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Operant Test Battery Performance in Children: Correlation with IQ

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PAULE, M. G., J. J. CHELONIS, E. A. BUFFALO, D. J. BLAKE AND P. H. CASEY. *Operant test battery performance in children: Correlation with IQ*. NEUROTOXICOL TERATOL **21**(3) 223–230, 1999.—The relationship between intelligence and money-(nickel-)reinforced operant behaviors were compared in 115 six year old children. The Operant Test Battery (OTB) consists of tasks thought to engender responses dependent upon specific brain functions that include motivation, color and position discrimination, learning, short-term memory, and time estimation. OTB endpoints were compared with Full Scale, Verbal and Performance IQ scores. Highly significant correlations were noted between several OTB measures (e.g., color and position discrimination accuracy) and IQ scores, but not in others (e.g., motivation task response rate). The results demonstrate the relevance of these measures as metrics of important brain functions. Additionally, since laboratory animals can readily perform these same tasks, these kinds of behaviors in laboratory animals should be useful in studying the effects of neuroactive/neurotoxic compounds on aspects of cognitive function in animals and in predicting adverse effects of such agents on related brain functions in humans.

Intelligence quotients Operant behavior Learning Motivation Color and position discrimination
Short-term memory Memory Operant test battery Timing behavior

A schedule-controlled Operant Test Battery [OTB (54,55)] was initially designed for the purpose of simultaneously monitoring several aspects of central nervous system function in laboratory animals (rhesus monkeys). Five different tasks are included in the National Center for Toxicological Research (NCTR) OTB, each designed to specifically "require" experimental subjects to demonstrate behaviors thought to represent or be dependent upon a specific brain function. These include a progressive ratio (PR) task thought to model aspects of motivation, a conditioned position responding (CPR) task for assessing color and position discrimination, a temporal response differentiation (TRD) task for monitoring time estimation, a delayed matching-to-sample (DMTS) task for quantifying aspects of short-term memory, and an incremental repeated acquisition (IRA) task for the assessment of learning behavior.

Although test–retest reliability data are not yet available for human subjects, monkey data are characterized by reliabilities that generally range from about 0.5 to greater than 0.9, depending upon task and endpoint (unpublished results). Also, in monkeys, correlations between representative behavioral endpoints for each of the five tasks contained in the battery are, in general, not statistically significant; when endpoints do correlate, however, the correlation coefficients are small, the largest being less than about 0.4 (38). Additionally, the acute effects of several prototypic psychoactive compounds on OTB performance also clearly demonstrate differential task sensitivity: the profiles of behavioral effects vary depending upon which drug is administered (38). For example, performance on the time estimation task is disrupted by doses of delta-9-tetrahydrocannabinol that do not affect behavior on the other tasks (54). Atropine, on the other hand,

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disrupts learning task performance at doses that do not affect performance on the other tasks (53). Numerous other drugs, including marijuana smoke (55), amphetamine (56), morphine (57), diazepam (58), chlorpromazine (9), pentobarbital (10), LSD (14), phencyclidine (13), physostigmine (15), methylenedioxymethamphetamine (12), caffeine (2), and MK-801 (3) have all yielded their own individual patterns of behavioral disruption. Thus, performance on each task is quite independent of performance in the others and can be selectively manipulated pharmacologically.

