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BIAS AND UNDERMATCHING IN DELINQUENT BOYS' VERBAL BEHAVIOR AS A FUNCTION OF THEIR LEVEL OF DEVIANCE

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Eighty-one 13- to 14-year-old boys at risk for delinquency (target boys) engaged in brief dyadic conversations with their peer friends. The target boys' verbal behavior was coded into two mutually exclusive content categories, rule-break talk and normative talk. Positive social responses from peer boys for each category of talk were also recorded, and were presumed to reinforce the target boys' verbal behavior. A measure of child deviance was available for each target boy. The generalized matching law was fitted to the target boys' response and time allocation data and provided an excellent description of their verbal behavior, with an expected degree of undermatching and strong bias in favor of normative talk. When the boys' data were separated into groups of increasing child deviance, the matching law continued to provide an excellent description of the boys' verbal behavior regardless of their level of deviance, but undermatching became more severe and bias favoring normative talk became less strong as child deviance increased. Based on a selectionist theory of adaptive behavior dynamics from the basic science, it was suggested that the increasing degree of undermatching might be due to a decline in the reinforcing value of positive social responses with increasing child deviance. It was also suggested that the trend in the bias parameters might be due to different histories of reinforcement and punishment of rule-break and normative behavior for boys characterized by different levels of child deviance.

Key words: generalized matching law, verbal behavior, antisocial behavior, juvenile delinquency

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Researchers studying the development and maintenance of aggressive, antisocial, and delinquent behavior in children and adolescents have often considered their findings in light of matching theory (e.g., Snyder & Patterson, 1995). An approximate statement of matching theory is that organisms allocate their behavior to concurrently available response alternatives in the same proportion that reinforcers are received from those alternatives. Herrnstein (1961) expressed this statement algebraically for the simplest case of two concurrently available response alternatives as

$$\frac{B_1}{B_1 + B_2} = \frac{r_1}{r_1 + r_2}, \qquad (1)$$

where the *B*s represent response rates or times spent responding (Baum & Rachlin, 1969), the *r*s represent reinforcement rates, and the numerical subscripts refer to the two response alternatives. It is now well known that Equation 1 is only approximately correct and has been superseded by what is sometimes referred to as the generalized matching law, or as power function matching (McDowell, 1989), which can be written in a proportional form analogous to Equation 1,

$$\frac{B_1}{B_1 + B_2} = \frac{br_1^a}{br_1^a + r_2^a}, \qquad (2)$$

or, as is more common, in an equivalent ratio form,

$$\frac{B_1}{B_2} = b\left(\frac{r_1}{r_2}\right)^a, \qquad (3)$$

where the parameters, *a* and *b*, appear in both forms. Equations 2 and 3 are algebraically equivalent, which is to say that they are different forms of the same equation. For example, Equation 3 can be obtained from Equation 2 by taking the reciprocal of Equation 2, separating terms, subtracting one from both sides, and then taking the reciprocal of the result. Equation 3 has been extensively tested and, unlike Equation 1, has robustly resisted disconfirmation (McDowell, 1989).

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Until very recently the parameters of Equations 2 and 3 have been ignored in developmental research on antisocial and delinquent behavior. The purpose of the present article is to examine how these parameters characterize the verbal behavior of a sample of antisocial 13- and 14-year-old boys engaged in dyadic conversations with their peers, as a function of the boys' level of deviant behavior in their natural environments. Before discussing the data and analyses, the relevant developmental research on antisocial behavior will be reviewed, followed by a brief discussion of the effects and meanings of the parameters in Equations 2 and 3.

Matching Theory in Developmental Research on Antisocial Behavior

Patterson and his colleagues (Patterson, 1982; Patterson, Reid, & Dishion, 1992) have repeatedly found that negative reinforcement, which is often referred to as coercion in this literature, plays an important role in the development and maintenance of aggressive and antisocial behavior in children. Snyder and Patterson (1995), for example, found that 4- to 5-year old boys' aggressive behavior in interactions with their mothers was maintained by the termination of maternal behavior that otherwise would have caused conflict to continue, such as a demand for compliance. They also reported a positive correlation between the relative frequency (proportion) of the boys' aggressive behavior and the relative frequency (proportion) of maternal negative reinforcement for the behavior, which they interpreted as being consistent with the matching law. Notice that data described by either Equation 1 or Equation 2 will show a positive correlation between response and reinforcement proportions.

Snyder, Schrepferman, and St. Peter (1997) replicated Snyder and Patterson's (1995) findings with 6- to 13-year-old boys, and again found a positive correlation between the relative frequencies of responding and negative reinforcement, and again concluded that their results were consistent with matching theory. They also extended Snyder and Patterson's findings to interactions between siblings, and further found that negative reinforcement of the boys' aggressive behavior was significantly associated with their antisocial behavior 2 years later, as indicated by placements out of the home, arrests, and disciplinary incidents in school. Snyder and Patterson concluded that "the coercion [negative reinforcement]/matching model…offers a rich and complex picture of social reinforcement of aggression in the natural environment (p. 388)."

