receiving rewards or recognition	Increases academic engagement; increases attention; increases recall and long term memory; improves behavior; reduces dangerous behavior; increases social competence; improved sports performance; reduced health problems	Barker and Jones (2006), Ben Shalom (2000), Bray and Kehle (2001), Buggey (2005), Clare et al. (2000), Clark et al. (1992, 1993), Clement (1986), Davis (1979), Dowrick (1999), Dowrick et al. (2006), Elegbeleye (1994), Hartley et al. (1998, 2002), Hitchcock et al. (2004), Houlihan et al. (1995), Kahn et al. (1990), Kehle et al. (2002), Law and Ste-Marie (2005), Lonnecker et al. (1994), Meharg and Lipsker (1991), Meharg and Woltersdorf (1990), Owusu-Bempah and Howitt (1983, 1985), Possell et al. (1999), Ram and McCullagh (2003), Reamer et al. (1998), Rickards-Schlichting et al. (2004), Rickel and Fields (1983), Schunk and Hanson (1989), Schwartz et al. (1997), Walker and Clement (1992), Wedel and Fowler (1984), Woltersdorf (1992) (All TS)
Self-monitoring	Coding target behavior with a relational frame, which is often charted or graphed for public or semi-public display, occasioning verbal praise from others	Reductions in alcohol, tobacco use; reductions in illness symptoms from diabetes; increased school achievement; changes in other social competencies or health behaviors; reductions in ADHD, Tourettes and other DSM-IV disorder; improvement in brain injured persons	Agran et al. (2005), Blick and Test (1987), Boyle and Hughes (1994), Brown and Frank (1990), Buggey (1995, 1999), Burch et al. (1987), Carr and Punzo (1993), Cavalier et al. (1997), Clare et al. (2000), Clarke et al. (2001), Dalton et al. (1999), de Haas-Warner (1991), Foxx and Axelroth (1983), Glasgow et al. (1983a, b), Gray and Shelton (1992), Hall and Zentall (2000), Harris et al. (2005), Hertz and McLaughlin (1990), Hitchcock et al. (2004), Hughes et al. (2002), Kern et al. (1994), Martella et al. (1993), Mathes and Bender (1997), McCarl et al. (1991), McDougall and Brady (1995), McLaughlin et al. (1985), Nakano (1990), O'Reilly et al. (2002), Petscher and Bailey (2006), Possell et al. (1999), Rock (2005), Selznick and Savage (2000), Shabani et al. (2001), Shimabukuro et al. (1999), Stecker et al. (1996), Thomas et al. (1971), Todd et al. (1999), Trammel et al. (1994), Winn et al. (2004), Wood et al. (1998, 2002) (TS & RCT, latter most from medical studies)

Table 1 continued

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Paragraph shrinking	After hearing or seeing some content, person learns to "shrink" meaning to eight to ten words, full sentence; praise typically happens for good summaries	Improved reading responses and retention	Bean and Steenwyk (1984), Mathes et al. (1994), Spencer et al. (2003) (TS)
Errorless discrimination training	Stimuli are faded or shaped in such a way that errors are nearly non-existent	Improved reading, letter recognition and life-task discriminations; reductions in symptoms of mental retardation or brain injury	Akhtar et al. (2006), Egeland and Winer (1974), Etzel and LeBlanc (1979), Fillingham et al. (2003), Hunkin et al. (1998), Keel and Gast (1992), Lambert (1979), Melchiori et al. (1992), Plummer et al. (1977), Schilmoeller et al. (1979), Stawar (1978), Terrace (1969), Walsh and Lamberts (1979) (TS)
Kernels affecting behaviors primarily via relational frames			
Adjectival noun for belonging to status group	Verbal phrase "I am/we _____" is paired with status, belonging, protection or safety	Increased rule governed behavior; increases behavior associated with the named group; decreases aggression within group; may affect physical health	Choenarom et al. (2005), Embry et al. (1996), Gaskell and Smith (1986), Juarez (2002), Mishima (2003) (RCT)
Public commitment	Individuals sign or pledge self to collective behavior	Voting, contributing money, recycling	Burgess et al. (2000), Chen and Komorita (1994), Wang and Katzev (1990)
"US" and "THEM" role framing	Individuals or groups divided into two groups, with differences framed by clothing, adornment, language, social position, etc.	Increase aggression and violence by each group toward each other	Roos (2005), Sherif (1958, 1968, 1970), Sherif, Hogg and Abrams (2001), Sherif et al. (1955) (RCT)
Graphic/node maps	A graphic organizer for goal-based behavior, guided by other status individuals	Increased sobriety and goal completion; increased treatment compliance	Collier et al. (2001), Czuchry and Dansereau (1996, 1999, 2003), Czuchry et al. (1995), Dansereau et al. (1993, 1995), Dees et al. (1994), Joe et al. (1994, 1997), Melville et al. (2004), Newbern et al. (1999, 2005), Pitre et al. (1996, 1997, 1998) (RCT)
MI	Oral or written questions by status individual (or on paper) around major goals of target person with clarifying questions about interfering behavior	Reduced substance abuse, increased social competence & related goals; reduced injuries or antisocial behavior; increase in healthy behaviors, increase achievement	Cohen et al. (2006), Bernstein et al. (2005), Burke et al. (2003), Monti et al. (1999), Resnicow et al. (2001), Rusch and Corrigan (2002), Smith (2004), Sobell et al. (2003), Stein et al. (2006) (RCT)
Media associating behavior with *immediate* negative social outcomes	Media (TV, video, radio) showing behavior results in social rejection or escape from social rejection	Reduces sexually transmitted diseases; reduces alcohol, tobacco and other drug use	Beyth-Marom et al. (1993), Downs et al. (2004), Pechmann (2001), Pechmann and Ratneshwar (1994), Pechmann et al. (2003) (RCT)
Kernels affecting behaviors primarily via physiology			
Pleasant greeting with or without positive physical touch	Friendly physical and verbal gestures, on a frequent basis	Affects donations; social status an perceptions of safety or harm; affects behavior streams of aggression, hostility or politeness	Edwards and Johnston (1977), Ferguson (1976), Field (1999), Fry (1987), Howard (1990), La Greca and Santogrossi (1980), Schloss et al. (1984) (TS)
Massage, brushing or stroking	Any method of rubbing, stroking and therapeutic touch applied to the body	Reduces aggression, arousal, cortisol, depressive symptoms, PTSD symptoms, and pain	Diego et al. (2002), Field et al. (1996a, b, c, d), Field (1998), Jones et al. (1998), Scafidi and Field (1996) (RCT)

