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JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

Randomized Trials and Case Replications of the Good Behavior Game®*/ PAX Good Behavior Game® Updated March 2020

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PAXIS Institute is the official purveyor of the Good Behavior Game® for replicating famous gold-standard randomized, comparative effectiveness trials at Johns Hopkins University, Center for Prevention and Early Intervention. The commercial version, Good Behavior Game®/PAX Good Behavior Game®, includes the original recipe used at Hopkins, originally written by and trained by Dr. Jaylan Turkkan [1]. The commercially available version has been used at Hopkins since 2002, which includes additional evidence-based kernels [2, 3] to improve ease of learning, training and fidelity of implementation as well as improve reliability of proximal outcomes across diverse ages, grades, languages, social-economic backgrounds and cultures [4, 5]. Materials, training, coaching/mentoring, and data monitoring for implementation and proximal results are standardized in iOS, Android & Web applications. Each classroom implementation can be measured for effectiveness with the App system, in keeping with the origins of the Good Behavior Game that works by changing everyday behavior [6].

Since 1999 when PAXIS began real world replications, approximately 50,000 teachers have been trained to use the Good Behavior Game® by PAXIS Institute in 38 states, multiple provinces of Canada, as well as First Nations in North America, Europe, and Australia. PAX GBG is the only version, independently replicated in randomized trials or field trials in the United State, Canada, Estonia (Estonian and Russian), Sweden, the United Kingdom, Ireland, and Australia. Randomized trials and scale-up/replication studies related to Good Behavior Game (Cohorts 1-2) and PAX Good Behavior Game commercialized for replication at Hopkins and other sites nationally or internationally include:

Our Randomized Trials at Johns Hopkins

All past and current randomized trials at Johns Hopkins used randomized comparative effectiveness trials.

1. Citations for Cohort 1 Randomized Trial at Johns Hopkins *(principal investigator: Kellam)* [7-22], which involved two years of exposure to GBG (1st and 2nd grade).
2. Citations for Cohort 2 Randomized Trial at Johns Hopkins *(principal investigator: Ialongo)* [15, 22-27], which had one year of exposure in 1st grade.
3. Citations for Cohort 3 Randomized Trial at Johns Hopkins in schools and on-line *(principal investigator: Ialongo)* [22, 28-36].

Our Other Randomized PAX GBG or Precursor/Replication Trials

4. Citations for Randomized Trial in Pennsylvania in Afterschool Settings *(principal investigator: Phillips-Smith)* [37-40]
5. Citations for Population-Level (All Districts), Randomized Trial in Manitoba, Canada *(Manitoba Centre for Health Policy/Healthy Child Manitoba)* [41, 42].
6. Citations for Randomized Trial in Alberta, Canada *(principal investigators: Prinz and Embry)* [43].
7. Citations for Randomized Trials in the European Union *(Estonia and Northern Ireland)* [44, 45].
8. Citations for PeaceBuilders Randomized Trial K-5 schools (precursor of PAX evidence-based kernels plus GBG) *(principal investigator: Embry)* [5, 46-48].

Our PAX GBG Case Studies or Population-Level Replications

9. Whole County Evaluation of PAX GBG impact on standardized reading and math scores [49].
10. Case PAX GBG replication in the Republic of Ireland [50].
11. Case PAX GBG replication in 200+ K-8 classrooms in South Chicago [51].
12. Case PAX GBG rapid 8-week replication in 186 Title I classrooms across 8 school districts commissioned by the Substance Abuse and Mental Health Services Administration [52].

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The Good Behavior Game: A Best Practice Candidate as a Universal Behavioral Vaccine

Dennis D. Embry[1]

A "behavioral vaccine" provides an inoculation against morbidity or mortality, impacting physical, mental, or behavior disorders. An historical example of a behavioral vaccine is antiseptic hand washing to reduce childbed fever. In current society, issues with high levels of morbidity, such as substance abuse, delinquency, youth violence, and other behavioral disorders (multiproblems), cry out for a low-cost, widespread strategy as simple as antiseptic hand washing. Congruent research findings from longitudinal studies, twin studies, and other investigations suggest that a possibility might exist for a behavioral vaccine for multiproblem behavior. A simple behavioral strategy called the Good Behavior Game (GBG), which reinforces inhibition in a group context of elementary school, has substantial previous research to consider its use as a behavioral vaccine. The GBG is not a curriculum but rather a simple behavioral procedure from applied behavior analysis. Approximately 20 independent replications of the GBG across different grade levels, different types of students, different settings, and some with long-term follow-up show strong, consistent impact on impulsive, disruptive behaviors of children and teens as well as reductions in substance use or serious antisocial behaviors. The GBG, named as a "best practice" for the prevention of substance abuse or violent behavior by a number of federal agencies, is unique because it is the only practice implemented by individual teachers that is documented to have long-term effects. Presently, the GBG is only used in a small number of settings. However, near universal use of the GBG, in major political jurisdictions during the elementary years, could substantially reduce the incidence of substance use, antisocial behavior, and other adverse developmental or social consequences at a very modest cost, with very positive cost-effectiveness ratios.

KEY WORDS: substance abuse prevention; violence prevention; public policy; best practice.

INTRODUCTION

A behavioral vaccine is a simple, scientifically proven routine or practice put into widespread daily use that reduces morbidity and mortality. A powerful example comes from an epidemic that occurred 150 years ago.

During the nineteenth century, women died in childbirth at alarming rates in Europe and the United States. Up to 25% of women who delivered their babies in hospitals died from childbed fever (puerperal sepsis), discovered later to be caused by Streptococcus pyogenes bacteria.

In the late 1840s, Dr Ignaz Semmelweis worked in the maternity wards of a Vienna hospital. By meticulous observation, he discovered that the mortality rate in a delivery room staffed by medical students was up to three times higher than in a second delivery room staffed by midwives. Semmelweis postulated that the students might be carrying the infection from their dissections to mothers giving birth. He tested the hypothesis by having doctors and medical students wash their hands with a chlorinated solution before examining women in labor. The mortality rate in his maternity wards eventually dropped to less than 1%. Washing of hands with antiseptic solution—a behavioral vaccine—now saves millions of lives every year. Today, the Centers of Disease Control and Prevention (CDC) web site states, "[Antiseptic] hand washing is

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the single most important means of preventing the spread of infection."

Other behavioral vaccines have been promoted on the premise of reduced mortality or morbidity. In the 1960s and 1970s, seat-belt use for adults and car seats for children were examples from the injury control literature.

In contemporary society, an epidemic affecting young people has waxed and waned since the 1960s. Substance abuse; delinquency; school failure; psychiatric disorders such as ADHD, oppositional defiance, and depression; teen suicide; teen pregnancy; and youth violence have adversely affected the lives of America's adolescents (see the various Surgeon General's reports on these topics). These problems often co-occur in what Biglan (2001) describes as multiproblem youth. Could there be a behavioral vaccine, nearly as simple as antiseptic hand washing, which might significantly reduce the mortality and morbidity of multiproblem behavior? Yes, there could be. This paper details what one might be and how it might become as common as a doctor or nurse washing hands with antiseptic solution.

Behavioral Vaccine Defined

A behavioral vaccine is a simple procedure that can dramatically change an adverse outcome. Unlike prevention programs, which are typically described as a collection of procedures delivered over a set time such as 8–12 weeks, a behavioral vaccine is given only once or used as a simple *routine* of daily life. Traffic safety research offers some useful examples. A drivers' education program is a prevention program. Both optional air bags and seat belts are behavioral vaccines. In the case of optional air bags when they were introduced, a person only needed to make a decision to buy a new car *with air bags* to enjoy the benefit of increased safety. In the case of seat belts, one must buckle up each time to maximize safety from harm. Both types of behaviors are relatively easy, unlike the complexity of a drivers' training course on accident avoidance. A hallmark of a behavioral vaccine is that a simple action yields large results. Per se, behavioral vaccines do not preclude other strategies, and may even work synergistically with or be combined with more strategies to leverage effects. Behavioral vaccines are typically very inexpensive, and work for a broad population, with few adverse effects.

The Logic Model of Behavioral Vaccines

Like any public-health measure, behavioral vaccines must be able to be used across the whole population to achieve the full societal as well as individual prevention effect. The need for universality can be modeled mathematically and logically (e.g., Embry & Flannery, 1999). Mathematically, prevalence rates of multiproblem behaviors (e.g., substance abuse, misuse, juvenile crime) typically range from 1 to 15% for the purposes of illustration here. Prediction of who will develop these problems over life span is quite clearly *not* 100%, and ranges vary dramatically depending upon the complexity, comprehensiveness, and sensitivity of the prediction tools. Issues of false negative and false positive identification loom large, however (Embry & Flannery, 1999). If one presumes that certain problem behaviors happen in around 5% of the population, then 500 out of 10,000 people ought to be afflicted. An 85% accurate prediction model (which would be the envy of most behavioral epidemiologists) could correctly classify 425 people, missing 75. How many might be false positives though? In a rough way, that can be calculated by subtracting the 425 correct positive predictions from 10,000. Then, multiply that number by the prediction error term (15%). The result is that public-health practitioners, school, law-enforcement, and/or parents might have erroneously identified 1,436 people as at-risk when they are not. In times of scarce resources, implementing selected or targeted interventions for those 1,436 people makes little economic, logical, political, social, or health sense—especially when the delivery of targeted or selected prevention strategies may run thousands of dollars per person, be very difficult to deploy, or both.

The logic of a behavioral vaccine improves the power, prediction, and cost-effectiveness of targeted and selected prevention strategies. This can be illustrated by problems posed by bioterrorism prevention and early detection. Chills, fevers, vomiting, and other such symptoms are common early signals of some agents suitable for bioterrorism, such as anthrax—necessitating an elaborate screening and detection (U.S. Surgeon General, 2002). These signals are also the early symptoms of the flu and colds, which are perversely common, resulting in false negatives or positives. Thus, an epidemic of flu-like symptoms could precipitate a dramatic overresponse from authorities (false positive)—which uses up valuable social, economic and political capital making, paradoxically making the society more vulnerable.