Additionally, data exist suggesting the involvement of different brain areas in the performance of these and similar tasks. Performance of the short-term memory (DMTS) task, for example, is thought to involve the hippocampus (16,19). DMTS performance is impaired in individuals with temporal lobe lesions or amygdalo-hippocampectomies, but not in patients with frontal lobe lesions (37). Functional imaging studies in humans using positron emission tomography (PET) have shown that DMTS task performance is associated with bilateral deactivation in the temporal lobes, and activations in regions of the posterior perceptual cortex, thalamus, anterior cingulate, and cerebellum (7). The prefrontal cortex, on the other hand, appears to be important for the performance of tasks such as the color and position discrimination (CPR) task (20,31) and the hippocampus is thought to be important in learning processes. Functional imaging studies into brain areas associated with time estimation are just beginning but early data suggest involvement of the frontal cortex, striatum, and thalamus, and indicate participation of frontal-striatal circuitry (27). And lastly, a final common pathway in motivational/reward systems appears to involve the nucleus accumbens (47). Thus, given the apparent differences in brain structures thought to subserve the expression of the different functions modeled by OTB behavior, it should not be surprising that each behavior can be differentially affected by drug treatment or that performance on one task does not necessarily correlate highly with performance on the others.

Although the use of operant techniques in nonhuman primate behavioral/developmental toxicology studies is not new [see, e.g., (4,22,48,49), and a brief overview in (39)], the packaging of several tasks into an automated behavioral battery to allow for the simultaneous assessment of multiple functions is unique. Because it is possible to repeatedly sample performance in these same tasks over extended periods of time, this approach has been applied in chronic exposure studies to examine the long-term effects of marijuana smoke (40), methylenedioxymethamphetamine (11), and the gestational exposure to cocaine (35) in the rhesus monkey. It is the ability not only to easily automate operant behavioral procedures (such as those modeled using the NCTR OTB) but also to use them

TABLE 1
MEANS AND (SD) FOR OTB VARIABLES ACROSS IQ

		Full Scale IQ					
Task	Variable	IQ < 70 (n = 14)	70–79 (n = 23)	80–89 (n = 21)	90–99 (n = 25)	100–109 (n = 20)	IQ > 110 (n = 12)
PR	PTC	52 (9)	49 (12)	53 (9)	51 (11)	53 (13)	49 (15)
	BREAK	146 (26)	137 (37)	150 (26)	144 (33)	150 (39)	139 (45)
	RR	2.1 (0.6)	1.9 (0.9)	2.2 (0.7)	2.1 (0.8)	2.3 (1.0)	2.0 (1.1)
CPR	PTC	86 (25)	83 (18)	92 (22)	94 (3.1)	97 (12)	100 (0)
	ACC	63 (21)	60 (18)	75 (21)	94 (15)	91 (15)	95 (4.4)
	RR	0.50 (0.22)	0.47 (0.13)	0.48 (0.16)	0.53 (0.14)	0.55 (0.14)	0.61 (0.17)
	ORL	3.5 (2.2)	3.1 (1.5)	3.2 (1.6)	2.7 (0.8)	2.7 (0.7)	2.5 (0.6)
	CRL	1.3 (0.6)	1.5 (0.8)	1.8 (1.8)	1.3 (0.6)	1.2 (0.7)	0.9 (0.5)
	CCRL	1.4 (0.7)	1.6 (1.0)	1.9 (2.4)	1.3 (0.8)	1.1 (0.5)	0.8 (0.2)
	ICRL	1.5 (0.7)	1.6 (0.7)	2.3 (1.7)	1.6 (1.1)	1.6 (1.0)	2.1 (3.2)
TRD	PTC	16 (9)	16 (28)	27 (27)	38 (35)	40 (34)	40 (31)
	ACC	8 (4)	8 (12)	18 (18)	23 (22)	27 (24)	26 (22)
	RR	0.18 (0.15)	0.19 (0.18)	0.09 (0.04)	0.10 (0.07)	0.09 (0.04)	0.09 (0.04)
	AVG HOLD	8.2 (7.0)	7.8 (7.3)	9.3 (5.0)	9.3 (6.3)	10.1 (3.9)	10.0 (3.6)
DMTS	PTC	39 (21)	42 (28)	60 (28)	57 (26)	76 (14)	80 (11)
	ACC	61 (22)	61 (25)	76 (26)	77 (21)	87 (8)	89 (7)
	RR	0.18 (0.11)	0.13 (0.08)	0.16 (0.06)	0.18 (0.09)	0.22 (0.08)	0.23 (0.05)
	ORL	5.9 (8.6)	7.9 (10.0)	5.0 (5.9)	5.5 (6.6)	3.1 (2.8)	2.0 (0.6)
	CRL	3.8 (2.7)	3.2 (1.2)	2.8 (0.7)	2.8 (1.2)	2.4 (0.8)	2.5 (0.7)
	CCRL	3.9 (3.9)	3.1 (1.2)	2.6 (0.9)	2.6 (1.1)	2.2 (0.7)	2.3 (0.6)
	ICRL	4.1 (2.0)	3.5 (1.4)	4.5 (2.0)	3.9 (1.7)	3.7 (1.6)	4.1 (2.2)
IRA	PTC	29 (10)	39 (21)	46 (19)	51 (27)	74 (27)	71 (27)
	ACC	33 (16)	36 (14)	36 (13)	45 (14)	56 (15)	63 (18)
	RR	0.50 (0.36)	0.38 (0.24)	0.40 (0.20)	0.43 (0.21)	0.62 (0.28)	0.50 (0.25)