Table 1 continued

Kernel example	Description	Behaviors affected	Evidence and experimental designs
Turtle technique	Using a turtle metaphor, child holds self, verbal frame, breaths through nose, and engage in sub-verbal or verbal self-coaching, with peer or adult reinforcement	Reduces arousal and aggression against peers or adults	Heffner et al. (2003), Robin et al. (1976) (TS plus embedded in RCT with other kernels)
Omega-3 fatty acid supplementation or increased fish consumption	1–3 g taken orally per day; or fish consumption several times per week high in omega-3	Reduces aggression, violence, depression, bipolar disorder, post-partum depression and borderline personality disorder; early evidence for reducing symptoms of developmental disorders; and for reducing CVD and asthma	Fava (2001), Freeman et al. (2006), Gesch et al. (2002), Hibbeln et al. (2006), Jarvinen et al. (2006), Mickleborough et al. (2006), Richardson (2006), Stoll et al. (2000), Vaddadi (2006), Zanarini and Frankenburg (2003) (RCT)
Zinc supplementation or dietary consumption	15 mg/day eaten or supplemented	Evolving evidence finds the addition of zinc to the diet or by supplementation to increase the effectiveness of drug treatment and/or may prevent ADHD symptoms	Akhondzadeh et al. (2004), Arnold et al. (2005), Arnold and DiSilvestro (2005), Bilici et al. (2004), McGee et al. (1990), Sandyk (1990) (RCT)
"Rough and tumble" free play with higher status conspecific	Several times per week child or adolescent engages in rough and tumble play, causing increased arousal and self-control mediated by status adult or peer	Reduces aggression, teaches self-control, may improve status among same-sex peers; changes c-fos gene expression in lab animals; the behavior may be especially important to the development of positive behavior among boys and unique contribution of fathering	Boulton and Smith (1989), Gordon et al. (2002), Hines and Kaufman (1994), Jacklin et al. (1984), Paquette (2004), Pellegrini and Smith (1998), Reed and Brown (2001), Scott and Panksepp (2003) (RCT, TS and ethology studies)
Aerobic play or behavior	Daily or many times per week child or adult engage running or similar aerobic solitary activities, game, or food gathering behavior	Reduces ADHD symptoms, reduces depression; reduces stress hormones; may increase cognitive function; decreases PTSD	Antunes et al. (2005), Atlantis et al. (2004), Berlin et al. (2006), Blue (1979), Blumenthal et al. (2005), Crews et al. (2004), Doyne et al. (1983), Dunn et al. (2001, 2005), Dustman et al. (1984), Khatri et al. (2001), Kubesch et al. (2003), Manger and Motta (2005), Marin and Menza (2005), Phillips et al. (2003), Stein (2005), Stella et al. (2005) (TS and RCT)
Nasal breathing	When aroused, person breaths through nose, not mouth	Reduces panic, anxiety and hostility; may improve cognitive function; changes core temp of limbic area	Backon (1990), Block et al. (1989) (RCT)
Progressive muscle relaxation	Person tenses and relaxes sequence of muscles combined with anxiety evoking stimulus	Reduces panic, fear, anxiety; decreases negative attributions; decreases phobic responses with paired with evoking stimuli	Larsson et al. (2005), Norlander et al. (2005), Pawlow and Jones (2005), Wencai et al. (2005) (RCT)

TS, time-series; RCT, randomized control trial

each of the following, we describe the empirical evidence in detail for one kernel.

Designating Example Kernels for This Paper

The 52 kernels presented in Table 1 are not exhaustive; they are simply examples that meet the definition of a kernel from the four types. That is, the kernel has one or more peer-reviewed experimental studies showing behavior change. We are aware of many more kernels; the more kernels we identified, the more we found others. Because of the year-long process that gave rise to the need for and idea denominating the active ingredients of evidence-based prevention and a book about the science of preventing problems of adolescence (Biglan et al. 2004), many of the 52 kernels were evident to us at first blush because of our own published studies and that of our colleagues on parenting, violence prevention, substance abuse prevention, etc.; others we chose deliberately to illustrate the potential theoretical diversity of kernels—an interesting point in itself, exemplified by reactions to early drafts of the paper. Some early readers were delighted to see the inclusion of examples from behavior analysis, yet chaffed at the physiological kernels such as omega-3 and massage—despite the scientific evidence available for each. Others objected to behavioral procedures, arguing that behavioral procedures were proven to be ineffective—despite studies showing otherwise. We are aware that any given professional community might disagree with the theoretical approach of another professional group, yet a taxonomy of kernels begins to elucidate how, where, when, for whom, and for what scientifically proven strategies might be more or less beneficial in influencing human behavior. We imagine that a database of kernels will emerge, much like the human genome project (i.e., http://genomics.energy.gov/) wherein the breadth, depth, magnitude, and replications of the effects of any given kernel might be reported by the international research community in order to build an open-source molecular technology of behavioral influence. The arbitrary selection of the 52 kernels in this paper illustrates the possibility of a rich "behaviornome" type project for fundamental units of behavioral influence. Subsequent paragraphs detail examples of four types of kernels for influencing behavior from Table 1, as a proof of concept from 52 experimentally demonstrated kernels.

Kernels Altering Consequences for Behavior

Increasing Rate or Probability of Behavior

Many kernels increase behavior by mobilizing reinforcement for the targeted behavior. These include vocal praise, written praise notes, prize bowls, and public posting of feedback about the rate of a targeted behavior. Each delivers positive consequences contingent on a behavior. In the case of public posting of feedback, it is necessary that the recipients of the post in some sense want to increase the behavior recorded in the postings. An example of a powerful yet simple reinforcement kernel involves writing positive notes to increase behavior. Written praise notes from a supervisor increase work performance (Nordstrom et al. 1988), notes written by a teacher to students increase academic success (Hickey et al. 1979), and notes from students to each other increase social competence (Skinner et al. 2000).

We also put special play with parents in this category. It involves adults letting the child lead in free play activities (Webster-Stratton and Reid 2007). Its purpose is to facilitate interactions in which parents do not command, criticize, or unduly restrict activities of the child and allow the child to engage in fantasy play with the parent. Such interactions presumably are reinforcing for parent and child; the child receives the undivided attention of the parent contingent on cooperative play, and the parent experiences cooperative and pleasant interactions with the child contingent on listening to the child and following the child's lead.

Decrease Behavior by Altering Consequences

Other procedures alter consequences in order to decrease the frequency or probability of a behavior. Some involve ensuring an undesirable behavior does not elicit reinforcement. Timeout is one such procedure. Rewarding behavior incompatible with the undesirable behavior is another.

A third set (ostensibly designed to decelerate behavior rates) involves delivering aversive consequences for a certain behavior—traditionally termed *punishment*. However, many so-called punishments (e.g., lengthy grounding, mandatory minimum sentences) have no beneficial effect and, in fact, cause harm (Sampson and Laub 1994). Indeed, a major challenge for many parenting programs is getting parents to be less punitive. Thus, in developing procedures to make aversive consequences contingent upon behavior, we must evaluate them carefully to ensure they are effective and have few side effects.