Or, the authorities might underrespond, dismissing the events as simply colds or flu (false negative). In the case of multiproblem behavior such as substance abuse and juvenile crime, behaviors such as early impulsivity, inattention, and disruptiveness among children—nearly as common as flu-like symptoms metaphorically—predict serious problems a decade or so later (e.g., Tremblay, Masse, Perron, and Leblanc, 1992); even though, a good half or so of the children will desist a decade later in these behaviors (e.g., Walker, Colvin, & Ramsey, 1995). If every young child who exhibits these behaviors receives medication, behavioral interventions at home, and behavioral interventions at school, the personnel and economic cost would be substantial. And, substantial numbers of children or families would be subjected to medication or services simply not needed and possibly iatrogenic. Now, imagine that a universal precaution can cut the incidence rate of the key manifestations of a behavioral or a public-health problem from 20 to 50%. Such prevention effects dramatically improve the sensitivity, power, and and cost-effectiveness of selected or targeted interventions—which can be modeled mathematically. This efficiency effect can be exemplified by the harried school counselor or psychologist who now has 20–50% *fewer* referrals for evaluation for conduct or attention problems, and who now has more time for more accurate screening and treatment.

The logic of a behavioral vaccine has even more potency if there are suspected contagion effects. Contagion can be real or via social learning in multiproblem behaviors. For example, placing a child with risk factors among other children who manifest those same symptoms for an intervention or prevention can dramatically escalate the expression of the rate and severity of symptoms, causing more harm to the individuals, peers, and society (e.g., Dishion, McCord, & Poulin, 1999). Even the simple random assignment of impulsive or disruptive 1st graders to classrooms with high, medium, or low levels of peer aggression can dramatically escalate or mitigate serious behavioral problems a decade later (e.g., Kellam, Ling, Merisca, Brown, & Ialongo, 1998). These adverse contagion effects could be the result of imitation, peer reinforcement of antisocial behavior, or escape conditioning from aversive behaviors by adults, or some combination. One might usefully think about contagion effects as "tipping points," which could be altered by classroom management, school climate, or community-wide behavioral vaccines.

A final set of issues exists in the logical model of behavioral vaccines: ability to scale to nearly universal coverage, low adverse reactions, and robustness to be used in combinations with other strategies.

Logically, a behavioral vaccine must be easily scaled to cover large areas of social geography and its attendant population to achieve protective effects. Logically, the behavioral vaccine would have to work with very diverse ages and work across different ethnic or cultural groups. Mathematically, it is virtually impossible to affect community-level outcomes (e.g., crime rates, drug use) without near universal coverage of a primary prevention strategy. A behavioral vaccine must also have low negative side effects, if used at scale. Why so? Lipsey (1992) reports that approximately 29% of the interventions to prevent delinquency actually make young people worse, and this may be a significant underestimate because efforts with adverse results are less likely to be published for many reasons. Thus, a behavioral vaccine with significant adverse effects for a subset could actually make community-level results worse, instead of better. An extension of the logic of reducing adverse reactions would extend to how the vaccine interacted with other prevention or intervention efforts, as a behavioral vaccine could be like certain drug interactions. To the dismay of most program developers, users of prevention protocols often do not implement them with fidelity or may mix them with home grown strategies. A potential behavioral vaccine could have robust internal validity in carefully randomized control-group studies, yet fail miserably in the field. Thus, a behavioral vaccine would need to have evidence of impact and utility in sloppy, naturalistic conditions.

The logic model for a behavioral vaccine shares some elements of the risk and protective factor literature currently driving much of the prevention policy in the United States (e.g., Catalano, 2001), yet is quite different in other ways more akin to large public-health campaigns. Both models rely on empirical data. In the risk and protective factor model (Catalano, 2001), small units of government (e.g., schools, school districts, or communities) attempt to create a plan presumptively based on their *unique* data. The behavioral vaccine model holds that certain risks or protective factors must be considered at a population or near universal level. The nature of the data construct (normative based) of the risk and protective factor model makes it very difficult to detect general population factors adversely affecting child development vis-a-vis small unit prediction. Further, the risk and protective factor model does not take into account the time

sequence of prediction, only the current prediction in a cross-sectional mode. The behavioral vaccine model presumes a developmental sequence or vector, which if interrupted, has long-lasting effects.

If the logic model is true for behavioral vaccines, then great benefits could accrue for individuals, families, schools, and communities from a powerful prevention strategy that could be used in large-scale public health models. The question begs: does prevention science suggest any strategies as potentially appropriate as a behavioral vaccine for multiproblem behavior?

A Candidate Behavioral Vaccine

A bit over 30 years ago, two graduate students, Harriet Barrish and Muriel Saunders, and one of the founders of behavior analysis, Montrose Wolf, published a study on the effects of something called the Good Behavior Game (hereinafter, the Game; Barrish, Saunders, & Wolf, 1969). It worked pretty well, and became a behavior-modification "trick" most graduate students in behavior analysis or special education learned during the heyday of behavioral psychology. Neither Barrish, Saunders, or Wolf, nor the graduate students who learned to use the Game as a classroom strategy, had the slightest idea then how powerful the strategy might be for changing the future of children destined for lifetime multiproblems of substance abuse, violence, and school failure (Kellam & Anthony, 1998; Reid, Eddy, Fetrow, & Stoolmiller, 1999; White, Loeber, Stouthamer-Loeber, & Farrington, 1999).

Even with the spread of "best practice" guides, very few policymakers, government agencies, educators, prevention specialists, mental-health providers, or even research scientists know about the Good Behavior Game. Very few people know about the potential for the Game to prevent multiproblem behavior that gobbles up special education, juvenile delinquency, and treatment dollars.

The Game is the simplest of behavioral strategies, which has been described in detail in a manual (Embry & Straatemeier, 2001). First, the adult inducts children's definitions of the rules of the setting, specifically what would make the classroom or nonacademic setting a good place to learn, more enjoyable, pleasant, etc., all labeled as the "good things we all want." Second, the adult inducts children's descriptions of behaviors that would interfere with desirable outcomes and labels these generically as "fouls." Third, examples of both are presented physically and in words for the children to form a generalized concept. Fourth, the adult explains that the Game is played at intervals, like innings, but never for the whole day. Fifth, the adult divides the group into teams and explains that a team may win the Game by having the fewest fouls (or below a criterion in later research, enabling multiple winners), because that means more good has happened. Every team can win some brief activity prize if they have less than a predetermined number of fouls during an interval. Sixth, the adult makes sure a daily scoreboard is highly visible, just like the scoreboard of baseball or football, with fouls much smaller than wins. The Game has procedures for how to play in certain circumstances, how to keep it exciting, how to improve generalization, and how to solve problems for players who cheat or flout the conventions.

In this paper, I outline why and how the widespread application of the Game might be one of the most cost-beneficial prevention strategies available for schools and other settings. The paper will also map out the scientific and practical ways that the Game might become a universal public-health measure or vaccine for the prevention of multiproblem behavior. The rationale for the idea of a universal behavioral vaccine can be advanced on the basis of epidemiological research, findings from the neurochemistry of behavior, evolutionary psychology, replicated behavioral studies, and simple mathematics. This paper also discusses research and practical issues related to a "behavioral vaccine" for prevention.

EPIDEMIOLOGY OF MULTIPROBLEM BEHAVIOR AS FOUNDATION FOR A BEHAVIORAL VACCINE

The foundation for a behavioral vaccine would, of necessity, make sense only if there were evidence of a behavioral trajectory that predicted adverse outcomes. That evidence would be even stronger for the vaccine if the behavioral trajectory were measurable, meaningful, and malleable. Such a foundation is becoming much stronger because of the quality and quantity of scientific research on multiproblem behavior of substance abuse, delinquency, violence, school failure, and related mental-health disorders.

Just a few years ago, practitioners and scientists built program and scientific castles about the causes, prevention, and treatment of substance abuse, delinquency, violence, various mental-disorders, and school failure. Champions argued that each problem was caused by very unique factors, necessitating a

tobacco prevention program, a marijuana prevention program, a violence prevention program, etc. These prevention castles have been defended to the death, even when they are expensive and show weak or no effects. Typically, the prevention models emerged largely as a result of simple cross-sectional studies or incomplete epidemiological information. It was and is a classic case of inadequate experimental design on *developmental* issues, leading to erroneous conclusions—just as Schaie and Baltes (1975) warned.

Over time, well-controlled multiple longitudinal and twin-studies stormed and demolished the castles, though defenders of the rubble still continue. Consider some examples of the castle sieges.

In 1990, Shedler and Block published landmark results on substance abuse from a long-standing longitudinal study. They reported that substance abuse (vs. substance experimentation) at age 18 could be predicted by simple measures of coercive parent–child interactions at age 8. Shedler and Block's findings mirrored the more fine-grained longitudinal studies on the role of parent–child coercive interactions in the cause of antisocial behavior by Patterson and Stouthamer-Loeber (1984), by Patterson, De Baryshe, and Ramsey (1989), and more recently by Ary et al. (1999). Other longitudinal studies, such as by Walker, Stieber, Ramsey, and O'Neill (1993), followed, showing the links between early aggression in boys and lifetime problem behavior. Tremblay et al. (1992) observed these connections in boys in Montreal. Consistent reports emerged from researchers in other locations. Raine, Venables, and Mednick (1997) found similar relationships in a long-term study in Mauritius. In the longstanding Child Development Study in New Zealand, Moffitt (1990, 1993) provided strong evidence for life-course continuity of early problem behaviors and adverse adolescent outcomes. Swedish studies showed long-term relationships between aggression, alcohol use, and criminals behaviors (Andersson, Mahoney, Wennberg, Kuehlhorn, & Magnusson, 1999). In the United Kingdom, Champion, Goodall, and Rutter (1995) have shown the connections between various adverse developmental outcomes in a decade-long study. Recently, more complex longitudinal studies have revealed similar data (Loeber, Stouthammer-Loeber, & White, 1999), yet expand on how depression and internalizing symptoms affect the outcomes along with early aggression. What do all these longitudinal data tell us? In general, the data suggest that many serious behavioral problems of adolescence and young adulthood emerge from similar behavioral pathways. These studies clearly suggest that the behavioral trajectory is measurable and meaningful. Are the trajectories malleable?