Patterson and his colleagues have discussed the developmental trajectory of antisocial behavior from preschool age to early adulthood (Dishion, French, & Patterson, 1995) and have proposed stages in this development (Patterson et al., 1992). Early, preschool, stages appear to be well characterized by the "coercion [negative reinforcement]/matching model." As antisocial boys enter school, their well developed repertoires of aggressive behavior are likely to be met with consequences similar to those at home, namely, termination of aversive stimuli (e.g., demands) from peers and teachers, and hence their aggressive behavior may be maintained and perhaps further developed in the school environment by negative reinforcement. At the same time, an important new source of social influence, interactions with peers, comes to bear at this stage of development. Peer interactions and their contribution to the development and maintenance of antisocial behavior have been studied extensively by Patterson, Snyder, and their colleagues, and have been described as consistent with the matching law (e.g., Snyder, West, Stockemer, Gibbons, & Amquist-Parks, 1996). In a study that included a longitudinal component, Snyder, Horsch, and Childs (1997) found that, for aggressive and nonaggressive 4- to 5-year old boys and girls, the proportion of time allocated to interactions with various peers was correlated with the proportion of positive social consequences that were delivered during those interactions, a finding that the authors noted was consistent with the matching law. Snyder et al. (1997) also found that children tended to associate with others who were similar to themselves in degree of aggressiveness, and that children who associated substantially with aggressive peers showed increased aggressive behavior 3 months later, as indicated by both behavioral observations and teacher reports. This finding, together with Snyder, Schrepferman, and St. Peter's (1997) longitudinal finding, suggest that aggressive, antisocial, and delinquent behaviors may be forged in children's interactions with parents, siblings, and peers. Dishion, Spracklen, Andrews, and Patterson (1996) have referred to this as ''deviancy training.''

Dishion, Andrews, and Crosby (1995) and Dishion, et al. (1996) studied in greater detail the peer interactions of antisocial 13- and 14-year-old boys participating in the Oregon Youth Study (OYS) (Capaldi & Patterson, 1987; Patterson, Reid, & Dishion, 1992). Dishion, et al. (1996) coded the boys' verbal behavior into mutually exclusive ''rule-break'' and ''normative'' content categories, where rule-break talk involved the violation of legal or social norms, and normative talk did not. Peer responses to these categories of verbal behavior were also coded, either as ''positive social'' or as ''other''. They treated the dyad, rather than the behavior of individual boys, as the unit of analysis, and found a correlation between the proportion of rule-break talk in the dyad and the proportion of positive social responses the dyad provided for rule-break talk. They noted that this finding was consistent with the matching law. Importantly, they also found that positive social reinforcement for rule-break talk, that is, deviancy training, in these antisocial dyads was related to the boys' self-reported delinquent behavior in the ensuing two years. This supports the authors' contention that these types of interactions constitute training in antisocial behavior, and it is also consistent with the longitudinal findings of Snyder, Schrepferman, and St. Peter (1997) and Snyder, Horsch, and Childs (1997). In a related study of boys' substance use, Dishion, Capaldi, Spracklen, and Li (1995) found that a similar kind of verbal deviancy training in peer interactions was associated with subsequent escalation of tobacco, alcohol, and marijuana use. In addition, Dishion and Andrews (1995) found that when at-risk adolescents were randomly assigned to groups with other at-risk adolescents, their problem behavior and tobacco use increased, implying again that deviancy training in the peer interactions was at work.

Overall, this developmental research has shown (1) that negative social reinforcement, operating in a manner that may be consistent with the matching law, maintains aggressive behavior in children's interactions with parents and siblings, (2) that positive social reinforcement, also operating in a manner that may be consistent with the matching law, maintains antisocial peer interactions in general, and antisocial verbal behavior in particular, and (3) that these interactions with parents, siblings, and peers are related to antisocial and delinquent behavior in the youths' natural environments. It is especially noteworthy that all of the research reviewed here involved naturally occurring social behavior and reinforcement in unengineered environments, that is, environments where no contingencies were imposed by the experimenters.

One weakness of this body of research is that its assertions about the matching law are based only on correlations between response or time allocation proportions and reinforcement proportions. In particular, no equation was fitted to the data in this literature, and hence no information about the expected superiority of Equations 2 and 3 over Equation 1, or about how the parameters in Equations 2 and 3 characterize behavior, is available. We turn now to a brief explanation of the parameters of Equations 2 and 3.

The Parameters of the Generalized Matching Law

The parameter, a, in Equations 2 and 3 reflects what is sometimes referred to as the sensitivity of behavior to reinforcement allocation. Values of a that are typically found in laboratory experiments are less than one (Baum, 1974, 1979; Wearden & Burgess, 1982), which indicates a degree of insensitivity to reinforcement allocation. This is usually referred to as undermatching and is illustrated in the top panel of Figure 1. The solid diagonal is a plot of Equation 1; the dashed curve is a plot of Equation 2 with $a = 0.8$ and $b = 1$. Notice that when $b = 1$, this parameter effectively drops out of the equation. The value of the exponent, a, typically found in laboratory experiments with vertebrate species, including humans, varies around a value of about 0.8 (Baum, 1974, 1979; Wearden & Burgess, 1982), indicating a relatively small degree of undermatching.

The parameter, b, in Equations 2 and 3 is usually referred to as bias. It takes on values other than unity when one of the concurrently available alternatives is preferred over and above the preference produced by the difference in reinforcement rates associated with the two alternatives. In the simplest two-alternative environment, this preference, which is constant across changes in the allocation of reinforcement, may be due to a