Fining is an example of a negative consequence affecting behavior. Agras et al. (1980) found that receiving a fine reduced individual, but not business, water wastage. Fletcher (1995) found that fines for parking in disabled-reserved spaces notably decreased the behavior.

Kernels Altering Behavior Through Antecedents

Many kernels work by establishing the functions of antecedents to behavior. A common example in schools is

teachers establishing signals to guide transitions (Marion and Muza 1998; Rosenkoetter and Fowler 1986; West et al. 1995). For example, many teachers turn lights off and on to signal students to return to their seats and become quiet and attentive. Of course, positive consequences (e.g., praise) are involved in establishing effectiveness of the stimulus, but once established, the salient feature is the influence of the light on the behavior.

Assigning students meaningful roles (Rutter 1981), such as setting up equipment for an assembly, taking roll, or taking photographs for communicating desirable school functions, are activities that organize useful behavior. Antecedents may also include organized playground activities to reduce aggressive behavior and occasion various social competencies (Murphy et al. 1983). Reinforcement follows naturally from the enactment of the role.

It would be arbitrary to classify antecedent interventions based upon whether they increase or decrease behavior. This is because antecedents that prompt a desired behavior simultaneously make troublesome behavior less likely.

Kernels Altering Behavior by Influencing Relational Responding

Tradition within psychology suggests it is unfeasible to deal with cognitive and emotional influences on behavior within a basic behavioral framework of antecedents and consequences. However, recent work on relational frame theory (Hayes et al. 2001) has shown that human cognitive and verbal behavior can be understood in terms of basic operant processes, while honoring that humans do appear to have unique evolutionarily selected brain structures supporting language. To the extent this is true, it provides a parsimonious account of complex human functioning within a contextualist framework focusing on manipulable influences on behavior (Biglan and Hayes 1996).

Research on Relational Responding

There is growing evidence that a fundamental feature of human cognitive or verbal processes is the relating of stimuli (Barnes et al. 2000). Because this analysis is a recent development and likely to be unfamiliar to most readers, we will elaborate on it here. Barnes et al. (2000) present a theoretical analysis of relational responding. According to them, relating stimuli is the core feature of verbal behavior. Perhaps the most rudimentary relational responding involves naming. At the beginning of learning language, young children learn to say names for objects and separately learn to orient to objects when they hear their names. Each response is operant behavior reinforced by consequences such as attention, praise, and gaining of an object. After multiple experiences of this sort, however, a child also learns that if an object has a name, the name also goes with the object. In other words, they become able to derive the *mutual entailment* of name to object and object to name. Further experiences like this enable children to derive relations that are more complex. For example, learning that a puppy is a kind of dog and that Buddy is a puppy, a child is able to derive that Buddy is a dog. We call this ability to derive relations between two stimuli based on their relations with a third stimulus *combinatorial entailment.*

The third defining feature of relational responding is the *transformation of function*. Humans' derivation of relations among stimuli can transform the functions of stimuli that participate in the relation. For example, discovering that one coin is worth more than another makes the coin more reinforcing. Learning that water has bacilli in it may have no impact on a child, but upon learning that bacilli are germs, and that germs can you make you sick, a child's reaction to the water changes.

A fourth defining feature of relational responding is *arbitrary applicability*. Many of the relations we learn arise from physical relations among stimuli. For example, *smaller than* and *larger than* are terms based on the relative size of objects. However, humans become able to relate stimuli in these terms even though the stimuli do not have physical features involving relative size. If you hear that one person has a bigger heart than another person does, you may expect that person to be kinder, even though you understand that his heart is not literally larger.

For theorists accustomed to the panoply of existing cognitive constructs, which admittedly do a good job of predicting much human behavior, the value of this analysis may be obscure. Its value lies in providing a direct analysis of the specific procedures that influence relational responding and thereby transform the functions of stimuli.

Increasing Behavior by Altering Relational Responding

Perhaps the simplest and most important procedures of this type are those that augment the value of stimuli by influencing people to relate them to stimuli they already value. If we tell children they can stay up a half hour more if they get five stickers, we change their valuing of the stickers. In essence, any procedures influencing people to relate a stimulus with stimuli they already value make that stimulus more reinforcing. Prevention and treatment scientists, unlike marketing professionals, are often unfamiliar with relational responding.

One example of relational responding involves branding to influence behavior (Fischer et al. 1991). A recent study shows that children preferred foods "branded" as McDonald's (logos, wrapping papers, etc.), even for

carrots, which McDonald's does not sell (Robinson et al. 2007). Another example of branding is the introduction to the PeaceBuilders program (Embry et al. 1996). It used kernels like peer-to-peer praise/tootle notes and positive notes home to establish the word PeaceBuilder as a valued concept and to make being a PeaceBuilder—and all behaviors later related to this concept—more reinforcing. The program improved social competence and reduced aggression and injuries due to violence (Flannery et al. 2003; Krug et al. 1997). Biglan and colleagues recently completed a study showing that pairing fun social activities for middle-schoolers with a non-smoking brand (f2b—for Freedom to Breathe) reduced smoking among students even when the program had little overt antitobacco content (Gordon et al. 2008).

Another example of a kernel using relational responding involves public commitment. When people publicly commit to engage in a behavior, they are more likely to follow through on the behavior (e.g., Burn and Oskamp 1986). The public oath makes behavior inconsistent with that pledge aversive due to expected disapproval for failing to follow through with the promise.

In self-modeling, the professional helps to create a story about a person's behavior (Hosford 1980); the person typically participates in the process. The story embeds a person's self in a set of relations with desired behaviors and attributes (e.g., depicting a child as a hero at school or home for helping bring about peaceful behaviors; Embry et al. 1996). A child might learn a series of self-help skills through photographs or video (Hartley et al. 1998), making the child more apt to relate engaging in the behavior with valued ideas, such as being a "PeaceBuilder" (Embry et al. 1996).

Motivational interviewing (MI) is a powerful example of relational responding. MI may seem complex, yet we believe that subdividing it would destroy its effects. In MI, the interviewer prompts a person to discuss a topic he or she generally avoids (e.g., one's drinking patterns and difficulties associated with them; Bernstein et al. 2005; McCambridge and Strang 2004; Miller et al. 1988). The interviewer is warm and accepting as the person talks but asks questions designed to put the person in psychological contact with negative consequences of his/her behavior and the possible benefits of changing the behavior. It is clear this process has reinforcing and antecedent features, but the most salient aspect of the process seems to be that it alters the way people relate their problematic behavior to negative consequences and the possible alternatives to more reinforcing consequences. In other words, MI changes people's networks of relations in ways that make some behaviors more, and others less, desirable. Although most treatment professionals are familiar with complex forms of MI, very brief, scientifically validated forms do exist (McCambridge and Strang 2004)—including just 15 min (Cohen et al. 2006).