Some of the longitudinal studies, by happy circumstance, indicate that environmental or social events alter the apparent trajectory of multiproblem behavior. Consider just a few examples from the longitudinal literature. Patterson and colleagues have had the opportunity to study behavioral interactions (interval-by-interval coding) in the context of longitudinal study of antisocial children. What did they find? Patterson, Dishion, and Yoerger (2000) reported that more than 50% of the outcome of substance use, health-risking sexual behavior, and police arrests can be predicted by how much reinforcement of deviant behavior children receive. In a 1998 study, Patterson, Forgatch, Yoerger, and Stoolmiller argued that the prediction of lifetime deviancy had stable behavioral roots at least as early as the 4th grade, based on their data. One of Patterson's key colleagues has further documented that deviance reinforcement and delinquent behavior follow the matching law (Dishion, Spracklen, Andrews, & Patterson, 1996). The pattern of reinforcement delivered by parents and the reciprocal interactions between parent and child have been well documented to be malleable in high-quality, thorough behavior analysis or in other studies (e.g., Kosterman, Hawkins, Spoth, Haggerty, et al., 1997; Tremblay, Pagani-Kurtz, Masse, Vitaro, et al., 1995; Webster-Stratton & Hammond, 1997).

Most of the above work focuses on the family context, and other researchers have examined school or community contexts in terms of behavioral trajectory. Rutter, Maughan, Mortimore, Ouston, and Smith (1979) and Rutter (1985) show powerful effects of school organization on delinquency, behavior problems, and other outcomes. Rutter proposes that the structure and organization of school may differentially reinforce resilient behavior versus antisocial behavior. One of the original descriptive studies of the Baltimore Prevention Project (Kellam, Mayer, Rebok, & Hawkins, 1998) showed that classroom context had a 6-year impact on developmental outcomes for children with elevated developmental risk. Specifically, Kellam, Ling, et al. (1998) report that high-risk children who were randomly assigned to classrooms with naturally occurring low or high levels of aggression by other children had very adverse impact on the randomly assigned longitudinally studied boys but not girls. Collectively, Kellam's work suggests that the boys in his research settings might have been reinforced for aggressive behavior by peers

(both negatively and positively), in much the same way as Patterson's cycle of coercion was observed in a family context. School context, at least, offers evidence of a behavioral trajectory that is measurable and meaningful.

Some evidence suggests that the behaviors might not be easily malleable, perhaps reducing the likelihood of a behavioral vaccine. It appears, from several types of inquiry, that some children have an innate vulnerability to the cycle of family or peer coercion, and possibly, the reinforcement of aggressive behavior. Some of the longitudinal studies strongly suggest a genetic modulation of outcome, as well as leverage points for intervention or prevention. In a report from their Montreal study, Tremblay, Pihl, Vitaro, and Dobkin (1994) obtained teacher ratings on 1,161 kindergarten boys from 53 schools with the lowest socioeconomic status, on the dimensions proposed by Cloninger, Sigvardson, and Bohman (1988). Tremblay et al. (1992) correlated the teacher survey results with the presence of self-reported delinquent behavior at age 13. Scores for *high impulsivity* and *hyperactivity* were the strongest predictors of delinquency ($p < .0001$), whereas scores for low anxiety ($p < .016$) and low reward dependence ($p < .029$) provided a lower level of prediction (see Fig. 1). The results confirmed the prediction of Cloninger's neurotransmitter model that high impulsivity and novelty seeking predict high risk for antisocial behaviors, which are behaviors modulated by serotonin, dopamine, and norepinephrine (e.g., Cloninger, 1994).

If the longitudinal studies are correct, then the need for a strong behavioral vaccine might be even greater for individuals who have a genetic risk for multiproblem behaviors. The question is whether such genetic vulnerability exists. The answer is yes. Studies of twins amplify and refine the general longitudinal studies on multiproblem behavior, suggesting strong genetic linkages. Slutske et al. (1997) utilized the Australian Twin Registry for the largest twin study of conduct disorder ever reported. They examined 2,682 adult twins, and concluded that genetic factors contributed to at least 71% of the disorder. A

Fig. 1. Longitudinal prediction from Montreal Study.

related publication from the Australian Twin Registry (Slutske et al., 1995) showed that girls with conduct disorder had a 10-fold greater risk of having problems with alcoholism than girls without conduct disorder. The Minnesota Twin Study shows a strong association for alcoholism, ADHD, and other behavioral problems among 1,200 twins (Disney, Elkins, McGue, & Iacono, 1999). Most of the twin studies suggest a strong linkage between problems of attention, hyperactivity, and aggression as key underlying factors predicting multiproblem behavior in boys. Reduction in rate, intensity, and duration of these behaviors might be the logical target of a behavioral vaccine—unless such behaviors were so profoundly genetically driven as to be immutable. The research on genetic mechanisms of these findings has considerable implications for prevention.

Genetic studies of multiproblem behavior have advanced significantly in the last decade, and these advances suggest that genetic vulnerability is not static but sensitive to social events—potentially making the need for behavioral vaccine higher, which might prevent the disturbing problems from unfolding. Few social scientists realize the significance of advances in genetics research, which regulate some of the neurotransmitter candidates identified by Cloninger as implicated in multiproblem behavior (e.g., Comings, 1995; Comings et al. 2000; Comings, Gade, Muhleman, & MacMurray, 1996; Comings, Gade, Wu, et al., 1996). Importantly, candidate polygenic alleles for multiproblem behaviors have strong evidence for being turned on by exposure to perceived human stress (e.g., Madrid, Anderson, Lee, MacMurray, & Comings, 2001), and the neurotransmitters implicated in multiproblem behavior are clearly related to social interactions (e.g., Quist & Kennedy, 2001). Because the evolutionary psychologists and other scientists have convincingly documented that individuals who likely carry these genes (and behaviors) do not randomly mate (e.g., Buss, 1984; Krueger, Moffitt, Caspi, Bleske, & Silva, 1998), a behavioral vaccine for multiproblem behavior in children might have to operate in schools or community. The advances in genetics research help resolve the tension between nature versus nurture debate (see Embry, in press, for a complete discussion), and a behavioral vaccine might mitigate against the interactions between genetic vulnerability and common social risk factors articulated by numerous investigators found in schools, communities, peers, and even homes.

What are the implications of all of these diverse epidemiological findings? First, reductions in

early inattention, disruptiveness, and related behaviors ought to decrease long-term adverse socially undesirable outcomes—nothing particularly new but worth restating. Second, the *biological* processes of multiproblem behaviors are clearly affected by social events, and scientific advances now make it possible to understand how the social environment might affect the expression of genes related to the biology of multiproblem behavior. Third, the epidemiological data suggest that effective behavioral procedures, universally promoted and used, might well be powerfully effective environmental or behavioral "vaccines" to prevent the occurrence of multiproblem behavior.

A BEHAVIORAL VACCINE

Presently, society has two current operative definitions or venues of the vaccine concept. In medicine, a vaccine is a preparation containing weakened or dead microbes of the kind that cause a particular disease administered to stimulate the immune system, protecting the individual from future exposure. In computer science, it is a software program that protects a computer from a virus or worm infection. Both of these concepts can be extended to the behavioral realm.

With a behavioral vaccine, a person might be exposed to a weakened behavioral risk, which could stimulate a protective response to a more full-blown exposure to the social, emotional, or psychological risk. Or, a person might learn a protective program of behavior that attacks, dislodges, or protects against any exposure to a dangerous behavioral assault in the future.

Vaccines are most effective when everyone who has a risk receives a critical dose. Under such circumstances, the virus has no host population to infect. Childhood immunizations are classic cases of vaccines for a vulnerable population, with few children in developed countries now dying from scourges of the past.

A vaccine is not like treatment, the latter of which is typically given after the onset of the disease or disorder. Vaccines are typically given universally before onset.

Could certain simple-to-apply, universal behavioral interventions confer some sort of "immunity" against multiproblem behaviors such as substance abuse, juvenile delinquency, and other problems? The answer appears to be "yes." The Good Behavior Game is a good candidate to consider as a potential behavioral vaccine, and the next sections of this paper present the evidence and logic for the possibility.

The Good Behavior Game: General Theory and History

Some 100 years of solid psychological research shows that behavior varies as a function of its consequences (e.g., Catania, 1992; Malott, Whaley, & Malott, 1997). Thorndike first labeled this as the "Law of Effect" back in the early 1900s. Since that time, the observations have been codified into the most robust replicated general principles of the science of behavior such as the "Matching Law" (e.g. Herrnstein, 1970). There is a profound reason that scientists refer to this principle as a "law." It is universal, highly replicated, easily demonstrated, and parsimonious. Against this backdrop, graduate students like Harriet Barrish and Muriel Saunders and scientists like Montrose Wolf thought disruptive, disagreeable behaviors by students might happen because peers and others somehow reinforced them in school settings. Perhaps, the smiles, giggles, laughs, and even pointed taunting from other students were *reinforcing* the high rate of the behaviors that teachers found so difficult to handle or harmful to the learning process. In this context and time, the graduate students and senior scientists reasoned that some kind of group-based reward for *inhibiting* negative behavior might be a boon for classrooms. Already, there were powerful precedents for such an idea. The idea for the Good Behavior Game was born.

Behavior Analysis Studies of Good Behavior Game Demonstrate Efficacy

Applied behavior analysis (Baer, Wolf, & Risley, 1968) posits careful testing of strategies to change human behavior in context, most frequently using time-series methodologies such as reversal or multiple-baseline evaluations, which have powerful advantages in applied research (e.g., Barlow & Hersen, 1973). The initial efficacy evaluations of the Game occur in this context.

First Test of Efficacy

In 1969, Barrish et al. published the first study on the Good Behavior Game using a multiple-baseline design in a very difficult classroom. It was this class that became the first to try the Game in a controlled study. The 4th-grade children were observed during maths and reading. Trained observers coded student behavior every minute for an hour, 3 days a week for several weeks. The children were out-of-seat or

talking-out for about 80–96% of each class period, making instruction nearly impossible. Bedlam would have described the class.

The Game was played everyday during maths, with the class divided down the middle row into two teams. One or both teams could win privileges (e.g. wear victory tags, be first in lunch line, get a star on a winners' chart, earn free time) by having the lowest number of marks tallied on the board for disruptive behaviors. Teams with under 20 marks for the week earned special privileges at the end of the week.

The rate of disruptions fell immediately from about 91% to 10% in the hour, a great improvement. Meanwhile, the disruptions during reading time stayed pretty much the same.