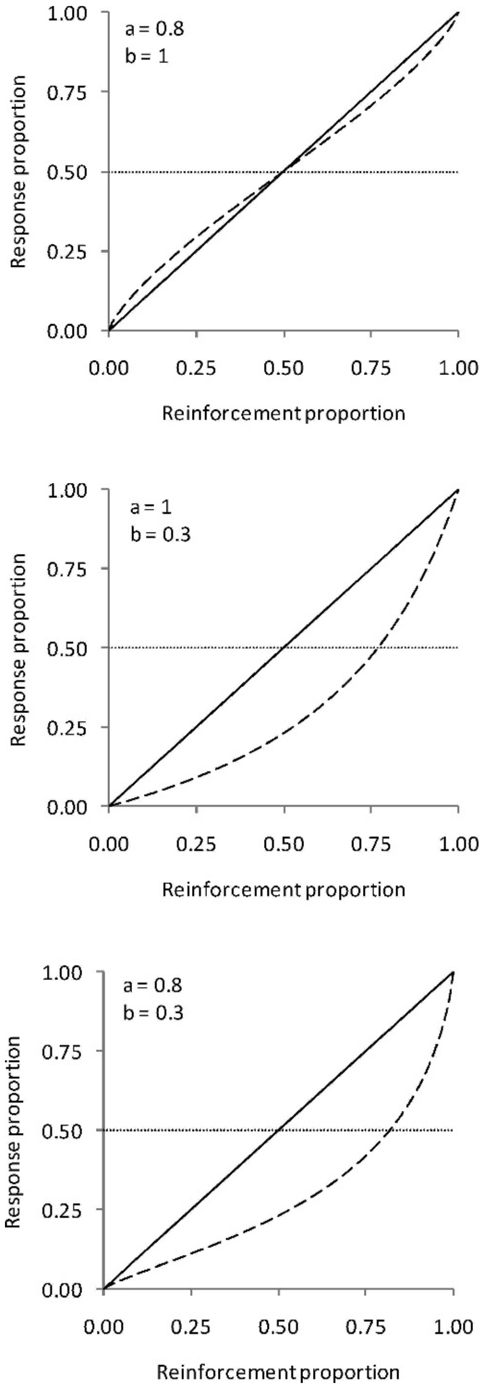

Fig. 1. Plots of Equation 1 (solid lines in all panels) and Equation 2 (dashed line in all panels) with the values of a and b for the latter plots given in each panel. The dotted horizontal lines represent complete behavioral indifference to reinforcement allocation.

preference for one behavior over the other, one reinforcer over the other, or for any other difference between the alternatives other than the reinforcement rate difference. Bias is illustrated in the center panel of Figure 1, where again the solid diagonal is a plot of Equation 1 and the dashed curve is a plot of Equation 2 with $b = 0.3$ and $a = 1$. The parameter, a, effectively drops out of Equations 2 and 3 at this value. When $b < 1$, bias favors the second alternative in Equations 2 and 3. When $b > 1$, bias favors the first alternative. Evidently, a bias in favor of the second alternative in a two-alternative environment causes the response or time proportion to bow below the plot of Equation 1. A bias in favor of the first alternative causes the response or time proportion to bow above the diagonal. Furthermore, the greater the bias—that is, the greater the departure of b from one—the greater the bow away from the diagonal.

In many experiments, there will be both bias and undermatching. Their combination is illustrated by the dashed curve in the bottom panel of Figure 1, for which $a = 0.8$ and $b = 0.3$. This curve looks much like the dashed curve in the center panel, but notice that it is pulled a bit higher at reinforcement proportions below .5, due to the added effect of undermatching, and is pulled a bit lower at reinforcement proportions above .5, again because of the added contribution of undermatching.

The Present Study

McDowell and Caron (2010) improved on the existing literature on the development of antisocial behavior by fitting Equation 3 and two related equations of matching theory to the OYS verbal behavior data from delinquent boys and their peer friends (Dishion et al., 1996). They found that the equations of matching theory accurately described the rule-break vs. normative talk of these boys. Equation 3 accounted for between 87% and 97% of the variance in response rate and time allocation ratios averaged across subjects in two OYS samples of target boys and their peer friends. For the averaged data, exponents, a, of about 0.7 were obtained from the fits, which are close to the value of about 0.8 that is expected on the basis of laboratory research. Bias parameters, b, of about 0.4, were obtained from the fits (rates and time allocations of rule-break talk appeared in the numerators of the behavior ratios), indicating, interestingly, a strong bias in favor of normative talk. Finally, McDowell and Caron found that the residuals left by the least-squares fits of the equations were random. These results improved upon earlier findings by showing that the naturally occurring verbal behavior of the boys in the OYS samples was governed specifically by the equations of matching theory.

The present study further analyzed a subset of the OYS verbal-behavior data. Each target boy in one of the samples (referred to as n4 in McDowell and Caron, 2010) was measured on a composite variable called child deviance (Dishion et al., 1996). The child deviance variable was used to separate this subsample into groups of boys with different levels of deviant behavior in their home, school, and neighborhood environments, and then Equation 3 was fitted separately to the data at each level of deviance. This made it possible to determine whether the matching law (Equation 3) described the verbal behavior of these boys regardless of level of deviance, and how the parameters of Equation 3 were related to their level of deviance.

METHOD

All procedures described in this section, including the coding of videotapes, were conducted by researchers at the Oregon Social Learning Center (OSLC).

Participants

The participants were eighty-one 13- to 14-year-old boys participating in the second wave of the fifth phase of the longitudinal Oregon Youth Study (OYS; Capaldi & Patterson, 1987), plus 81 similarly-aged male friends who served as their partners. Each pair thus consisted of one target child from the OYS and a friend of his, the peer child, who participated in this portion of the study only. The target boys had been recruited for the OYS at ages 9 and 10 in two waves during 1983 and 1984 from 10 elementary schools in high-crime neighborhoods of a medium-sized city in the northwestern United States. These boys were considered to be at risk for juvenile delinquency because they came from neighborhoods with higher than average rates of juvenile delinquency. The resulting samples were 90% European American, of lower socioeconomic status, and with a relatively high percentage of unemployed parents. The peer boys were selected by asking each target boy and his parents to name the male friend with whom the target child spent the most time.