Decreasing Behavior by Altering Relational Responding

Some behavior–influence procedures discourage behavior by prompting a person to relate the behavior to aversive stimuli. In general, any procedure that prompts a person to relate undesirable behavior to negatively valenced stimuli would qualify as such a procedure—*provided there was experimental evidence of its effect*. For example, media associating drug use with negative outcomes have sometimes been shown to reduce drug use (Palmgreen et al. 1995). Messages suggesting that youth's peers will reject them for smoking affects their motivation to use tobacco (Pechmann and Knight 2002; Pechmann et al. 2003).

Kernels Altering Behavior Through Physiological Interventions

Finally, some procedures primarily affect physiological behavior. For centuries, humans have altered their health and mood by manipulating physiological states. Anthropological and archeological literatures are replete with examples (Lalramnghinglova 1999; Rajan et al. 2002; Rodrigues 2006; Spindler 1995). Hunters and gatherers often consume plants with stimulant properties, apparently since they confer an advantage during tasks such as hunting, which requires sustained effort and attention. Modern humans have similar reasons for using caffeine.

The impact of omega-3 fatty acid is a particularly important example of a physiological kernel (Olafsdottir et al. 2005). We use this example because of its exemplary laboratory, epidemiological, and randomized control studies across many domains of prevention, intervention, and treatment. Aside from epidemiological research on the relationships of omega-3 fatty acid (n-3) to a wide variety of causes of morbidity and mortality (Hibbeln 2001), experimental and quasi-experimental studies find supplementation of omega-3 reduces violent aggression among men (Gesch et al. 2002). Its use also reduces depression or bipolar disorder (Mischoulon and Fava 2000; Stoll et al. 1999; Sund et al. 2003) and other health or public health concerns, such as low birth weight and offspring IQ (Helland et al. 2003). Although not yet proven, omega-3 may even alleviate some of the problems associated with poverty, since poorer people have diets lower in omega-3 (Egeland et al. 2001; Liu et al. 2004).

Another intervention affecting behavior through direct impact on physiology is deep breathing, shown to reduce anxiety, arousal, and aggression among all ages (Appels et al. 1997; DiFilippo and Overholser 1999; Peck et al. 2005; Sharma et al. 2005; Suzuki et al. 2000). Zinc supplementation may reduce or moderate ADHD symptoms (Arnold et al. 2005; Bilici et al. 2004). We include a variety of strategies that enhance self-regulation in aroused

states such as "rough and tumble" play and related martial arts training for children, as studies have shown it to reduce children's aggressive behavior (Bjorklund and Brown 1998; Paquette 2004; Pellegrini 1992; Shannon et al. 2002) and the mechanism appears to involve alteration of brain chemistry (Panksepp et al. 2003; Siviy et al. 1996; Taylor et al. 1986). The martial arts studies with children show improved self-regulation, less aggression, and positive mood along with decreased impulsiveness (Lakes and Hoyt 2004; Palermo et al. 2006; Twemlow and Sacco 1998; Zivin et al. 2001), though student self-report may show less change than classroom teacher reports (McDiarmid 2008).

The distinction between biological and environmental interventions is not certain. Of course, any environmental manipulation may influence biological functioning. Below we discuss interventions that directly manipulate biological processes instead of changing psychological or behavioral functioning.

Although many pharmacological agents alter behavior and meet our definition of a kernel, the substantial literature on these influences is beyond the scope of this paper. Moreover, unlike nutritional supplements and nasal breathing, FDA-approved pharmacological agents require prescriptions; thus, they would not be available to most prevention practitioners or consumers directly.

Prevention scientists, oriented toward the implementation of programs, may overlook physiological interventions. Publications about these kernels are not in journals devoted to behavioral science but more likely to appear in medical, public health, or specialty journals. However, the evidence for them suggests that treatment and prevention scientists should pay greater attention to the reciprocal relationships between physiology and behaviors.

Types of Experimental Evidence Supporting Kernels

We define kernels as procedures shown empirically to affect a behavior. In keeping with the Society for Prevention Research Standards of Evidence (Flay et al. 2004), our criteria for empirical support include RCTs and interrupted time-series designs in which a procedure's impact is evaluated on a repeated measure of target behavior. Most evaluations of kernels have been via interrupted time-series designs, while some, such as omega-3 impact, have been in randomized trials. Some have undergone evaluation both ways. Some studies measured generalizability of results across time, behaviors, people, or places; others measured only proximal or immediate effects.

Many kernels result from interplay between basic and applied research. Variable interval or ratio contingency management kernels (e.g., Mystery Motivator, Prize Bowl) have roots in animal (Ferster and Skinner 1957) then human (Majovski and Clement 1977) research. Researchers next conducted clinical studies using interrupted time series (Henderson et al. 1986; Leibowitz 1975; Libb et al. 1973; Madaus et al. 2003; Moore et al. 1994; Robinson and Sheridan 2000; Snell and Cole 1976) and formal RCTs (Petry et al. 2004, 2005).

Physiological kernels have a similar scientific trajectory. For example, the understanding of omega-3 (n-3) has roots in early epidemiological or forensic inquiries showing differences among individuals with diseases or disorders (Anderson and Connor 1989; Gudbjarnason et al. 1991; Lieber et al. 1969; Rudin 1981). Initial epidemiological findings (Hibbeln 1998, 2001, 2002) prompted precision-oriented laboratory studies (Hibbeln et al. 1998; Hibbeln and Salem 1995) and larger epidemiological inquiries. All this work led to clinical trials evaluating omega-3 supplementation (Nemets et al. 2002; Sund et al. 2003; Zanarini and Frankenburg 2003).

The frequent use of interrupted time-series designs in developing kernels deserves further comment. It reflects not simply an arbitrary methodological preference but an incremental, inductive, bottom-up strategy to build effective behavior–influence practices. Kernels are of necessity simple steps targeting a behavior one can easily measure repeatedly; it is thus easy to implement interrupted time-series designs. Single-subject studies are quite robust in terms of reducing threats to validity (Sidman 1960) and in answering questions of whether a particular medication, procedure, or process is efficacious in changing the behavior of a person or small group of persons (e.g., families, classrooms, and organizations; Dadds et al. 1984; Greenwood and Matyas 1990; Mayer et al. 1983; McGrath et al. 1987; Reagles and O'Neill 1977). Such interrupted time-series designs are not limited to evaluating individuals but are often the choice for evaluating policy impact on large, important social issues (Briscoe et al. 1975; Hayes and Cone 1977; Wagenaar et al. 1988). One may summarize interrupted time-series designs effectively via effect sizes and meta-analyses (Campbell 2004; Stage and Quiroz 1997).

An important limitation on current understanding of kernels is that we have relatively little information about situations in which they will be effective and those in which they will not be effective. Further research should explore the range of situations in which given kernels work and seek to develop a theory of the relationship between situations and the efficacy of kernels.