After a few weeks, the teacher stopped playing the Game during maths but started playing it in reading. The results immediately showed the efficacy of the Game. Behavior during maths looked pretty bad again, just like the "baseline." Behavior during reading was greatly improved. After a week, the teacher played the Game during both times, and the rate of problem behavior fell quite low.

Efficacy Test of Game Components

The Good Behavior Game actually has several potentially "active ingredients" that might account for its efficacy. In 1972, Medland and Stachnik tested the good-behavior Game in a 5th-grade reading class consisting of two groups of 14 students each in a reversal design, using the class as its own control. They tested the whole game and different components to see how they worked. Game components included rules, red or green lights (response feedback using nonemotional cueing), and group consequences of extra recess and extra free time. Two observers counted talking-out, disruptive, and out-of-seat behaviors. The graphs from the study show that the total Game package reduced all the disruptive behaviors from their baseline rate by almost 99% for one group and 97% for the other. The component analysis revealed that after association in the Game, the nonemotional cueing stimuli of rules and lights were moderately effective in reducing the problem behaviors; the whole Game package was, however, most efficacious. What was particularly noteworthy was the fact that the students and teacher were able to cover 25% more academic material during the Game. This study revealed that the use of the signal light decreased bad behavior, underscoring the importance of a consistent, unemotional response or cue about bad behavior. The study also revealed that enunciation of the rules by the teacher each day had a small effect, which could explain the often reported comment by teachers that the children "need to be nagged" about the rules. Figure 2 summarizes Medland and Stachnik results.

Efficacy Test With Higher Risk Population

Children who ultimately develop multiproblem outcomes often have a special-education history (e.g.,

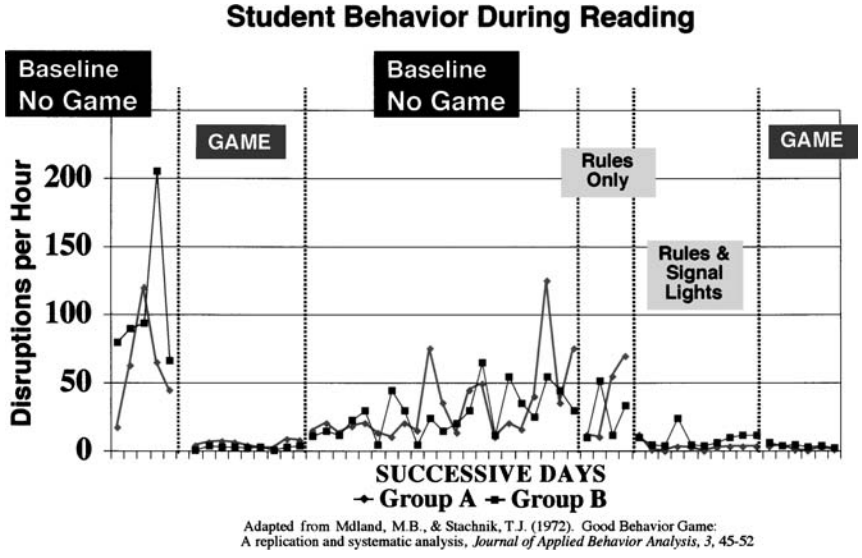

Fig. 2. Medland and Stachnik (1972) results.

Walker et al., 1995), and it would be important to demonstrate that a potential behavioral vaccine could be efficacious with such higher risk populations. Grandy, Madsen, and De Mersseman tried the Game with elementary-age special-education students in 1973 in a behavior analysis design. Again, the disruptive behaviors went way down. This study showed that the Game could generalize to a higher risk population.

Refinement of the Efficacious Components

Medland and Stachnik (1972) did not test all the salient components of the Game package, which might be crucial in understanding the active ingredients of this potential behavioral vaccine. Harris and Sherman tested the Game components in 1973, and they too found that disruptive talking and out-of-seat behavior fell dramatically in 5th- and 6th-grade students. By testing the Game in multicomponent reversal design, they allowed for a better understanding of key, effective components of the Game. Key ingredients turned out to be the division of the class into teams, positive consequences for a team winning the Game, and a low number of marks set as criteria for winning the Game. Harris and Sherman did find that reductions in negative behavior only slightly affected academic achievement, which flags the need for other research to determine whether the Game could be combined with explicit academic improvement strategies without adverse effects as teachers and schools would be likely to pursue additional components.

Efficacy Test With Young Primary School Children

In the chronology of efficacy studies, all had been focused on intermediate-level students in elementary schools. No evidence existed that it could be efficacious with younger students, which would naturally boost its potential as behavioral vaccine. Bostow and Geiger evaluated the Game's effects using a behavior analysis design on 2nd graders in 1976. Here again, it was effective, expanding the generalizability to younger ages.

Comparative Efficacy Trials for Rival Strategies

The Game is not the only school-based strategy that could be used to decrease the impulsive, disruptive, and inattentive behaviors that predict multiproblem behavior. A good candidate for a behavioral vaccine is likely to have a family of related interventions, and finding the most efficacious alternative would be logical. One of the most obvious alternative strategies is teacher attention, that is, training a teacher to pay more attention to a child's good behavior. In 1977, Warner, Miller, and Cohen compared the effects of the Game against simple teacher attention for being good among 4th and 5th graders. The Game was much more effective and simpler to use, which was important for building a case for it as a potential behavioral vaccine. Warner and colleagues also provided a key finding for social validity of the Game as a potential behavioral vaccine. As teachers often complain that they cannot praise for a variety of reasons, the differential effects of the Game met a key objection to a common recommendation of increasing praise.

The Role of Peer Pressure as Key Component

Deviant peers are clearly a risk factor in the epidemiology of multiproblem behavior (e.g., Dishion et al., 1999), and the Game historically made explicit use of peer-related variables: peer pressure, peer competition, and peer recognition via teams. Was this an important element for the Game achieving its therapeutic effects, which is important to understand for the use of the Game as a behavioral vaccine. Hegerle, Kesecker, and Couch directly replicated the Game again in 1979, but examined the efficacy of these peer-related components. They found that peer pressure, competition, and social recognition were all important components. This added to the understanding of why the Game might work. These components fit well into the notion of the matching law with peers and school systems (e.g., Dishion et al., 1996; Embry & Flannery, 1999). The matching law (Herrnstein, 1970) can be expressed as

$$B = kr/(r + re)$$

B is the behavior in question. k is a asymptotic constant and r is the rate of reinforcement of the B; this is divided by the same r plus re (the rate of reinforcement of all other behaviors. Peer pressure and competition reduce the re term, thereby making the r (social recognition) more potent for positive actions in the classroom. This author believes this matching law effect helps explain why just putting check marks up by individual children's names is far less effective than the strategy of a mark for a child's team. The

competition diminishes the re (e.g., peer attention to negative behavior), making the rewards controlled by the teacher for wining the game (e.g., the *r*) more potent.

Efficacy of the Game After Initial Training

How long might the effects of the Game last after being played briefly with no coaching from anyone outside the classroom? Johnson, Turner, and Konarski answered that question in 1978. The answer helps shape how an effective behavioral vaccine might be delivered. Among highly disruptive intermediate classrooms, they found that the effects of the Game did last but started to decay after 2 months when the "coach" stopped coming to the classroom to encourage the use of the Game. This particular study suggests, not surprisingly, that a diffusion model of the Game as behavioral vaccine might require some attention to produce longer term effects.

Efficacy of the Game Across Cultures

If the Game worked across different cultures then it might mean that the processes were very strong, profound, and universal. Such a finding would boost confidence that the Game could be a viable candidate as a behavioral vaccine. Huber reported positive results in Germany in 1979 in a behavior analysis efficacy study. Saigh and Umar (1983) found strong effects for Sudanese 2nd graders whose parents could not read or write, in a reversal design. Saigh and Umar were among the first investigators to report that the Game reduced aggression. It is interesting to note that younger children vis-a-vis older children seem to show reversal effects rather quickly, suggesting that young children will require more consistent, lengthy use of the Game. These published studies suggest that the Game can be effective in culturally diverse contexts.

Generalized Efficacy of the Game to Non-classroom Settings

Previously, all published studies had focused on the efficacy of the Game in classrooms. From a behavioral vaccine perspective, the odds for success would be strengthened if the "vaccine" could be administered in other settings where the epidemiologically relevant behaviors are manifest. In 1981, Fishbein and Wasik showed that the Game could be played in the school library and bridge to the classroom at the same time. Their study also illuminated a variable that could improve the social validity of the Game, its widespread use: A delightful twist involved having the students help set and define the rules, with no loss of effects. As almost any classroom teacher could articulate, students are more likely to "buy in" and not resist the Game, if they can help set the rules. Although the efficacy of the Game in the library is nice, bad behavior in the library is not a huge known predictor of substance abuse, violence, and other ills. In 1998, Patrick, Ward, and Crouch found that the Game could be powerfully adapted to physical education or play-type activities outside. This suggested that the Game could also be used to solve playground or recess problems—which is an epidemiologically relevant risk predictor (e.g., Walker et al., 1995).

Efficacy of the Game for Special Education Students in Regular Classrooms

A behavioral vaccine would have limited value if it could not buffer or protect a vulnerable child in a high-risk setting. Children with special education designation in regular classrooms are an example of such a risk. Did the Game work for really serious behavior-problem children who were "mainstreamed" in a regular classroom when the whole class played the Game? Yes, discovered Darveaux in 1984. She had the Game played in a classroom while observing two targeted children on each team. The two target behavior-problem children did improve when the whole class played the Game. This suggested that classroom teachers would be able to use the Game as an effective behavior management strategy for children at-risk for placement in special services.

Impact of Different Kinds of Rewards on Efficacy

Teachers typically select and apply rewards for behavior quite idiosyncratically, which could seriously impair the efficacy of the Game if significant fidelity of implementation were required for rewards for the behavioral vaccine to work. What kind of rewards work for the Game? Kosiec, Czernicki, and McLaughlin found in 1986, that students did equally well when they played the Game for activity rewards versus candy. The children did like the candy as a reward, but it

was useful to discover that activity rewards were powerful. The fact that activity rewards appear to be as powerful as material or edible rewards helps with the acceptability of the Game by teachers and school administrators, who often express dislike for material rewards.