The variables in the table are defined as follows: PTC (percent task completed) for each task refers to the number of reinforcers earned divided by the maximum number of reinforcers that could be earned in that task; BREAK refers to breakpoint, which is the number of lever presses emitted for the last nickel reinforcer obtained; RR is the response rate measured in responses per second; ACC is accuracy defined as the percentage of correct responses; ORL is the observing response latency in seconds; CRL is the choice response latency in seconds; CCRL is the correct choice response latency in seconds; ICRL is the incorrect choice response latency in seconds; and AVG HOLD is the mean duration of each lever hold in seconds.

for repeated assessments of the same subject(s) over time that make them powerful tools, not only in the animal laboratory, but potentially in the clinic.

In the field of toxicology, the effects of a chemical or chemicals in animals or animal tissues are determined and then several assumptions are made in using these data to predict what likely will happen to humans exposed to the same chemical(s). It is felt that toxicological assessments can be improved by decreasing the uncertainty associated with these assumptions by choosing appropriate animal models and examining similar or identical endpoints across species (34). In behavioral toxicology studies, it is generally accepted that any significant alteration of behavior away from some baseline level of performance caused by a given test agent is considered an adverse or toxic event; those effects that are reversible (i.e., that disappear over time) are considered less problematic than those that persist beyond the exposure period.

Because the behavioral or operant panel (43,54) used in administering the NCTR OTB was designed for use by relatively large laboratory animals (rhesus monkeys), and the tasks contained in the OTB were designed to model behaviors thought to be relevant to humans, it was felt that the use of this same instrument in human subjects would be useful in obtaining comparative data (44) and demonstrating the relevance of OTB measures. Use of identical behavioral measures in both laboratory subjects and humans is important because it can provide valid laboratory animal test data and strengthen risk assessment analyses. In the current study in children, we sought to determine if there were correlations between traditional measures of cognitive abilities (IQs) and our nonverbal measures of relatively complex instrumental behavior. The demonstration of significant correlations between our operant behavioral measures and IQ serves to validate the relevance of such measures as metrics of intellectual functioning.

A population of low birth weight, preterm children was studied here because it was suspected they would provide a wider sampling of IQ than would children characterized by normal birth weights and gestational lengths. All had been followed since birth by one of us (P.H.C.) as part of a national collaborative study (the Infant Health and Development Program, IHDP) designed to test the effectiveness of an educational intervention in a large group of preterm, low birth weight