Procedure

During the first four phases of the OYS, the target boys and their parents completed various surveys and experimental tasks on multiple occasions at the OSLC. During each wave of the fifth phase, each pair of boys participated in a videotaped 25-min session. At the start of each session, a researcher seated the 2 boys in front of a video camera set up in a room at the OSLC. In accordance with the directions of the Peer Interaction Task (Forgatch, Fetrow, & Lathrop, 1985; Panella & Henggeler, 1986), the researcher told the boys that they were to engage in conversation for 25 min about a variety of topics to be announced by the researcher. Each session started with a 5-min warm-up discussion about planning an activity together, followed by four 5-min segments with four randomly-ordered, assigned problem-solving discussions related to self-selected problems with the target child's and peer child's parents and peers. The researcher was present in the room only to introduce each topic; during the discussions the boys were alone.

Videotapes of the boys' conversations were transcribed and coded by trained observers. The boys' verbal behavior was coded into two mutually exclusive categories: rule-break talk and normative talk. As defined for this study, rule-break talk contained some element that indicated a violation of legal and/or conventional norms of conduct. Examples of rule-break talk included climbing out of bedroom windows, lying to parents, cheating at school, engaging in criminal behavior, and behaving defiantly. Examples of normative talk included gossiping about friends, and talking about school, family, or what to do for fun. These categories constituted two mutually exclusive, concurrently available response alternatives. The frequencies and durations of verbal bouts were recorded for each boy. Each bout began when a boy started speaking and ended when the boy stopped speaking. This permitted the calculation of both response rates and time allocations.

In addition to coding for content, social consequences from the ''other'' boy (which was the peer child when the target child's behavior was under consideration, and the target child when the peer child's behavior was under consideration) for bouts of both rule-break and normative talk were also coded into two mutually exclusive categories: positive social responses and nonpositive social responses. A positive social response was assumed to reinforce a bout of talk if it immediately followed that bout in the behavior stream (Snyder & Patterson, 1995). Examples of positive social responses included making approving statements, smiling, nodding, laughing, and giving a thumbs-up. Nonpositive social responses included anything other than positive social responses, including remaining silent. Frequencies of positive social responses for each category of verbal behavior were recorded for each boy. This permitted the calculation of reinforcement rates for each category of verbal behavior.

The boys' data were coded separately by two coders following the instructions from the Topic Code (Poe, Dishion, Griesler, & Andrews, 1990). Coders were blind to all other data related to the participants, and they were involved only in the coding of the data. Reliability scores were calculated for a randomly selected 15% of pairs in this sample. A mean percent agreement of 94.2 and a kappa coefficient of 0.674 were obtained across coders (Dishion et al., 1996).

For the target boys only, data were also available on a variable referred to as child deviance. Child deviance scores were based on the self-reported delinquency scale of the National Youth Survey measure (Elliot, Huizinga, & Ageton, 1985), the boys' criminal records, and measures of antisocial behavior reported by the boys' parents and teachers. Dishion et al. (1996) provide details about the specific measures and how they were weighted in the total scores. All components of the child deviance scores were collected during the fifth phase of the OYS, that is, when the boys' conversations were videotaped. The total scores were expressed as *z*-scores, such that higher scores indicate greater deviance from same-age, same-gender norms. The target boys' child deviance scores ranged from -0.88 to 1.79 ($M = 0.05$, $SD = 0.63$).

RESULTS

All analyses were conducted on the n4 sample (McDowell & Caron, 2010) using data supplied by the OSLC in the form of SPSS files. Data were missing from one peer boy in the sample, making the data from the corresponding target boy unusable (because reinforcement rates were not available for his verbal behavior). The entire 20 min of conversation for each boy was used to generate a single data record for that boy, consisting of two reinforcement rates, two response rates and two time allocations. Because only the target boys in the n4 sample were assigned child deviance scores, only their response and time allocation data were analyzed. Following McDowell and Caron (2010), rule-break talk in all analyses was taken as response alternative 1, and therefore appeared in the numerators of Equations 1–3, and normative talk was taken as response alternative 2, and therefore appeared in the denominators of Equations 1–3.

McDowell and Caron (2010) fitted equations of matching theory, including Equation 3, to the n4 target boys' response and time allocation data and obtained exponents, a, of 0.76 and 0.74 and bias parameters, b, of 0.34 and 0.33, for response and time allocation data respectively; these values are listed in the ''n4-Target'' rows of their Table 2. As noted earlier, the exponents were close to the value of 0.8 that is commonly found in laboratory research with vertebrate species, including humans, and the bias parameters indicated a strong bias in favor of normative talk.

It is instructive to examine the target boys' response and time allocation data when plotted in proportional form. In each panel of Figure 2, one data point was contributed by each of the 80 target boys, and represents the proportion of bouts of rule-break talk (top panel), or proportion of time spent engaging in rule-break talk (bottom panel), as a function of the proportion of social reinforcement obtained from the peer friend for rule-break talk. The solid diagonal is a plot of Equation 1. Most of the data points fall below the diagonal, reflecting the strong bias in favor of normative talk. The dashed curves are plots of Equation 2 with the parameters from McDowell and Caron's (2010) fits, which are listed in each panel of the figure. Obviously, both response and time allocation proportions

Table 1

Parameters, *a* and *b*, and proportions of variance accounted for (*pVAF*) by fits of Equation 3 to response and time allocation data sorted into child deviance quartiles (1 = least child devi-ance), and for fits to the unsorted re-sponse and time allocation data (All data).

Quartile	*a*	*b*	*pVAF*
		Responses	
1	0.96	0.27	0.97
2	0.75	0.32	0.85
3	0.53	0.36	0.88
4	0.62	0.53	0.92
All data	0.75	0.38	0.90
		Time	
1	0.93	0.24	0.93
2	0.80	0.36	0.89
3	0.52	0.39	0.77
4	0.62	0.60	0.89
All data	0.76	0.41	0.89

were strongly correlated with their corresponding reinforcement proportions; the correlations were .77 and .74 (which are only coincidentally similar to the exponent values). Correlations like these led Patterson, Snyder, Dishion, and their colleagues to conclude that their results were consistent with the matching law. But the least squares fits of McDowell and Caron provided more specific information. They showed that Equation 2 (or, equivalently, Equation 3), but not Equation 1, described the data, and that the boys' verbal behavior was characterized by both bias and undermatching.