Efficacy of the Game With Adolescents

Previous prevention research has suggested that boosters, rather like vaccine boosters, improve long-term results. Thus, it is reasonable to ask if the Game might work with adolescents. In 1986, Phillips and Christie found the Game worked quite well for intellectually impaired students whose ages ranged from 12 to 23 years. In 1989, Salend, Reynolds, and Coyle proved that the Game worked for emotionally disturbed adolescents. The older students liked the Game and stopped doing inappropriate verbalizations, inappropriate touching, negative comments, cursing, and drumming. These findings suggest that the Game could be played, possibly as a booster, with older youth.

Efficacy With Very Young Children

People often apply medications for other uses or for different age groups. It is natural to wonder if the Game might be used with very young children, which would broaden the basis for the Game as a behavioral vaccine. A special puppet helped the preschoolers learn the Game in the study by Swiezy, Matson, and Box in 1992. Some other adaptations were required, however. Special colored badges were needed by the teacher to track the preschoolers as they moved from place to place in the room.

Summary of Efficacy Studies

The early phases of science are best served by repeated measure studies such as those used in applied behavior analysis. Such studies provide a powerful, simple way of determining if the procedure has any probability of effect and helps identify how it varies based on different conditions, something not easy to do in randomized control group studies or is very very expensive. The early studies on the Good Behavior Game show it to be a very promising, robust procedure.

Social Validity Studies

A potential behavioral vaccine might be efficacious, but highly disliked by its putative users. Consumer liking of a product can obviously affect word-of-mouth, fidelity of use, and other factors that would be relevant to long-term prevention. Social validity is an important concept in large-scale behavior change, which measures (1) the social significance or importance of the goals, (2) the social appropriateness of the procedures, and (3) the social importance of the effects (Sulzer-Azaroff & Mayer, 1991). These questions are pivotal in the diffusion of any science-based practice. How does the Game measure in the field of consumer satisfaction? In 1994, Tingstrom found out that over 200 teachers did like the Game and would use it. An important signal came from that study in that teachers who did not "believe in positive reinforcement" were not as likely to adopt it, however.

Randomized Control Studies for Effectiveness of a Potential Behavioral Vaccine

The efficacy studies discussed certainly point to the utility of the Good Behavior Game in changing modifiable, meaningful, and measurable risk factors of multiproblem behavior. However, the "Gold Standard" of science is the use of random assignment to condition, especially large numbers of participants. By the late 1980s, it was apparent that the Game had strong effects and could be something to try in a large randomized trial, which happened with the Baltimore Prevention Project.

A total of 864 1st-grade students from 19 Baltimore public schools participated in the study during the 1985–86 academic year. Short-term results relied on assessments of all students in the fall and spring of 1st grade using three tools:

- The Teacher Observation of Classroom Adaptation Revised (TOCA-R)—measuring a variety of childhood developmental psychopathologies,
- The Peer Assessment Inventory (PAI)—measuring peer social networks, and
- Direct observations of student behavior by classroom observers.

The study had both control classrooms within (internal controls) and across schools (external controls), making for a more powerful but complicated study.

In Baltimore, as in the earliest versions of the Game, classes were divided into teams, which were rewarded when members behaved appropriately and participated in classroom activities rather than broke rules and fought. Three teams were created per class, with equal distributions of aggressive and shy children per team. During the first weeks of the intervention, the Good Behavior Game was played three times each week, for a period of 10 min. Over successive weeks, duration per Game period was increased by 10 min, up to a maximum of 3 hr.

What were the early results? Dolan and the other Johns Hopkins scientists made an initial report in 1993. First, both teachers and peers rated boys as more aggressive. Second, boys were seen as more shy by teachers, but not by peers. Third, the Good Behavior Game had a significant short-term impact on teacher ratings of aggressive and shy behavior for both males and females. There were some useful subfindings:

- The intervention had greater impact in reducing aggressive behavior in students who began the year with high aggressive ratings compared with students who began with low aggressive ratings—an important finding if the Game were to be viable as a potential behavioral vaccine.
- Peer nominations of aggressive behavior among boys by their classmates were also significantly reduced. Only one of the three peer nominations of shy behavior showed significant impact ("has few friends") and that was only in the case of females.
- Finally, the Good Behavior Game increased students' on task performance in the classroom as assessed through direct observations.

What were the longer term results? These are exceptionally important from a developmental perspective, because the real problems, related to early predictors such as aggression, do not show up until the adolescent years. In Baltimore, the longitudinal results were collected 6 years later. Kellam, Mayer, et al. (1998) reported that although the positive effects reported by teachers during intervention years in 1st and 2nd grades waned somewhat in the 3rd and 4th years, they reappeared in 5th grade and strengthened in 6th grade. More aggressive 1st-grade males benefited the most from the Game, with the aggression rating of over 30% significantly dropping by 6th grade. It appears, then, that the Game might function as a behavioral vaccine in a long-term study.

There were other long-term effects, not wholly predicted when the study started, strengthening the potential of the Game as a behavior vaccine for multiproblem behavior. For example, males were significantly less likely to initiate smoking (a 50% reduction in initiation rate) in the early teens (Kellam & Anthony, 1998). Teacher ratings and self-reported age at first use of tobacco showed that (1) boys who had received the Good Behavior Game intervention were rated as better-behaved than their counterparts in the other study conditions ($p < .05$), and (2) the risk of starting to smoke tobacco by age 13–14 years was substantially greater for boys in the "standard setting" control classrooms as compared to those who had spent 1st and 2nd grades in the Good Behavior Game classrooms ($p < .05$). Kellam and Anthony (1998) concluded from the long-term follow-up that targeting early risk of aggressive behavior is an important smoking prevention strategy, something that longitudinal tracking studies with no intervention had suggested but not proved. To this author's knowledge, the result published by Kellam and Anthony is the first inkling that a single classroom teaching strategy by an individual teacher might substantially reduce substance abuse, misuse, or initiation (see Fig. 3).

A whole array of publications exist on the Baltimore project, noting its theory, design, and results (e.g., Ialongo et al.,1999; Kellam et al., 2000; Kellam, Ling, et al., 1998; Kellam, Mayer, et al., 1998;[n] Kellam & Rebok, 1992; Kellam, Rebok, Ialongo, & Mayer, 1994). Kellam and associates are continuing longitudinal follow-ups of the original cohorts, which will likely reveal more information about the life-course effect of the Game on such issues as arrest, educational attainment, and other milestones. When new

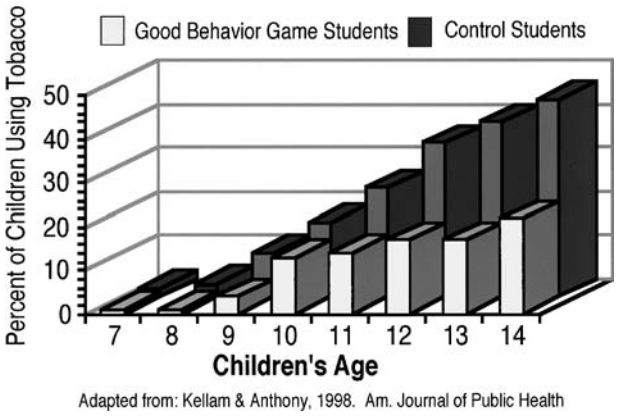

Fig. 3. Good Behavior Game impact on tobacco initiation.

medicines are introduced and approved by the Federal Drug Administration, it is rare for the approvals to cite ongoing inquiries with a decade or more long-term follow-up. Game is similarly rare in the prevention science literature, and the long-term follow-up strengthens the case for the use of the Game as a potential behavioral vaccine.

Not all reviewers concur about the value of the Game for prevention. Greenberg, Domitrovich, and Bumbarger (1999) offer a critique of Kellam's studies, observing that the intervention did not include family or the larger school ecology (which this author views as a strength, in terms of the utility of the Game as a behavior vaccine). The 1999 critique did not have the benefit of the Ialongo, Poduska, Werthamer, and Kellam (2001) study comparing the impact of combined classroom intervention (both the Game and Mastery Learning) against a Family Program, which showed that the combined classroom approach was superior to the family-only program. Greenberg and colleagues also argue that two of the primary sources of data (teachers and peers) were aware of the treatment condition and in some ways had a stake in the outcome, which may have affected internal validity. Again, the fact that these two sources of data did show change is a source of strength, considering that both peer nominations and teacher ratings are extremely resistant to *any* intervention, yet are highly predictive of serious antisocial behavior many years later (e.g., Embry & Flannery, 1999; Embry, Flannery, Vazsonyi, Powell, & Atha, 1996; Walker et al., 1995). To provide a comparison in top-rated prevention programs, Second Step (a violence prevention curriculum for elementary students) shows no impact on teacher ratings or parent ratings after a considerably more intensive classroom intervention in a randomized control group study (e.g., Grossman et al., 1997). Greenberg and colleagues review (Greenberg et al., 1999) of the Good Behavior Game erroneously reported that there had been no independent replications of the intervention, failing to cite the extensive, prior, peer reviewed studies mentioned herein while also observing that the Linking the Interests of Families and Teachers (LIFT) project incorporated the Game as part of its overall strategy.

Linking the Interests of Families and Teachers (LIFT), a prevention program designed for delivery to children and parents within the elementary school setting (e.g., Eddy, Reid, & Fetrow, 2000), worked in 12 public elementary schools with about 700 students in higher risk neighborhoods. The LIFT targets child oppositional, defiant, and socially inept behavior and parent discipline and monitoring—many of the variables targeted by Kellam and colleagues. The LIFT is (a) classroom-based child social and problem skills training, (b) playground-based behavior modification using an adaptation of the Good Behavior Game, and (c) group-delivered parent training. The results of a randomized controlled evaluation of the LIFT are reviewed. To date, during the 3 years following the program, the LIFT delayed the time that participants first became involved with antisocial peers during middle school, as well as the time to first patterned alcohol use, to first marijuana use, and to first police arrest. Reid et al. (1999) report reductions in playground aggression, with the largest effect size among the most aggressive children, as well as improvements in family problem-solving actions. At 30-month posttest, children from the treatment group were also significantly less likely to have been arrested. Microcoding of real-time playground aggression showed that intervention benefited the most aggressive children at recess with substantially high effect sizes (Stoolmiller, Eddy, & Reid, 2000).

The LIFT effort by Reid and his colleagues is noteworthy, because it is a systematic rather than direct replication of the Game, which was imbedded in a larger effort. This means that the Game can be incorporated with family and social skills interventions with no apparent adverse effects. From the perspective of a behavioral vaccine, it is vital that a strategy be able to work in combination with other strategies and still show benefit.