TABLE 2
CORRELATIONS BETWEEN OTB VARIABLES AND IQ

			IQ		
Task	*n*	Variable	Full Scale	Verbal	Performance
PR	109	PTC	0.032	0.029	0.032
	109	BREAK	0.032	0.029	0.032
	109	RR	0.067	0.064	0.061
CPR	107	PTC	0.333†	0.298†	0.306†
	107	ACC	0.583†	0.516†	0.569†
	107	RR	0.243*	0.182	0.250
	107	ORL	−0.233*	−0.169	−0.252†
	107	CRL	−0.187	−0.189	−0.137
	107	CCRL	−0.202*	−0.194*	−0.162
	88	ICRL	0.074	0.025	0.138
TRD	86	PTC	0.260*	0.247*	0.248*
	86	ACC	0.318†	0.294†	0.305†
	86	RR	−0.384†	−0.357†	−0.337†
	86	AVG HOLD	0.183	0.176	0.132
DMTS	99	PTC	0.497†	0.431†	0.487†
	99	ACC	0.442†	0.380†	0.457†
	99	RR	0.342†	0.284†	0.325†
	99	ORL	−0.254*	−0.220*	−0.229*
	99	CRL	−0.354†	−0.276†	−0.377†
	97	CCRL	−0.367	−0.287†	−0.398†
	99	ICRL	−0.037	−0.025	−0.044
IRA	92	PTC	0.492†	0.425†	0.473†
	92	ACC	0.532†	0.461†	0.516†
	92	RR	0.214*	0.144	0.248*

The variables in the table were defined as follows: PTC (percent task completed) for each task refers to the number of reinforcers earned divided by the maximum number of reinforcers that could be earned in the task; BREAK is the number of lever presses emitted for the last nickel reinforcer obtained; RR is the response rate measured in responses per second; ACC is accuracy defined as the percentage of correct responses; ORL is the observing response latency in seconds; CRL is the choice response latency in seconds; CCRL is the correct choice response latency in seconds; ICRL is the incorrect choice response latency in seconds; and AVG HOLD is the mean duration of each lever hold in seconds.

*$p < 0.05$.

†$p < 0.01$.

infants. These children have been studied extensively since birth and, at age 5, they underwent detailed clinical assessments, which included determination of Full Scale, Verbal, and Performance IQ scores. Because IQs in most children are thought to remain relatively stable after 5 years of age (33, 64), we used the IQ data obtained at age 5 for comparison with NCTR OTB (42,43) behavior obtained during a scheduled visit to the IHDP clinic about 1 year later at age 6.5. Correlation analyses were performed using measures of operant performance for each OTB task and IQ scores to test the hypothesis that quantifiable measures of several OTB behaviors are significantly correlated with traditional measures of intelligence.

METHOD

Subjects

One hundred and fifteen children (60 female, 55 male; 46 Caucasian, 67 African-American, 1 Hispanic, and 1 mixed race) participating in the IHDP study at Arkansas Children's Hospital served as subjects. All were preterm (⩽37 weeks of gestation) and low birth weight (⩽2500 g) infants.

IQ Assessments

The Verbal, Full Scale, and Performance subscales of the Wechsler Preschool Primary Scale of Intelligence [WPSSI (63)] were used to obtain Verbal, Full Scale, and Performance IQ scores for all subjects at age 5.

Operant Behavioral Tasks

Assessment using the NCTR Operant Test Battery occurred when subjects were approximately 6.5 years of age (mean = 6.54, range 6.43–6.76). The apparatus used and the five tasks in the NCTR Operant Test Battery have been described in detail elsewhere (45,54). Briefly, the tasks were as follows.

Progressive ration (PR), or motivation task. This task is thought to generate behavior dependent upon the subject's motivation to respond for reinforcers (here, nickels) by increasing the work required to obtain each subsequent nickel reinforcer. Specifically, after the first lever press was made, a nickel was delivered. Subsequently, the number of lever presses required to obtain the next nickel was increased by 10. Thus, the first reinforcer "costs" 1 lever press, the second costs 11, the third 21, and so forth.