The target boys' data were analyzed further to examine their relationship to the child deviance variable. The entire set of data records was sorted by reinforcement rate ratio and divided into sedeciles (sixteenths). Reinforcement rate ratios, response allocation ratios, and time allocation ratios were then averaged within sedeciles. This method of averaging is analogous to the method used by McDowell and Caron (2010), who noted that between-subject differences added noise to the data which could be damped by averaging.

As is customary in the basic science, the log transformation of Equation 3, which linearizes the power function, was fitted to the response allocation and time allocation data. Plots of the data and the best least-squares fits of the log transform of Equation 3 are shown in Figure 3 for response (top panel) and time allocation (bottom panel). Equations of the best-fitting lines and the proportions of variance they accounted for (r^2) are given in each panel. Clearly, Equation 3 provided an excellent description of the target boys' verbal behavior. The negative *y*-intercepts in the two plots reflect the boys' strong bias in favor of normative talk. The parameters obtained from these fits of Equation 3 are listed in Table 1 (rows labeled ''All data''; the *b* entries are antilogs of the regression line intercepts), and were virtually identical to those obtained by McDowell and Caron (2010; listed in the ''n4-Target'' rows of their Table 2, and given in the present Figure 2), who used the unaveraged data and a more elaborate least-squares procedure. These nearly identical results indicate that the simpler fits to the sedecile averages used here were comparable to the more elaborate fits to the unaveraged data carried out by McDowell and Caron.

To examine the effect of child deviance on matching theory's account of the boys' verbal behavior, the 80 unaveraged data records were divided into quartiles on the basis of their child deviance scores. The mean child deviance scores for quartiles 1 through 4 were −0.67, −0.28, 0.21, and 0.92, reflecting increasing deviance from the first to the last quartile. The 20 data records in each child deviance quartile were then sorted into quartiles based on the reinforcement rate ratio of the data record. The five reinforcement rate ratios, response allocation ratios, and time allocation ratios in each of these quartiles were then averaged. This method entailed the same degree of averaging (viz., over five data records) that was used in the overall analysis shown in Figure 3, and yielded four averaged data records per child deviance quartile. Again, the purpose of this averaging was to damp the noise in the data caused by between-subject differences. The log transform of Equation 3 was then fitted to the response and time allocation data from each child deviance quartile separately. The proportions of variance accounted for (*pVAF*) by these fits are listed in the last column of Table 1 and show that Equation 3 described the data from each child deviance quartile well, accounting for between 77% and 97% of the variance in the logarithms of the behavior ratios.

The parameters, *a* and *b*, from the fits of Equation 3 are listed in Table 1 and plotted in Figure 4 as a function of child deviance quartile. The plots of the exponent, *a*, of

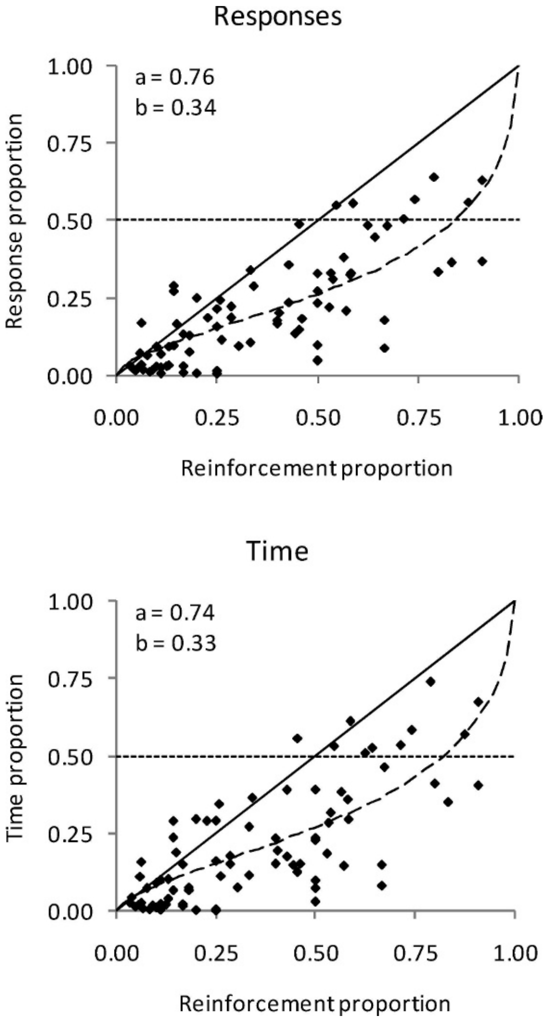

Fig. 2. Response (top panel) and time (bottom panel) proportions of rule-break talk as a function of the obtained reinforcement proportion for rule-break talk. One point was contributed by each of 80 target boys. The solid diagonals are plots of Equation 1. The dashed curves are plots of Equation 2 with the values of *a* and *b*, listed in each panel, from McDowell and Caron's (2010) fits.