Awards and Recognition for the Good Behavior Game

The positive effects of the Game have been recognized by a number of sources. The Game is one of the few "universal," simple strategies identified by the Colorado Violence Prevention Blueprints Project, funded by the U.S. Centers for Disease Control, as meeting the scientific standards for a truly promising violence prevention practice. The Substance Abuse and Mental Health Administration has also identified the Game as a research-based promising practice. The Surgeon General's Report on Youth Violence (U.S. Surgeon General, 2001) lists the Good Behavior Game as a desirable practice.

These awards and recognition are all the more remarkable, because the Game is the only such intervention in the public domain, and something that an individual teacher or staff member can implement

versus a comprehensive school-wide program. The breadth of replications of the Game by so many different investigators across time only strengthens the accolades.

Support From Current Field Trials and Other Studies for Potential Behavioral Vaccine

As established in the early parts of this paper, a behavioral vaccine envisions widespread use of a procedure. The Game needs to have some evidence of real-world diffusability.

Presently, my colleagues and I are engaged in a number of trials of the Game in a larger context. These community trials are described below.

Approximately 15 schools in the Greater Cleveland area are involved in an open field trial of the Game to determine if the game can be simply packaged and trained in the course of 4–6 h. The Game is referred to here as the PAX Game to denote the inclusion of some ancillary components documented to improve compliance and classroom management such as "beat the timer," nonverbal cues for stop (see Medland & Stachnik, 1972) and transition cues for walking in hallways. Early data show that schools can implement the game, and have impact on such variables as student referrals and suspensions.

Several years ago, my colleagues and I helped Cook County Health Department in Cook County, Illinois, design a protocol to have paraprofessionals visit classrooms and teach the Game to the students and their teachers. To date, Cook County Health Department has taught numerous classrooms the Game and collected simple observational data on those classrooms. The iteration of the Game designed by the author and colleagues incorporates the identified active ingredients from the efficacy and effectiveness studies, and it has been put together in such a way to encourage the use of other research-based protocols that might round out the effectiveness of the Game.

Besides the components of teams, peer pressure, competition, activity rewards, nonemotional cues, enunciation of the rules, and group-based rewards, the iteration includes some simple procedures to help improve the social acceptability, participant buy-in, facilitate generalization, and assist the tracking of the game. Here are a few examples. The students induct the rules and vision of the class using some special lessons. They pursue productivity, peace, health, and happiness by creating PAXIS™. Things that get in the way of PAXIS, a made-up word, are called spleems™, also a made-up word. The word for the goal helps foster positive debriefs (e.g., "What did you do to create PAXIS today?"), which has been shown to assist in the generalization of self-management and is a substitute behavior for teachers to avoid negative attention. Spleems are a word designed to reduce the verbally inflected emotionality attached to noticing a rule-breaking event, a key ingredient. Conversationally, it is much less explosive to say "that was a spleem" than "you broke the rule." The PAXIS version includes many small but useful stratagems needed to package a research-based practice for diffusion—a critical factor in a bringing a potential behavioral vaccine to scale.

The new words like PAXIS and spleems help track the behavioral contagion effects of the Game, as the words are completely novel. The words are what some cultural anthropologists define as "memes"—a sort of potentially self-replicating cultural concept, again to a gene. Lynch (2001) describes a meme (pronounced "meem") as a self-spreading thought, idea, attitude, belief, or other brain-stored item of learned culture. The idea of memes are frequently used in marketing as a way to track name recognition and build up brand recognition.

The use of words for the Game such as PAXIS and spleems create a "meme" in a school setting, providing a way to assess the frequency of the use of the Game. For example, children who have played the Game in the last week are able to explain in great detail if their team received any "spleems" that week. Children who do not know what the Game is, will look quite blankly at a visitor if you ask what "spleems" their team committed yesterday. Thus, prevention specialists such as the ones in Cook County Health Department can quickly assess whether staff are really following through with the daily repetitions—a necessary element of a putative behavior vaccine. It is rather like the question, "did you floss your teeth this morning" versus "do you practice good dental hygiene?"

The teaching of the Game by Cook County paraprofessionals is the first attempt to move the Game to a behavioral vaccine model, capable of being taught outside the context of graduate students and research personnel. A sample of data from one school and classrooms in Cook County appears in Fig. 4, showing observed "spleems" over time before and after the teaching of the Game, which are very encouraging. Not all schools and classrooms have the same results.

The current effort in Cleveland and the past effort in Cook County suggest that the Game can be

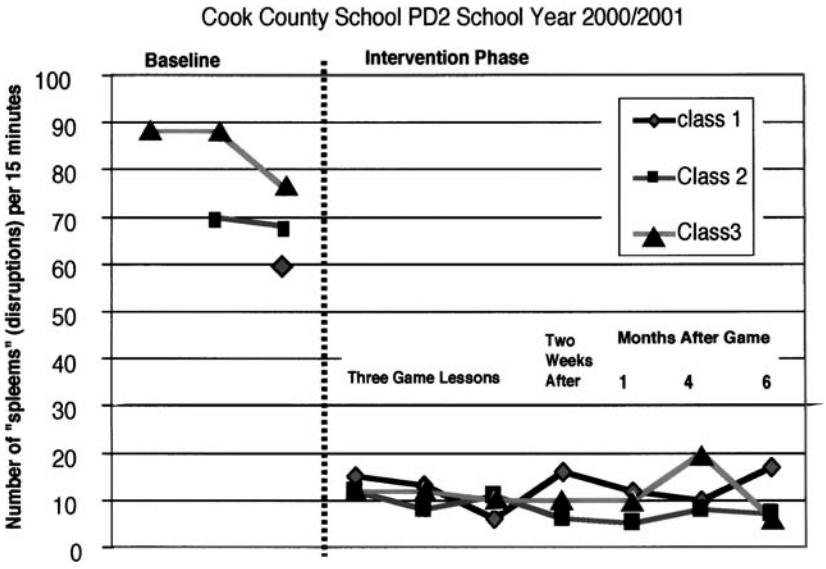

Fig. 4. Impact of Game taught by paraprofessionals.

practically disseminated in a real-world context. In the case of greater Cleveland, the Game was trained on a school site or across school sites in a brief training for teachers. In the case of the effort by Cook County, paraprofessionals learned how to implement and teach the game to many different schools in the actual classrooms. Other field trials are in place by the first author in Wyoming (a rural area with extremely high rates of substance abuse), in Tucson, AZ, with very high rates of Hispanic and Native American populations, in the multicultural context of some schools undergoing comprehensive school reform, and even in Singapore and Malaysia to assess the acceptability in very different systems and cultures.

MEDICAL RESEARCH ON INHIBITION RELATED TO A BEHAVIORAL VACCINE

Various studies implicate the problems of inhibition in the etiology of multiproblem behavior (e.g., Frick, Kuper, Silverhorn, & Cotter, 1995). For some time, it has been evident that medications, such as methylphenidate, increase inhibition and improve the kinds of behaviors studied in all of the studies on the Good Behavior Game (see Gadow, Nolan, Sverd, Sprafkin, et al., 1990). In the United States, the daily use of such stimulant medication is extremely widespread—representing a rival treatment for the risk factors that might be addressed by a behavioral vaccine.

It is documented that an effective behavior management protocol will reduce the dose need of medication (i.e., Carlson, Pelham, Milich, & Dixon, 1992). Recent reviews suggest that behavioral protocols ought to be the first line of defense for the treatment of such conditions as ADHD (e.g., Pelham & Fabiano, 2000), for a variety of legal, ethical, and practical considerations. The issue here is not whether behavioral interventions or medical interventions are better.

The fact that both medication and a powerful strategy like the Game result in inhibition of negative behavior suggests that the two techniques probably operate in similar ways in the brain. In science, this is called the Law of Parsimony or Occam's Razor. It typically means that if two things have similar effects they most likely have common causal mechanisms. In the beginning of this paper, I have hypothesized that the common factor is the inhibition circuitry of the brain, which may have been altered as a result of genetic expression, gene–environment interaction, exposure to traumatic events, coercive parenting practices, deviant peer reinforcement, or even exposure to environmental toxins such as lead. The potential mechanisms for this are becoming more apparent with various scanning technologies and reaction-time studies (e.g., Lazzaro, Gordon, Whitmont, Meares, & Clark 2001). Reaction times can be measured in two ways: go reaction and stop reaction.

Hyperactive children and children with oppositional defiant disorder compared to "normal"

children have similar "go" reaction times, but have longer stop times (e.g., Oosterlaan, Logan, & Sergeant, 1998). Methylphenidate improves children's stop times (Tannock, Schachar, Car, Chajczyk, & Logan, 1989). A study by Tannock, Schachar, and Logan shows various dose effects for stimulant medication. Pharmacologically, methylphenidate stimulates the inhibition circuitry of the brain via dopaminergic and serotonergic mechanisms. The Game creates social, activity, and primary reward for inhibition as well as a sense of belonging for inhibition—which appear to be dopamninergic and serotonergic respectively. The Game clearly and rapidly increases "stop" behavior, by rewarding it. The Game is not like most behavior programs (e.g., Kolko, Bukstein, & Barron, 1999) that reward positive behavior (e.g., social skills or attention to task); the Game rewards *not* doing things such as blurting, interrupting, getting out of seat, etc. All behavior modification is not the same in effectiveness on children with these attention or behavior problems, even with or without the use of medication (e.g., Baldwin, 1999; Northup et al., 1999). The Game is different from most behavioral protocols in that it is group based, decreases peer reinforcement for antisocial behaviors, and provides yoked individual and group rewards. The use of rewards for attention or positive behavior for individual behavior does not seem to have the same power compared with medication (e.g., Solanto, Wender, & Bartell, 1997). The fact that this simple Game can have profound long-term effects on the "stop circuitry" is very promising from a putative medical explanation of it as a potential behavioral vaccine.

MAKING THE GAME INTO A UNIVERSAL BEHAVIORAL VACCINE

Good research and best practices do not necessarily translate into public benefit. An effective behavioral vaccine must overcome a number of barriers. First, policymakers must be sold on the idea. Second, the vaccine must be appropriately packaged for delivery. Third, the vaccine must have appropriate infrastructure to support diffusion and practice. Fourth, regulations, policies, and even laws may need to change to support the distribution of a behavioral vaccine. Fifth, current practitioners may need enticement to change. It is wise to note that it took some 80 years to make the practice of antiseptic hand washing common practice. Figure 5 summarizes what is required to create a system for a universal behavioral vaccine.