The Utility of Kernels

Disseminating Effective Behavior–influence Practices

If our ultimate public health goal is to minimize the prevalence of behavioral and psychological problems and

improve wellbeing, then increasing the prevalence of effective behavior–influence practices is essential. Disseminating kernels could be an important supplement to current reliance on program dissemination for achieving this outcome. Kernels have most features that Rogers (1995) identified as important in fostering dissemination. He observed that people are more likely to adopt and implement a practice if it is simple and easily tested, its effects are readily observable, it appears to offer an advantage over existing practices, it addresses an important problem, and it is compatible with existing practices.

Most kernels are quite simple and consist of an easily tested, low-cost activity. Moreover, it is usually possible to observe their immediate impact on a person's behavior; it does not require statistical analysis of groups of individuals. As a result, the person who tries a kernel is likely to observe immediate benefit, which will likely reinforce its use. Finally, as the list of kernels in Table 1 shows, most kernels affect behaviors important to change agents.

As noted above, even if empirically supported programs were widely disseminated, numerous behavior–influence interactions in society would fall outside the scope of existing programs. For example, programs may teach social competencies to avoid aggressive behavior (Taylor et al. 1999) but teachers and youth leaders need ways to structure interactions among youth so that prompts for aggressive behavior decrease. Cooperative games (Murphy et al. 1983); peer-to-peer tootle/praise notes (Embry et al. 1996; Mayer et al. 1983, 1993; Skinner et al. 2000); the principal's lottery or preferrals (Thorpe et al. 1978, 1979); and non-verbal transition cues (Abbott et al. 1998; Embry et al. 1996; Krantz and Risley 1977; Rosenkoetter and Fowler 1986) are easy to build into daily school or afterschool routines. They can also structure student interactions to minimize prompts to engage in aggression. If we widely disseminated kernels to behavior–influence agents (e.g., teachers, therapists, youth leaders, human service workers, and parents), it could result in effective behavior support practices being more widely used than if we waited for these agents to generalize good practices from programs that they were trained to use in specific situations.

Glasgow et al. (1999) proposed the RE-AIM framework for thinking about the long-term public health effects of interventions. They argue that the benefit of a practice is a function of its *Reach* times its *Efficacy*. However, even an efficacious intervention that reaches many people will have limited impact over time, unless it is *Adopted, Implemented*, and *Maintained*. From this standpoint, kernels supplement program dissemination strategies because their readily observed benefits (efficacy) make them prone for adoption and maintenance and because they will increase the reach of beneficial behavior–influence practices since there are kernels relevant to so many situations.

A recent RCT of a media version of Triple P (Positive Parenting Program(s); Sanders et al. 2000) illustrates this point. Behavioral parenting skills programs consist largely of kernels (e.g., timeout, praise, and special play). Parents who go through such programs learn several important behavior–influence strategies. However, the reach of these programs is limited, due to administration costs and costs in time and money to participants. Triple P's media version reflects the recognition that a population-based impact may be greater if specific kernels of effective parenting practice can reach large numbers of parents. Preliminary data from this 18-county RCT showed that the promotion of "kernel-like" parenting practices through media, tip sheets, and brief, structured interactions reached about 25% of the population in intervention counties. Multiweek parenting courses were available for parents who needed support that was more intensive. The combination of kernels and programs, where needed, significantly reduced child-abuse reports, medical injuries, and out-of-home foster placement (Prinz et al. accepted).

In sum, in addition to empirically supported programs coming into wider use, we foresee the spread of kernels into the repertoires of many change agents for situations without designed programs and those where the problem does not require a multicomponent program.

Reducing the Cost of Beneficially Influencing Behavior

Making kernels widely available to behavior–influence agents may reduce the cost of bringing about widespread use of effective practices. Most of the kernels we identify are in the public domain, easy to adopt, and useful across many situations. Their dissemination requires no expensive materials. Training in their use can be accomplished much more cheaply (often simply by modeling or defining) than training in complex programs.

Since kernels are in the public domain, it discourages certain types of profit-motivated dissemination. For example, despite strong evidence of its efficacy for diverse problems, omega-3 (fish oil) offers little incentive to pharmaceutical companies to market it for treatment of bipolar disorder, post-partum depression, depression, developmental disabilities, or aggression.

Nevertheless, viable business models exist that would motivate dissemination of kernels. It is possible to make access to information about kernels a commodity sold on the Internet at low cost. Indeed, video modeling of—and supporting materials for—kernels could be available through iTunes, amazon.com, or e-bay. Alternatively, some kernels could be available at drug stores, supermarkets, or video rental stores. Workplaces, local governments, and other potential beneficiaries of kernels might well become bulk purchasers or distributors of kernels that they

calculate will affect health, safety, competitiveness, or other important outcomes.

Using Kernels Across Developmental Stages

The example kernels in this paper have utility with particular ages or developmental periods. Table 2 includes kernels with experimental evidence across multiple developmental stages, those predicted to be useful for ages for which they have not undergone testing, and those without data or clear hypotheses about their utility for developmental stages except the ones on which they have been tested. We will show kernels that are effective across multiple age ranges.

Implications of Kernels for Policy

The evidence on kernels points to the possibility that policies requiring or promoting the use of some kernels may be appropriate. For example, peer-to-peer tutoring of Title 1 students in first grade increases long-term academic success into middle school (Greenwood 1991a, b). Creating a federal, state, or district policy to use peer-to-peer tutoring in Title 1 schools or at-risk areas theoretically could raise academic performance and reduce historical racial, ethnic, and cultural disparities (Greenwood 1991a, b)—without adopting a new curriculum. Communities or school districts with high rates of dropping out in ninth grade might consider making a policy around using the 15-min motivational process in seventh grade that improves grades in ninth grade (Cohen et al. 2006). Another kernel, taking omega-3 (cod liver oil) during pregnancy increases the child IQ at age 4 (Helland et al. 2003). The evidence justifies a policy for providing free omega-3 to pregnant and post-partum mothers via Women, Infants, and Children (e.g., Helland et al. 2003; Hibbeln et al. 2006; Richardson 2006). The American Psychiatric Association recently created a policy recommending at least 1 g/day of omega-3 for all psychiatric patients (Freeman et al. 2006b), which is an example of a professional organization adopting a kernel.