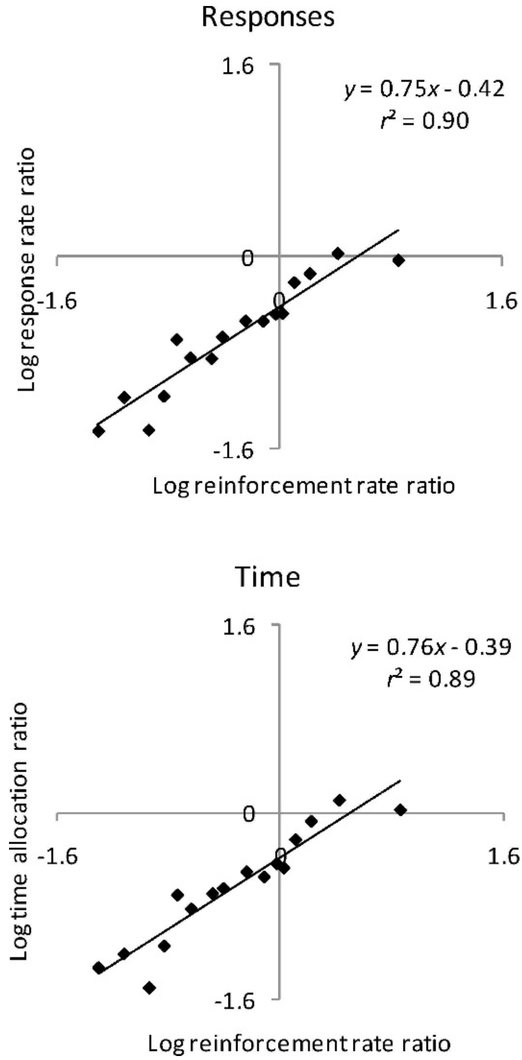

Fig. 3. Plots of the log transform of Equation 3 fitted to log response rate ratio (top panel) and log time ratio (bottom panel) data averaged within response rate ratio and time allocation ratio sedeciles. The best fitting equation and the proportion of variance it accounts for (r^2) are given in each panel.

Equation 3 show that it decreased as child deviance increased; hence, the greater the child deviance the more severe the undermatching. The effect sizes (r^2) for this result, which were calculated from the correlations of the exponents with their associated mean child deviance scores, were substantial, reaching 0.59 for response allocation and 0.60 for time allocation.

The plots of the bias parameter, *b*, in Figure 4 show that it increased with child deviance for both response and time allocation data. This means that the boys' verbal behavior became less biased in favor of normative talk the greater their deviance. Nevertheless, the verbal behavior of even the most deviant boys remained substantially biased in favor of normative talk. The effect sizes for this finding were very large, reaching 0.94 for response allocation and 0.96 for time allocation.

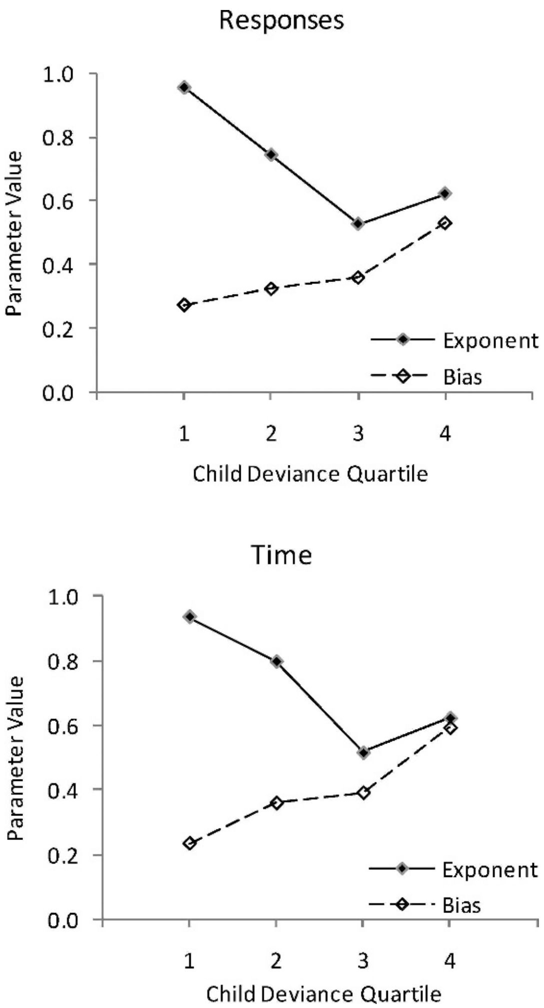

Fig. 4. Exponents, *a*, and bias parameters, *b*, from fits of Equation 3 to data within child deviance quartiles. Child deviance increased from the first to the fourth quartile.

DISCUSSION

McDowell and Caron (2010) found that the rule-break and normative talk of boys at risk for delinquency and of their peer friends was well described by the equations of matching theory, including the generalized matching law, Equation 3, with exponents that were close to the typically-found value of about 0.8, and substantial bias in favor of normative talk. The present analyses showed that when the boys' data were separated into groups according to their level of deviant behavior, Equation 3 provided a good description of the boys' verbal behavior at all levels of deviance. The exponent of the equation declined from the expected value of about 0.8 at the two lowest levels of deviance, to a value of about 0.6 at the two highest levels. The latter value represents a decrease in the exponent of about 25% and reflects a substantial degree of undermatching. The bias parameter from the fits of Equation 3 showed the opposite trend. It increased from the lowest to the highest levels of deviance, indicating that the greater the boys' deviance, the less biased their verbal behavior was in favor of normative talk, although the bias remained substantial at all levels of deviance.