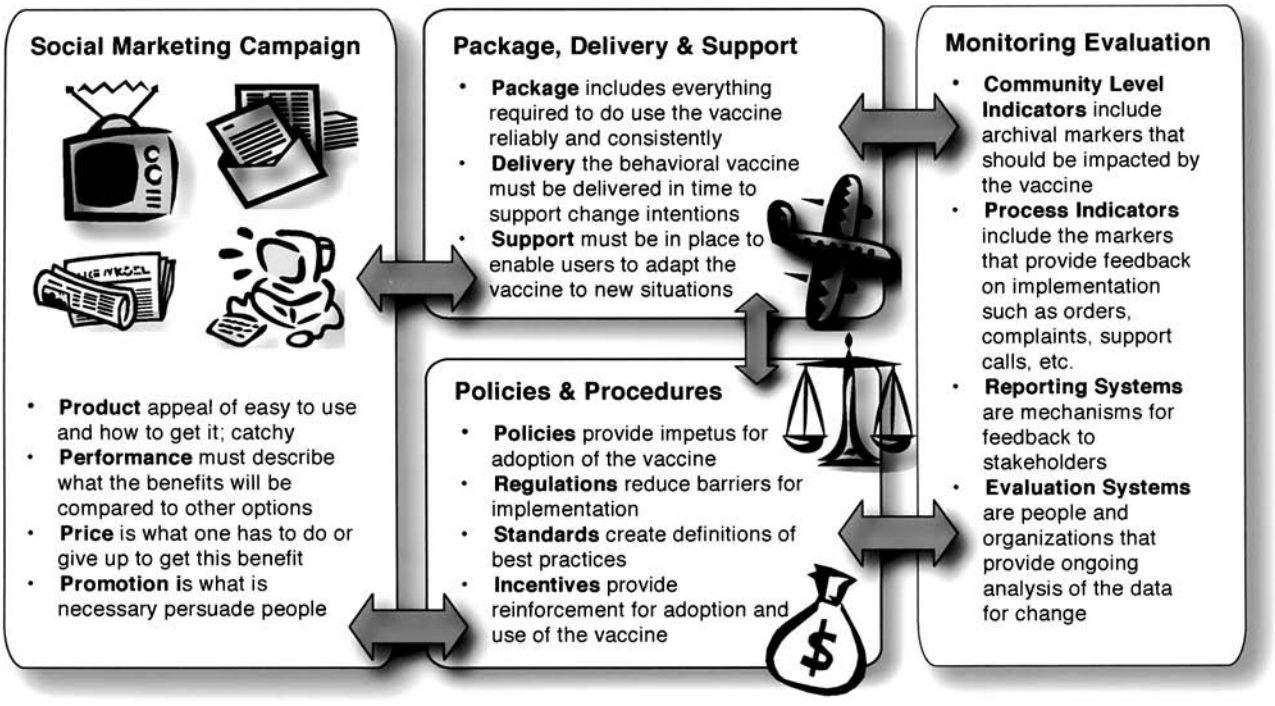

Fig. 5. System diagram for behavioral vaccine.

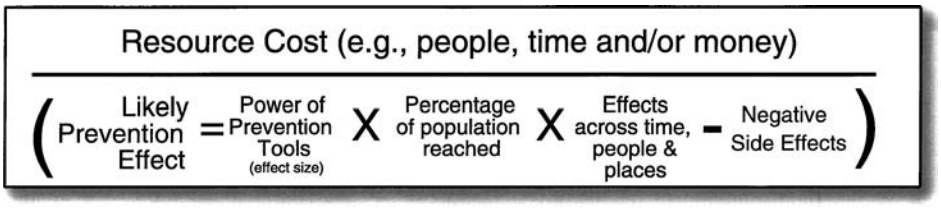

Fig. 6. Cost-effectiveness formula.

"Selling" the Game to Policymakers

Proven practices can take decades to become common practice, with many lives in forfeit as a consequence. A public-health model of prevention envisions that most effective practices must be universal for positive effect. This can be seen in a formula shown in Fig. 6. For a behavioral vaccine to work, the formula requires that the resource cost per participant be low, the effects potent, and the reach of the strategy be wide and long-lasting with few adverse side effects.

The Game works potentially well in this formula. The costs of implementation are low compared to other alternatives. The comparison between several alternatives illustrates the point. These types of data are crucial for selling state policymakers on the benefits of a behavioral vaccine.

Medication costs about $70 per child per month, plus medical supervision. Just 10 children in a school will cost at least $7,000 per year. Long-term positive results of medication are not well documented by comparison. Trademarked interventions such as Second Step, which are highly rated or extolled, have little or no impact on aggression in the classroom (e.g., Grossman et al., 1997), yet may cost at least $10,000 per school to use. (Note: this is not an exhaustive analysis of all the rival strategies).

Measures of lifetime prevention benefits are microscopic from a mathematical perspective at the time of this writing. Favorite strategies such as character education, peer mediation, conflict mediation, or police officers on campus have little or no effect size impact at this writing, though future studies or publications might change that. The fact that the Game might only cost a few hundred dollars per classroom to implement and reduce placement in special services represents an immediate cost savings; its long-term cost-effectiveness becomes even more impressive. For example, the long-term effects on reduced special education and correctional expenditures from the use of the Game are calculable and mind-boggling. Here are a just a few of the implications of the Game, if used widely in primary grades, on projections of public expenditures in a decade, for Wyoming—a state with the smallest population of all the 50 states yet with very high rates of multiproblem behavior that merit prevention. Why the example of Wyoming? Having just completed an extremely detailed blueprint for prevention of substance abuse in Wyoming (Embry & McDaniel, 2001), the author has easy access to state budget numbers.

- A 5% reduction in special education placement, not improbable based on the results from the Baltimore Prevention Project, could potentially save $2–4 million dollars per year—which has grown from $50 million to $83 million per budget period.
- A 2% reduction in involvement with corrections, not excessive based on the Baltimore Prevention Project, might yield at least $3–10 million per year in projected savings based on an analysis of growth in arrests of juveniles for serious drug arrests by the Wyoming Statistical Analysis Center at the University of Wyoming.
- A 4% reduction in lifetime prevalence of tobacco use, again not improbable from the Baltimore Prevention Project, could save the state millions of dollars per year in deferred medical costs associated with tobacco-related diseases based on cost data calculated by the U.S. Centers for Disease Control and Prevention for the state of Wyoming.

These savings from a prevention-effect sum to something like $15–20 million per year over time in Wyoming. What might be the cost of the prevention effort? There are about 5,000 1st and 2nd graders in Wyoming total. If the Game cost $200 per child per year to implement in those grades, the annual cost of implementation would run about $1,000,000 per year and thereafter. Breakeven would occur in about 3–5 years against special-education expenses, and the lifetime savings of the prevention effort would provide even stronger cost-savings.

Packaging of a Behavioral Vaccine

Public health models versus disease or disorder models envision universal coverage. To achieve the large-scale prevention or vaccine effect from something like the Game, it will be necessary to solve a number of problems for widespread social marketing:

1. *Make the research-based prevention strategies easy to use in the real world*. The public-domain protocols for the Game are not easy to use or understand. During the past 2 years, the author and colleagues have been conducting open trials on exactly this concern. For example, we have found it necessary to build in simple behavioral cueing strategies to improve effectiveness (e.g., Posavac, Sheridan, & Posavac, 1999), because many new teachers do not know these strategies.
2. *Increase social acceptability of the science-based intervention.* Unless large numbers of people adopt or participate in the strategy, the prevention effect will be small. It has been over 30 years since the Game was first invented, and very few classrooms use it nationally. Although the underlying principles are rock solid scientifically, they do require some social marketing elements. The emphatic behavioral language of the original research manual used by Kellam is potentially off-putting to many who typically have little exposure to such language, witnessed by the fact that strong behavioral concepts can impair adoption (e.g., Tingstrom, 1994).
3. *Integrate interventions for more difficult children in the front end*. Although the Game has powerful effects for aggressive children, staff typically voice worry about the children who are seen as the "worst kid ever." Having some front-end strategies for staff to use with such children when introducing the Game or "customizing it" could provide a greater confidence for the adoption of the Game as a sound practice. Explicit links need to be built in for more intensive clinical interventions for children who require higher doses of intervention such as in classroom behavioral coaching (e.g., Kotkin, 1998). Providing explicit components for higher risk young people would also minimize the chance that local innovations might combine to produce adverse effects.
4. *Strengthen linkages to other science-based strategies*. The Game has excellent results in reducing aggression and disruptive behaviors. This is good but not good enough. For example, the reduction in problem behavior only modestly translates into improvements in academic performance, unless there are other strategies introduced. The decline in problem behavior sets the stage for potent academic interventions such as class-wide peer tutoring (e.g., Greenwood, Terry, Utley, & Montagna, 1993), peer-assisted learning (e.g., Mathes, Howard, Allen, & Fuchs, 1998), or cooperative learning (e.g., Slavin, 1992). Presently, the author and colleagues have been conducting pilot efforts on such integration, combining several strategies. Although Kellam and colleagues originally tested both the Game and Mastery Learning singly and in combination, we found Mastery Learning simply not possible to implement in the current conditions of U.S. schools. Adoption and use of the Game as a daily practice would seem to be hypothetically better (and testable) if linked explicitly with some compatible empirically driven strategies that also improved academics.
5. *Address common barriers for adoption*. A well-proven science-based strategy can elicit many practical, emotional, or logistical barriers. The private sector typically responds to such issues by figuring out how to remove barriers to purchase or adoption, which is not always the case in the public sector. Current field trials have identified some significant barriers to adoption of the Game as a behavioral vaccine. Each barrier has testable potential solutions. Barriers and potential solutions follow:
   - *Restricted staff development time*. Some states or local districts now only have a few days available for any staff development. Mass media, Internet, and other approaches might help resolve this barrier. Mini demonstrations might be another mechanism.
   - *Competing demands for staff development time*. Major federal, state, or local initiatives with funding contingencies or political consequences attached tend to compete for staff

development time. Part of the promotional elements need to test whether putative linkages to these other demands improves adoption and diffusion.