Conditioned position responding (CPR), or color and position discrimination task. For each trial in this task, the center one of three horizontally aligned press-plates was illuminated (randomly) with either a red, green, yellow, or blue color. Subjects indicated that they had "observed" the color by pushing the colored plate, after which the color was immediately extinguished and the two side plates were illuminated white. If the center plate had been either red or yellow, a choice response to the left plate was correct (nickel delivered), if the center color had been either blue or green, then a right plate choice was correct. Incorrect choices initiated a 10-s timeout period (all plates dark) followed by initiation of a new trial.

Temporal response differentiation (TRD), or time estimation task. Subjects were required to hold a single response lever in the depressed position for at least 10 s but no longer than 14 s. Releases that were either too short or too long had no programmed consequences, whereas lever holds of 10 to 14 s in duration resulted in the delivery of a nickel.

Delayed matching-to-sample (DMTS), or short-term memory task. Each trial in this task began with the illumination of the center one of the three horizontally aligned press-plates with one of seven white-on-black geometric shapes. Subjects demonstrated they had "observed" the shape (the sample stimulus) by pushing the illuminated plate after which it was immediately extinguished. Following an interval that varied randomly from 2 to 32 s, all three plates were illuminated, each with a different stimulus shape, only one of which "matched" the "sample" stimulus. A choice press on the plate that was illuminated with the "match" resulted in reinforcer delivery. Incorrect choices resulted in a 10-s timeout followed by initiation of a new trial.

Incremental repeated acquisition (IRA), or learning task. Here, four horizontally aligned response levers served as the manipulanda and a row of colored lights above the levers served to indicate how many more correct presses were

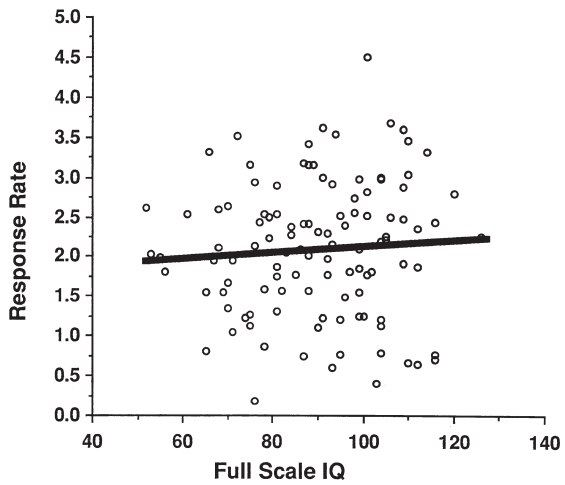

FIG. 1. Motivation Task: correlation between Full Scale IQ and performance (response rate) in the motivation (progressive ratio) task. There was no significant correlation between these measures ($R = 0.067$, $p = 0.491$).

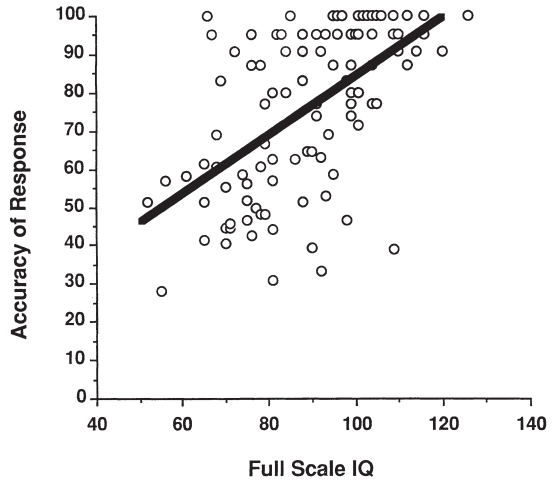

FIG. 2. Color and Position Discrimination Task: correlation between Full Scale IQ and performance (accuracy) in the color and position discrimination (conditioned position responding) task. There was a highly significant correlation between these measures ($R = 0.583$, $p = 0.0001$).