Some Concerns About Kernels

Some argue that kernels are useful only if their effects are lasting. Numerous kernels do have such effects. For example, the errorless-compliance training kernel has at least a 6-month maintenance of effects for parent–child pairs coming from violent homes (Ducharme et al. 2000) and for children diagnosed with autism (Ducharme and Drain 2004). The safe playing kernel (Embry 1984) has reduced dangerous behavior 9 months after parents

Table 2 Kernel utility across age groups

	Infants	Children	Teens	Adults
Verbal praise	*	*	*	*
Peer-to-peer written praise—"tootle" notes, compliments books/praise notes	NA	*	*	*
Beat the timer or beat the buzzer	*	*	*	*
Mystery motivators/grab bag/prize bowl/game of life	P	*	*	*
Public posting (graphing) of feedback of a targeted behavior	NA	*	*	*
Principal lottery	NA	*	*	
Safety or performance lottery	NA	*	*	*
Contingent music	*	*	*	*
Team competition	NA	*	*	*
Special play	*	*		
Choral responding	*	*	P	P
Mystery shopper	NA		P	P
Peer-to-peer tutoring	NA	*	*	*
Computer action game	P	*	*	*
Correspondence training, "Say-Do"	NA	*	*	P
Correspondence training, "Do-Say"	NA	*	*	P
Time out	*	*		
Sit and watch, contingent observation, or response lock out	*	*	*	*
Taxation on consumptive behaviors	NA	NA	*	*
Positive note home for inhibition	NA	*	*	
Timed rewards for inhibition (DRO)	*	*	*	*
Premack principle	*	*	*	*
Response-cost (point loss)	P	*	*	*
Low emotion or "private" reprimands	*	*	*	*
Stop clock	NA	*	*	*
Law enforcement fine or citation	NA	NA	*	*
Over-correction or positive practice	*	*	*	*
"Buzzer/noise training"	P	*	*	
Non-verbal transition cues	*	*	*	*
Stop lights in school settings or traffic settings	NA	*	*	*
Boundary cues and railings	*	*	*	*
Cooperative, structured peer play	P	*	*	
Self-modeling	P	*	*	*
Self-monitoring	NA	*	*	*
Paragraph shrinking	NA	*	*	P
Errorless discrimination training	*	*	*	*
Adjectival noun for belonging to status group	P	*	*	*

Table 2 continued

	Infants	Children	Teens	Adults
Public commitment	NA	*	*	*
"US" and "THEM" role framing	P	*	*	*
Graphic/node maps	NA	*	*	*
MI	NA	P	*	*
Media associating behavior with "immediate" negative social outcomes	NA	P	*	*
Pleasant greeting with or without positive physical touch	*	*	*	*
Massage, brushing or stroking	*	*	*	*
Turtle technique	P	*	NA	NA
Omega-3 fatty acid supplementation or increased fish consumption	*	*	*	*
Zinc supplementation or dietary consumption	P	*	*	*
"Rough and tumble" free play/ martial arts with higher status conspecific	NA	*	*	*
Aerobic play or behavior	P	*	*	*
Nasal breathing	P	*	*	*
Progressive muscle relaxation	NA	*	*	*

NA, not applicable; *, experimental evidence; P, predicted utility

implemented the strategy at home. Peer-to-peer tutoring has effects that last from first-grade intervention through middle school (Greenwood 1991a, b). Omega-3 supplementation of cod liver oil during pregnancy has effects on children's cognitive development at least through age 4. Emotional writing reduces or prevents medication use, healthcare visits, or continued unemployments months later (Richards et al. 2000; Smyth et al. 1999; Spera et al. 1994). Response slates—as opposed to having students raise their hands—improve performance on academic measures of retention, recall, and end-of-term tests for that content (Christle and Schuster 2003; Kellum et al. 2001). Finally, a 15-min motivational interview on paper has an 18-month lasting effect on the improvement of grades of high-risk African American students from seventh grade to ninth grade (Cohen et al. 2006).

Yet even if a kernel does not seem to have a lasting impact, we should not overlook its value. In numerous situations, parents, teachers, youth workers, and others need to influence a behavior. For example, if the only evidence for response slates was that they increased classroom participation (Christle and Schuster 2003; Kellum et al. 2001), they would be valuable to teachers who want to raise classroom participation. In general, providing people with simple and reliable ways of influencing behavior is an important benefit for them, even with no current evidence that the impact is long lasting. Put another way, if we wish to create a society with high levels of caring and effective guidance in all areas, the widespread dissemination of kernels could help in this quest.

Another concern might be that kernels needed daily or weekly are futile. Yet to exclude from the approved armamentarium of prevention any strategies that do not permanently change behavior seems odd both scientifically and practically. Such a stance would exclude taking a daily aspirin to prevent strokes and heart attacks; using UV lotion to prevent skin cancer before going outside; conducting daily physical activity to prevent obesity, health problems, and depression; using a car seat each trip to protect an infant, etc. From a contextual standpoint, behavior is always, to some extent, a function of the immediate environment (e.g., Biglan 1995). In order to ensure that the environment promotes prosocial behavior through kernels is a useful way to improve human wellbeing.

Population-level Prevention

The literature reports two tracks of parenting interventions: brief solution focused and general parent training, each with experimental evidence supporting its efficacy. Solution-focused parenting involves brief interventions that may be kernels like safe playing or good shopper; others may be to-the-point recipes for going to restaurants, bedwetting, cleaning up, doing homework, getting ready for bed, etc., showing experimentally controlled results (e.g., Dadds et al. 1984; Sanders et al. 1984). The more general strategies—8-to-12 week courses focusing on general parenting skills with high-risk populations—also have positive results (e.g., Hoath and Sanders 2002).

Recently, the U.S. Centers for Disease Control supported an RCT of a combined solution-focused and general-parenting skill model to prevent child abuse in 18 South Carolina counties (Prinz et al. accepted). In counties receiving the multilevel parenting model (e.g., Sanders et al. 2003), most of the utilization of services was for the solution-focused kernels or recipes and not for the intensive services, yet the intervention produced significant reductions in substantiated child maltreatment reports, child maltreatment-related medical injuries, and out-of-home placements (Prinz et al. accepted). It may seem counterintuitive that these simple and narrowly focused strategies could produce such effects, but many acts of child maltreatment happen precisely during the types of activities addressed by the solution-focused interventions—getting ready, mealtimes, homework, chores, bedtimes, etc. The defusion of the brief kernel-like recipes to solve these problems for thousands of parents in these communities makes further sense when one understands that official reports of child physical maltreatment

underestimate its prevalence by 40 times (Theodore et al. 2007), making logistics and staffing for intensive parenting courses clearly impractical and improbable for thousands of families at any given time in a community or county.

The South Carolina experiment suggests that providing individuals access to self-selected simple preventative strategies could have large implications for public health and safety. The study hints that science-based prevention of behavioral issues could be an individual consumer product. Currently, individuals cannot access best practice prevention programs, as they can consume products for child safety, such as car seats, bike helmets, or safety guards for electric sockets or kitchen cabinets.