The decreasing exponents shown in Figure 4 are especially interesting. In the basic science literature, the exponent of Equation 3 is rarely found to vary systematically with environmentally manipulable variables other than procedural ones, such as the change-over delay (Davison & McCarthy, 1988), or the temporal distribution of reinforcers in the component schedules (Elliffe & Alsop, 1996). In the applied literature, differential sensitivity to reinforcement allocation that clearly entailed the exponent of Equation 3 was reported by Kollins, Lane, and Shapiro (1997), who studied the behavior of 6 boys and 6 girls working on experimentally arranged concurrent schedules. Half the children had received diagnoses of attention deficit hyperactivity disorder (ADHD), and half had not. Kollins et al. found that boys with ADHD tended to exhibit greater degrees of undermatching (lower exponents in Equation 3) than boys without the diagnosis. To our knowledge, the only other data that clearly showed differences in sensitivity to reinforcement allocation were reported by Landon et al. (2007), who found that rats whose mothers had been undernourished during the rats' gestational periods, later showed consistently greater degrees of undermatching in concurrent schedules than rats whose mothers had been properly nourished during the rats' gestational periods.

Understanding the Trend in Bias

The bias parameters shown in Figure 4 raise two questions: Why was the boys' verbal behavior strongly biased in favor of normative talk, and why did this bias decrease with increasing child deviance? Notice that the only asymmetry between the alternatives in these conversations was the different behaviors of rule-break talk and normative talk. The reinforcers for the two alternatives were the same, and no other asymmetries between the alternatives were apparent. Behavior-based bias like this is usually studied in the basic science laboratory by changing physical properties of the behaviors, such as the force required to execute them.

In the case of the boys' rule-break talk and normative talk it seems unlikely that the difference between the behaviors was due to any specific property of the behaviors themselves. Instead, the difference may be due to different histories of reinforcement and punishment that were associated with the two behaviors. For example, it may be that a behavior that has been punished in the past is less preferred than a behavior that has not been punished, when the two are paired at equal rates of positive reinforcement in a concurrent schedule. Similarly, behavior that has been richly reinforced in the past might be more preferred than a behavior that has been only leanly reinforced in the past when paired at equal rates of positive reinforcement in a concurrent schedule. Oddly, to our knowledge, these specific effects of history on response value in concurrent schedules have not been studied in the basic science laboratory, although they are related to an extensive body of research on the application of behavioral momentum theory to behavior on concurrent chained schedules (Grace & Nevin, 1997; Nevin & Grace, 2000).

One possible explanation for the strong bias in favor of normative talk for these boys, then, is that they had histories of positive reinforcement for normative talk, and possibly for other normative behavior, and/or histories of punishment for rule-break talk, and possibly for other rule-break behavior, in their interactions with parents, teachers, and perhaps some peers. According to this explanation, a residue of a boy's history of reinforcement and punishment is present at every moment and may be expressed as a bias favoring a historically more reinforced and less punished alternative, over and above the effect of current reinforcement allocations. Furthermore, additional reinforcement for rule-break talk and other rule-break behavior in ongoing and subsequent interactions would gradually increment the historical residue in favor of rule-break talk, thus decreasing the overall bias in favor of normative talk. In other words, additional deviancy training would decrease the bias in favor of normative talk, which is consistent with the result shown in Figure 4. According to this explanation, the change in bias in these boys' verbal behavior is the signature of successful deviancy training, and this in turn explains why the bias parameters are correlated with concurrently obtained child deviance scores.

Further investigation of this explanation of the bias parameter and its trend should no doubt begin with basic science research on the effects of histories of reinforcement and punishment on later bias in concurrent schedules. This kind of research is a good example of how questions that arise in applied research can be brought back into the basic science laboratory for study. If histories of reinforcement and punishment are shown to affect bias in concurrent schedules, then the many important parameters of this effect, such as how long it lasts, can also be studied in the basic science laboratory. Attempts to study and verify such histories in the parent, teacher, and peer interactions of antisocial boys, perhaps in comparison to normal boys, could then be undertaken. Longitudinal studies of histories of reinforcement and punishment from parents, teachers, and peers, along with studies of bias in concurrent schedules of rule-break and normative behavior, and ongoing measures of child deviance also would be informative. The expectation, of course, is that all three would develop in tandem.

Understanding the Trend in Undermatching

To understand the significance of the trend in the exponents shown in Figure 4, it may be helpful to consider a recently proposed selectionist theory of adaptive behavior dynamics, which instantiates the idea that behavior evolves in the lifetimes of individual organisms under the selection pressure of reinforcement from the environment (McDowell, 2004). This is an instance of complexity theory (McDowell & Popa, 2009) and consists of a set of low-level rules that are applied repeatedly to a population of potential behaviors to generate an observed high-level outcome. The rules of this theory are behavioral analogs of Darwinian selection, reproduction, and mutation. The theory generates steady-state behavior that is perfectly described by the equations of matching theory (McDowell, 2004; McDowell & Caron, 2007; McDowell, Caron, Kulubekova, & Berg, 2008; McDowell & Popa, in press), has a boundary exponent of about 0.8 for behavior on concurrent schedules, and is consistent with a selectionist model of neural functioning, which can be understood as a material mechanism for the theory (McDowell, in press).

The selectionist theory of behavior dynamics suggests that an exponent of about 0.8 is the natural consequence of selectionist dynamics, but asserts that this value may vary as a function of two other quantities. One is the degree of perseveration or impulsiveness in behavior, the other is the value of the reinforcer to the organism. Both variables are illustrated in Figure 5, which is redrawn from McDowell & Popa (in press), and shows exponents generated by virtual organisms animated by the selectionist theory that worked on a variety of symmetric two-component concurrent schedules. The exponents in the figure are plotted as a function of the degree of perseveration or impulsiveness that characterized the virtual organisms' behavior, a property that can be set for each organism. Impulsiveness in this context refers to behavior that switches too readily from alternative to alternative, including switches away from reinforced alternatives. Perseveration refers to behavior that persists too long on individual response alternatives, including alternatives that may provide little or no reinforcement. The different symbols and connecting lines in the figure identify four levels of reinforcer value that were used in the symmetric concurrent schedules.