- *Existing activities or procedures that might be threatened by the Game*. The doctors of Vienna did not welcome the innovation by Semmelweiss, despite its scientific logic. Classically, innovations like the Game appeal to the "innovators" or "early adopters" in diffusion models (e.g., Rodgers, 1995)—

  but not if framed as bureaucratic mandate

  and especially if the innovators or early adopters have developed something from their own time investment, while the developers of science-based protocols diminish the potential for the practices developed by the innovators. Again, marketing appeals to different types of people on the wave of adoption postulated by Rodgers needs to be tested.
- Perceived as overwhelming by staff who may be experiencing depression or burnout. Different models of delivery need to be tested to determine how the Game or any school-based behavioral vaccine might be diffused in school settings where depression or burnout are common. (This problem cannot be underestimated. I have been shown tightly held data from various districts, suggesting that antidepressant medication use is one of the highest cost centers in their health plans—which needs to be verified in a national study.)
- Beliefs about causation that reinforce inaction (e.g., "we can't do anything until the families change"). In general, marketing research suggests that testimonial-based promotions would be effective in overcoming this barrier, yet this is not the way that science-based practices are typically promoted.
- A belief that children should not be reinforced for behavior, because of such popular books as *Punished by Rewards* (Kohn, 1993). The belief is surprisingly widespread based on the number of objections and comments I get in seminars, and already identified as a significant barrier to adoption in prior research (Tingstrom, 1994). Changing this belief and related behaviors needs to be experimental tested.

Infrastructure for a Behavioral Vaccine

All materials have to be manualized and standardized in ways compatible with current issues and concerns of potential stakeholders. The original research manuals and publications are typically not standardized. After that, a considerable amount of infrastructure must be created to support the rapid dissemination of a behavioral vaccine.

1. Training strategies must be developed that can be sustained in diverse settings and organizations. If trainers with advanced degrees, certain professional qualifications, or job titles can only successfully diffuse a strategy, then the diffusion will be inherently limited. The training capacity depends on extensive documentation, support materials, "error proof" instructions, and extensive flexibility to deal with diverse objections and problems likely to happen in the field. The materials from research projects do not typically meet these criteria.
2. Implementation strategies must include ways to reduce backfires, increase fidelity of implementation, and facilitate generalization across time, people, and places. These issues are not typically addressed in research studies. At the same time, the implementation strategies must encourage principle-driven innovation and adaptation, as this author has found an inverted U-shaped curve in past large-scale studies of the diffusion of behavioral explicit prevention strategies in school settings (e.g., Embry & Malfetti, 1982). That is, poor fidelity produced the worst results, modest levels of fidelity produced the best results, and high levels of fidelity also produced poor results. What seems to happen with medium level of fidelity, based on my observation, is that people are more focused on behavior change, adjusting their actions to produce result. Very high fidelity seems to be driven by adherence to process ("by the book"), which may not respond to poor behavioral outcomes. How to structure this kind of principle-driven implementation and adaptation in the context of fidelity of implementation is also a question that needs experimental testing in the field of behavioral science to further the diffusion of any behavioral vaccine.

3. Strategies and incentives will be required to help organizations and individuals adopt the Game as an innovation. A good idea is not enough. Local service providers for example may be wedded to their particular program or approach, which may or may not have scientific or empirical validity. Interestingly, research on other behavior approaches shows the power of incentives or other organizational strategies for increasing adoption, which is evident from long-term research initiated by Denise Gottfredson (e.g., 1988) on delinquency prevention or from the experimental analysis studies on the use of seat belts or car seats.
4. The entire package or approach must be able to ramp up to very large scale, which requires distribution, marketing, and technical support. The package or program must be sustainable in different cultural contexts. These issues have not been previously addressed as fully as they need to be but can be in the context of large-scale diffusion.
5. An entire marketing campaign must be created to encourage adoption and use, and such a campaign must have sufficient reach and exposure for effectiveness. Such campaigns are rare except by commercial products with high profitability, like prescription drugs. Marketing campaigns might test such variables as inquiries to obtain a kit, recruitment success for workshop participation, early use after training, and word-of-mouth marketing effects as a result of such campaigns.

Policies to Support a Behavioral Vaccine

Many policy issues need attention to make something like the Good Behavior Game a universal behavioral vaccine. I list a few, which have emerged in the past 2 years of field trials and state policy development work:

1. State Departments of Health need to be directed by the Governor, the Legislature, or both to implement behavioral vaccines. This might be achieved through the vehicle of the various federally mandated Governor's Advisory Boards for Title IV Safe and Drug Free Communities, the Juvenile Justice Board, etc.
2. Federal block grant funds such as Title IV to schools, juvenile justice, maternal health, and other such funds need to be consolidated by executive order to support statewide behavioral vaccines instead of Balkanized efforts so that a universal approach is justified and leveraged.
3. State Departments of Health, and Departments of Education or Public Instruction, Family or Child Services need to issue combined standards of prevention and early intervention that support a public-health approach to behavioral vaccines.
4. Legislatures may need to pass special legislation that allows governmental departments or "quangos" (quasi-governmental agencies) to mix public money and marketing funds from the private sector (sponsors) to support behavioral vaccines, so that incentives and other considerations may be undertaken.
5. State Medicaid provisions often need to be clarified so that qualifying practitioners might write a prescription for the behavioral vaccine and be appropriately reimbursed. Such provisions would allow, for example, a general practitioner to write a behavior prescription for something like the Good Behavior Game for a child's classroom, have the "prescription" paid for by Medicaid, and be reimbursed for the consult or follow-up. Presently, incentives only work for a general practitioner to write prescriptions for such things as medication for behavioral disorders, never to prescribe something like a behavioral intervention that must be purchased.
6. State Departments of Education or Public Instruction need to issue policies or procedures naming research procedures like the Game as desirable procedures for inclusion or mainstreaming of children with individual education plans (IEP's) or Section 504 Rehabilitation Plans.
7. The State Departments of Education or Public Instruction in conjunction with the State Attorney Generals may need to clarify that the public posting of team points for the Game does not violate the Family Educational Rights and Privacy Act (FERPA) regulations.

Monitoring and Evaluating the Impact of a Behavioral Vaccine

Most behavioral scientists conduct controlled experiments, typically seeking an effort with high internal validity. A behavioral vaccine, by nature, seeks to have broad community level impact—to decrease the population level indices. Public accountability as well as marketing of the vaccine also gains from high-quality monitoring.

The monitoring and evaluation might proceed with some of the following:

1. Extensive monitoring of the uptake and rates of the behavioral vaccine will be required, such as the number of Game kits requested, reusable supplies ordered (a proxy measure for fidelity), school entries in community competitions using the game, or other such markers.
2. Monitoring of archival records such as per capita rates of Schedule II medications used for treatment of disorders typically targeted by the Game collected from the state pharmacy board, Medicaid, or the local health care providers; nurses' office visits for medicine checks; etc.
3. The State Department of Health might use a standardized tool such as Strengths and Difficulties Questionnaire (Goodman, 1997), which is a brief, clinically normed instrument that compares well to the Child Behavior Checklist (e.g., Goodman & Scott, 1999) to monitor prevalence rates of key *DSM-IV* diagnoses at school enrollment, public health visits, etc.
4. A consortium of federal, state, or private groups should undertake a longitudinal sample to follow for exposure to the Game, examining the impact of the Game interacting with known polygenic cofactors predicting multiproblem behavior such as various alleles of the dopamine receptors and transporters, using such tools as buccal smears and SNP analyses (e.g., Comings et al., 2000). Such a longitudinal study might be augmented by other physiological measures that are known to be correlated with outcomes, such as heart rate and brain activity (e.g., Raine et al., 1997). Such a study would help answer some of the hypothesized interactions of behavioral outcomes between environment and polygenic mechanisms from an experimental way instead of just a correlational perspective.
5. The synergy of different types of behavior vaccines needs to be tested, because multiproblem behavior has multiple vectors (e.g., parenting) that might be ameliorated by research-based protocols for parenting that can be delivered in multiple contexts or levels with prospects of success (e.g., Sanders, 1999). It is quite conceivable that certain combinations of behavioral vaccines might confer considerable "resistance to" adverse developmental outcomes such as substance abuse, delinquency, and school failure.

The practicalities of a public-health level implementation make it difficult to have classic randomized-control group study. Several possibilities do exist to provide some element of control such as a multiple baseline across communities or age groups. Over time, epidemiological monitoring such as the commonly used Youth Risk Behavior Survey (Centers for Disease Control and Prevention, 2000) might be used to measure the longer-term impact of exposure to the Game in elementary school, by matching grade school and classroom exposure to the Game or other interventions, and the avoidance of multiproblem outcomes in a dose–response-type quasi-experimental paradigm.

The idea of behavioral vaccines—simple actions that can be repeated by nearly everyone on a daily basis with positive health effects—has face validity from the public health model. Antiseptic hand washing is a powerful example, and there have been other examples in very recent history such as seat-belt and car-seat use. The concept of a universal behavioral vaccine has intuitive appeal based on epidemiological and intervention studies of multiproblem behavior such as substance abuse, delinquency, violence, and other ills. Epidemiological studies of mutliproblem behavior suggest that there are apparent behaviors (e.g., early disruptiveness) that could be modified and reduce the future occurrence of the adverse outcomes. A behavioral vaccine for multiproblem behavior would have to be low cost, easy to use, have powerful effects, and be capable of wide distribution across the target population. A potential candidate for a behavioral vaccine against multiproblem behavior would have to have a strong history of efficacy and effectiveness studies, and be adaptable to many different circumstances. The Good Behavior Game, first reported by Barrish et al. (1969) represents a strong

candidate for a behavioral vaccine, because of the simplicity and multiple replications of positive results in efficacy studies with strong long-term results in effectiveness trials. Early field replications suggest that the Game can be used in very diverse circumstances. Large-scale testing of the Game as a behavioral vaccine could provide a rich source of theory building for the diffusion of science-based prevention practices, because the Game is rare in having measurable effects based on a single classroom instead of schoolwide adoption. Against the common practice of encouraging communities to engage in an elaborate processes of prevention logic models or the abnegation of powerful behavioral vaccines used across the country or states could substantially improve developmental outcomes, benefit many diverse stakeholders, and save substantial sums of government expenditures at scale.

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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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