Improving the Effectiveness of Prevention and Treatment

Eddy (2006) has noted that intervention research does not contribute to the extent it could to improve our understanding of basic psychological and social processes that interventions must target. In most cases, we have no models of preventive interventions to show which social or psychological processes they target, the effects of the intervention on those targets, and the effects of changes in these targets on outcomes. As a result, we have not developed a robust and generalizable theory of the key aspects of human functioning and the ways in which to affect them. We can therefore say little about how to construct new interventions in new problem areas and cannot easily communicate to nonscientists what they might do for novel problems. All we can say is "apply this program." However, often there are no evidence-based programs to apply.

A theoretical analysis that pinpoints specific procedures to influence behavior and psychological processes would stimulate research to refine and improve these component strategies and encourage creation of new, more effective programs, and practices. Specifying fundamental units of behavioral influence could point to components to add to the existing programs and provide building blocks for creating new and more powerful programs. We propose that kernels are candidate building blocks for a generalizable science of intervention and prevention. The next few paragraphs, therefore, loop back to the conditions that gave rise to the need for a taxonomy of active ingredients of science-based prevention and treatment (Embry 2004) and discussed early in this paper, showing how existing evidence-based programs can be analyzed or strengthened by kernels.

In order to illustrate how we created one evidenced-based program using kernels, we briefly outline the active ingredients of PeaceBuilders (Embry et al. 1996), constructed by using previously validated kernels (Embry et al. 1996; Embry 1997). Note we did not have the language for kernels then, but quite consciously used the principle of kernels in the program design. There were five core kernels in PeaceBuilders. First, the children and adults received a framing language repertoire via a self-modeling story kernel, which we had tested for its impact on behavior. Second, children and adults created a vision of peaceful behavior using a goal/node map kernel. Third, adults and children adopted an adjectival identity noun kernel, "I am a PeaceBuilder." Fourth, adults and children learned to use praise notes or "caught-you-being good" notes for reinforcing behaviors defined earlier in the self-modeling stories. At the same time, adults learned to use the positive-home note kernel to support the reinforcement of these same peacebuilding behaviors. Fifth, classrooms and schools received public recognition and posting for engaging in peacebuilding behaviors or creating peacebuilding "inventions" each week. Weekly walk-throughs of the school allowed monitoring of these active kernels. This combination of kernels was tested in a randomized control design over several years, and showed reductions in actual violent injuries (Krug et al. 1997), increased social competence and resiliency measures, as well as reduced aggression and inattention (Flannery et al. 2003). It affected the high-risk students the most (Vazsonyi et al. 2004). The selection and use of kernels in PeaceBuilders is an example of how kernels can both construct an intervention and clearly specify the putative ingredients.

In order to illustrate how kernels can clarify why programs work, we examine the Good Behavior Game (GBG), not created with kernels in mind. The GBG has already increased cooperative on-task behavior in school significantly (Barrish et al. 1969; Medland and Stachnik 1972) and reduced antisocial behavior and smoking in adolescence and adulthood (Kellam et al. 2008, 1994; Kellam and Anthony 1998). Its core kernels include a response cost for negative behavior (e.g., Conyers et al. 2004); team competition (e.g., Beersma et al. 2003); public posting of results (e.g., Parsons 1982); and team rotations (deemed critical but with no supporting study). Additional kernels include a low emotional response to negative behaviors (e.g., Abramowitz et al. 1987), playing three games per day, and using beat the timer (e.g., Adams and Drabman 1995).

The GBG also provides an occasion to describe the utility of kernels in helping disseminate programs. Until 2003, when the first author started collaborating with Johns Hopkins, there was virtually no diffusion of the GBG based on Kellam's work or even earlier behavior analysis studies, beyond journal articles. Inspection, direct replication, and systematic replication in different settings of the GBG (Embry 2002) as implemented by Kellam and colleagues, pointed to several ways that planned dissemination and

further testing underway at Johns Hopkins could strengthen it. First, it was necessary to stop edible reinforcers used by Kellam and colleagues, as social context and validity do not support this 20 years later. A switch to a kernel of prizes based on the Premack Principle (Andrews 1970; Homme et al. 1963; Hosie et al. 1974; Premack 1962; Van Hevel and Hawkins 1974) proved acceptable and reinforcing to children and adults alike.

Second, we added kernels to improve adoption, implementation, and maintenance of the GBG based on observations and consumer feedback. These included nonverbal cues (e.g., Cox et al. 2000; Rosenkoetter and Fowler 1986) to improve generalization and adoption of the Game and meaningful roles as differential reinforcement of other behaviors (e.g., Rutter 1981) to reduce accidental negative attention. Another includes setting generalization recipes for carrying over the GBG to hallways, restrooms, cafeteria, etc. (e.g., Fishbein and Wasik 1981) to improve generalization by students and acceptability by adults. Other kernels include symbolic self-modeling (e.g., Embry et al. 1996) to improve imitation of behavior and school-home notes (e.g., Kelley et al. 1988) for prompting family reinforcement and generalization of behavior to home. Others are peer-to-peer praise notes (e.g., Skinner et al. 2000) to improve social competence and reduce negative peer attention, and the good behavior lottery (e.g., Putnam et al. 2003) to increase generalization when not playing the Game. Inserting these kernels provided a more systematic approach to address the issues of diffusion of scientific innovation, raised by Rogers (1995), of relative advantage, compatibility, ease of use, trialability, and observability.

Kernels may also be useful in strengthening existing programs. Several investigations have noted problems replicating the results of Project Alert in community contexts (e.g., St. Pierre et al. 2005). In Houston, an agency requested assistance from the first author for improving implementation of Project Alert in the context of gym classes—they had never tested it scientifically but it was the only slot available in the school day. Attendance was poor and pre–post assessments did not show that the program affected the students. We recommended use of several kernels in order to make attendance more reinforcing and the lessons more participatory, and to create peer pressure for attendance: prize-bowl, random calling, peer-to-peer tutoring, tootle notes, response slates, pleasant greetings to students by program staff in the halls, and student jobs. In year-to-year comparisons, attendance doubled, increasing to 90% in most of the schools. Moreover, for the first time, students achieve the target scores for the post-tests proposed to measure dose and fidelity by the developers of Project Alert.

The analysis of kernels can also help construct new interventions by putting together a set of kernels that all appear relevant and useful for new problems. For example, methamphetamine addiction is a serious public-health problem and there is a dearth of evidence-based programs to reduce it (Embry et al. 2005). Table 3 outlines a potential community- or state-level response to methamphetamine use via evidenced-based kernels. The table tackles the huge public health problem that arises from meth-exposed infants or children who enter the medical, social service, and legal systems as well as intervention, prevention, and treatment issues associated with teens or adults using or at risk for using methamphetamine.

Of course, such a constructed program demands experimental evaluation via randomized trials or at least via quasi-experimental studies. At the same time, however, practitioners and policymakers desperate to deal with the methamphetamine problem must have a strategy, that, although not yet evaluated in an RCT, is composed of elements, each one shown in prior experimental work in RCT or interrupted time series to affect its target behaviors. The bundled kernels to address this public health and safety problem could face testing in an interrupted time-series design across neighborhoods, communities, or counties using naturally occurring archival data on meth-related crimes, arrests, emergency-room care use, or child removals.