The rectangle in Figure 5 encloses eight exponents that are located along the *x*-axis at what might be considered a normal, or adaptive, balance of perseveration and impulsiveness. At this level, the exponents vary around about 0.8. To the left of the rectangle, behavior becomes perseverative and the exponents begin to fall; to the right of the rectangle, behavior becomes impulsive and the exponents also fall, but more gradually. As shown in the figure, the exponents vary at all levels of perseveration and impulsiveness. Some of this variation is stochastic, but evidently, according to the theory, some of it is also systematic and due to the value to the organism of the identical reinforcers in the two components. This is shown in the figure by

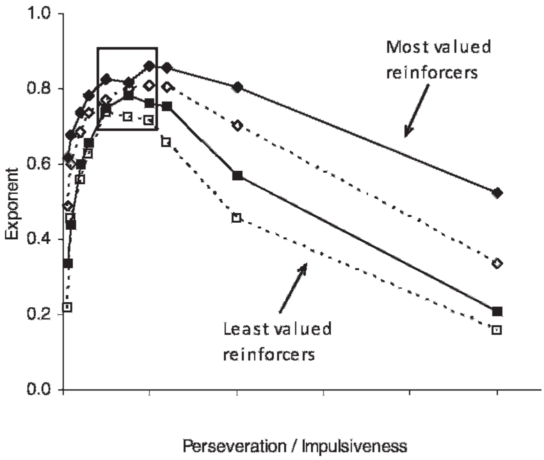

Fig. 5. Exponents, *a*, obtained from a selectionist computational theory of adaptive behavior dynamics at four levels of reinforcer value (represented by different symbols and line styles) and plotted as a function of degree of behavioral perseveration or impulsiveness. Exponents within the rectangle fall in a region where perseveration and impulsiveness may be adaptively balanced. To the left of the rectangle, behavior becomes perseverative; to the right it becomes impulsive. (Redrawn from McDowell & Popa, in press).

the different symbols, which maintain their ordinal rankings at all levels of perseveration and impulsiveness. Note that Equation 3 has no explicit way to deal with a situation where identical reinforcers in the two components of a concurrent schedule have different values to the organism under different conditions. An example of such a situation is an experiment where pigeons in one condition work on symmetric concurrent schedules with, say, 3-s of access to grain as reinforcers in the two components, and in another condition work on symmetric concurrent schedules with 6-s of access to grain as reinforcers in the two components. Bias cannot reflect the difference between conditions because the reinforcers in the two components of each schedule are identical, and matching theory itself does not indicate that the exponent should differ between the two conditions.

According to the selectionist theory of behavior dynamics (as illustrated in Figure 5), undermatching increases as behavior becomes more perseverative or more impulsive, and at a given level of perseveration or impulsiveness, undermatching is greater the less valuable the identical reinforcers in the two components of a concurrent schedule are to the organism.

Based on this theory, one explanation of the decreasing exponents in Figure 4 is that the boys' behavior was adaptively balanced between perseveration and impulsiveness, but that the positive social reinforcers delivered for the two categories of talk were less valued the more deviant the boy. This hypothesis can be tested in two ways. It may be that some other reinforcer, say money, has roughly the same value for the boys regardless of their level of deviance. If so, then according to the dynamic theory, behavior on symmetric concurrent schedules of monetary reinforcement will not show a systematic change in the exponent of Equation 3 with level of deviance. If on the other hand, the decreasing exponents in Figure 4 are due to greater perseverative or impulsive behavior in general, that is, to a more general defect in adaptive functioning, then the exponents obtained from symmetric concurrent schedules of monetary reinforcement will show a decrease with increasing child deviance, just as was obtained with positive social reinforcement.

A second way to test the hypothesis that social reinforcers are less valuable to more deviant boys is to arrange asymmetric concurrent schedules where positive social reinforcement is provided for responding on one alternative and a different reinforcer, perhaps points, is provided for responding on the other alternative. This asymmetry will generate biased responding, perhaps in favor of the points, which will be reflected in the bias parameter, *b*, obtained from fits of Equation 3. But if the value of positive social reinforcement decreases with level of deviance, then bias in favor of points will increase with level of deviance. This method of measuring reinforcer value has been discussed by Miller (1976), McDowell (1987), and most recently by Dallery, McDowell, and Soto (2004). To complete this second method of testing, it would be necessary to run symmetric concurrent schedules using points as reinforcers in both components, and find that the exponent does not vary with level of deviance. This would demonstrate that the reinforcing value of points is roughly constant across levels of child deviance and hence that the change in the bias parameters observed in the asymmetric schedules was due to the changing value of the positive social reinforcement.

Conclusion

While matching theory has figured prominently in the study of the aggressive, antisocial, and delinquent behavior of children and adolescents for many years, the present findings, together with those of McDowell and Caron (2010), show that more detailed analyses enhance our understanding of these socially important behaviors.

The behavior-analytic research pioneered by Gerald Patterson and his colleagues is noteworthy for two reasons beyond the specific information it provides about the development and characteristics of antisocial and delinquent behavior. First, it arguably constitutes the best and most extensively documented body of data showing the operation of basic behavior-analytic principles in the regulation of important human social behavior in natural, unengineered environments. McDowell and Caron (2010) argued that such documentation is essential if behavior-analytic explanations of naturally occurring human social behavior are to become widely accepted. The second additional noteworthy feature of this body of work is that it constitutes a case study of how basic and applied science can work together profitably. For example, in the present article, a quantitative steady-state theory from the basic science was applied to antisocial behavior, a theory of behavior dynamics from the basic science was used to generate testable hypotheses about how the antisocial behavior was regulated, and suggestions were made about studying questions raised by the applied research in the basic science laboratory. A strong partnership between basic and applied behavior analysis is no doubt the best path to understanding how behavior is regulated in natural environments.

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