The theoretical analysis of kernels also may help to develop new kernels. In essence, the framework suggests that, in any instance requiring altered behavior, it will pay to examine systematically whether it is possible to alter consequences or antecedents for the behavior, if it is possible to influence relational responding in ways that change the value of relevant behaviors, and finally, whether physiological interventions could alter the probability of behavior. A thorough understanding of existing kernels would contribute to the success of this effort.

Prevention science might also gain strength by mapping kernels onto risk and protective factors. For instance, much research points to early antisocial behavior, school bonding, and inadequate parental monitoring as predictors of various adverse outcomes (Arthur et al. 2002; Dekovic 1999; Duncan et al. 2000). Numerous kernels are relevant to affect these constructs. Examples include the percentage of students with meaningful roles in a day, the square footage of student work displayed on the walls, the number of peer-to-peer positive written notes, the caught-you-being good notes, or positive notes home (Rutter 1981). Articulating the kernels relevant to each risk or protective factor would provide practitioners with more precise guidance as to which kernels are most useful for altering key risk and protective factors.

Thinking in terms of kernels may also facilitate our identifying kernel-like practices that occur naturally in society, as has already happened in some cases. For example, epidemiological studies show that omega-3

Table 3 Applying kernel to community-level methamphetamine addiction issues

Kernel	Strategy and procedure	Sample citations	Quality of evidence
Prize bowl (contingency management) for sobriety and recovery	Multiple contracts/grants to organizations to recruit individuals at jails, ERs, shelters plus thru existing courts, clinics, faith-based organizations w/monitoring of results across settings	Petry and Martin (2002), Petry et al. (2000, 2001a, b, c, 2004, 2005), Rawson et al. (2006)	Multiple RCT; 1 with comparisons to proven program
Omega-3 supplements	2 g/day to reduce comorbid depression, bipolar disorder, aggression, plus CVD symptoms, promoted at jails, clinics, shelters, public health, and outreach workers. Policy changed to support addition to government formularies	Freeman et al. (2006), Gesch et al. (2002), Stoll et al. (2000)	Cross-national epi; lab studies; RCT with/without other meds
Kangaroo care for infants	Infants born to addicted moms or moved to foster care (Conde-Agudelo et al. 2003; Feldman and Eidelman 2003) given to reduce developmental problems; training of caseworkers, nurses, doctors; added to program policy standards	Ferber and Makhoul (2004), Ludington-Hoe et al. (2004), Priya (2004)	Lab studies for mechanisms; case studies; randomized trials
Errorless compliance training for exposed children	Toddlers/preschoolers neglected or abused by drug-using parents receive errorless compliance training by bio parent, foster parent, and/or teacher; Policy implemented via court order	Ducharme (2003), Ducharme et al. (2000, 2001, 2002, 2003)	Empirical case studies; several multiple baselines; randomized control studies
Self-modeling for exposed preschool and elementary children	Exposed preschoolers and elementary children under court petition or special ed receive self-modeling videos or digitally created storybooks for social skills and behavior at home, foster care, or care settings. Academic, social skills and self-regulatory behaviors taught related to developmental delays	Clare et al. (2000), Hitchcock et al. (2003), Kehle et al. (2002), Lonnecker et al. (1994), Reamer et al. (1998)	Multiple single subject studies using interrupted time-series designs; meta analyses of single subject studies
Community-wide adult to child/youth positive praise notes	Local governments and school districts promote community-wide praise notes from adults to increased protective factor of reinforcement of social competence, which protect against substance abuse and related antisocial behaviors	Gupta et al. (1990), Hutton (1983), Kelley et al. (1988), McCain and Kelley (1993), Taylor et al. (1984), Embry et al. (1996)	Multiple interrupted time-series studies on individual level and school level; a few RCT with practice embedded
Red flag training for exposed children or teens with serious emotional disturbance	Dependency or delinquency court order or special education plan includes Red Flag procedure to reduce explosive anger and aggression among children exposed to drugs, neglect, or abuse	Ninness et al. (1995), Ninness (1991)	Multiple interrupted time-series designs
MI for at-risk youth	Juvenile justice, emergency room, and school personnel conduct motivational interviews for youth engaged in problematic behaviors; supportive policies and contracts issued	Colby et al. (1998), Diamond et al. (2002), Monti et al. (1999), Smith (2004), Spirito et al. (2004), Stein et al. (2006)	Multiple randomized control studies

consumption was associated with many important health and behavior outcomes, such as reduced CVD, depression, and homicide (Hibbeln 2001, 2002; Hibbeln et al. 2007; McGrath-Hanna et al. 2003; Tanskanen et al. 2001). Then intervention studies showed that changes in the consumption of omega-3 reduced these types of adverse conditions (Freeman et al. 2006a; Gesch et al. 2002). In a similar vein, epidemiologists can use existing evidence about kernels to examine whether kernels occur naturally in social systems and benefit the population. Such research would strengthen the link between epidemiology and intervention research and practice, while strengthening empirically based theory about human development.

A Database Repository of Kernels

In the interest of fostering the dissemination and further development of kernels, we propose a database repository of kernels, analogous to the human genome project, which might be called the behaviornome. Initially, it would contain the kernels that Table 1 lists and would enable people to describe additional kernels and empirical evidence regarding their effects. The database would allow a user to search for specific kernels or to identify a behavior and search for kernels relevant to influence the behavior. We are hopeful that this repository will provide detailed information about how kernels influence behavior, the circumstances in which they do or do not work, and any iatrogenic effects, potential positive or negative combinations of kernels not documented presently, variations of kernels related to cultures or other establishing conditions, and proximal and distal behavioral effects. In time, the database would have hyperlinks to PsychInfo or PubMed. We expect the repository to help reduce the cost of beneficially influencing behavior and improving the efficacy of prevention and treatment practice and theory.

Summary

Kernels are fundamental units of behavior–influence technology. They provide a wealth of resources for those trying to influence human behavior in beneficial ways. The four primary mechanisms of kernels are providing consequences for behavior, establishing antecedent stimuli for behavior, altering people's relational framing about targeted behaviors, and altering physiology that affects behavior. Understanding the range and effectiveness of kernels could contribute to the public-health goals of decreasing the prevalence of problems and increasing wellbeing. Kernels could provide behavior–influence agents with a wider array of effective practices. Denomination of kernels could clarify the active components of existing programs. It could also lead to the development of new programs composed entirely of effective kernels. Finally, it could contribute to the development of an empirically based theory of behavior influence consistent with current knowledge of risk and protective factors and that clarifies the mechanisms through which behavior influence occurs.

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