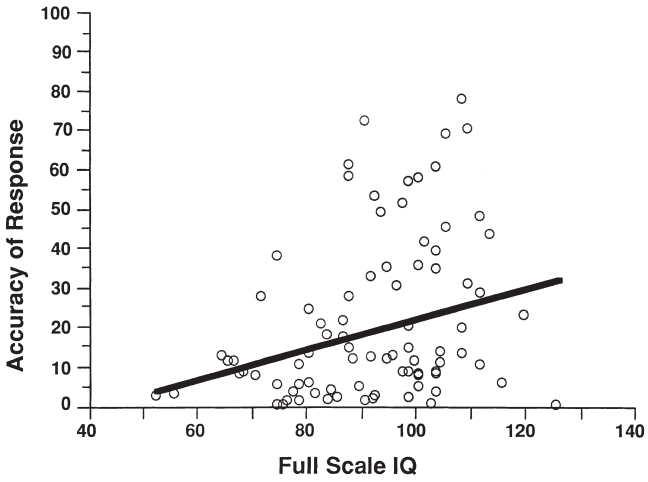

FIG. 3. Time Estimation Task: correlation between Full Scale IQ and performance (accuracy) in the time estimation (temporal response differentiation) task. There was a highly significant correlation between these measures ($R = 0.318$, $p = 0.0029$).

needed in order to obtain the next reinforcer. Correct and incorrect responses were also indicated by the illumination of white stimulus lights located slightly above and to the left and right of the response levers, respectively. Subjects were required to learn a specific sequence of lever presses (generated randomly), starting with one-lever "sequences" and progressing to sequences requiring up to as many as six lever presses.

Operant test battery sessions. As described elsewhere (42,43), the maximum durations of each task and the maximum number of criterion reinforcers obtainable were, in the order given to the test subjects: 1) The Motivation Task, 10 min, 30 nickels; 2) The Color and Position Discrimination Task, 5 min, 20 nickels; 3) The Time Estimation Task, 10 min, 30 nickels; 4) The Short-term Memory Task, 15 min, 60 nickels; and 5) The Learning Task, 15 min, 18 nickels. Performance of each task was immediately preceded by the presentation of videotaped instructions [described in (43)].

Correlation Analyses

Correlation analyses were performed using measures of OTB tasks and IQ scores (Full Scale, Verbal, and Performance) to determine where statistically significant relationships existed and to determine the direction (positive or negative) and magnitude (Pearson correlation coefficients; *R* values) of such correlations.

RESULTS

Table 1 shows the means and standard deviations for the OTB variables for children over different Full Scale IQ ranges. For the motivation (PR) task, none of the endpoints changed as a function of Full Scale IQ (see also Fig. 1). It is clear from the data for all other tasks, however, that, as IQ increases, so does percent task completed and accuracy (see also Fig. 2–5). Response rates for the conditioned position responding (CPR), delayed matching-to-sample (DMTS) and incremental repeated acquisition (IRA) tasks do not change as drastically as do accuracy or percent task completed as a function of Full Scale IQ, even though in all cases they are significantly correlated with it (see Table 2). For the temporal response differentiation (TRD) task, there was a relatively large effect of Full Scale IQ on response rate, with rate decreasing by about half from 0.18/s in the low IQ subjects (Full Scale IQ <80) to 0.09/s in subjects with scores >80 (Table 1). This rate decrease, versus the rate increases seen in the other tasks, likely relates to the unique reinforcement requirement of the TRD task for very low response rates (i.e., long lever holds). Table 2 shows the Pearson correlation coefficients for these same variables and Full Scale IQ, Verbal IQ, and Performance IQ. As can be seen here, the correlations between the operant variables and Full Scale IQ ranged from very small values that were not statistically significant in the progressive ratio task [0.032 for the breakpoint (the number of lever presses made for the last reinforcer earned)]; 0.067 for the response rate; see also Fig. 1) to the highly significant 0.583 for accuracy in the color and position discrimination task (see also Fig. 2). Furthermore, Performance IQ tended to correlate to a greater degree than Verbal IQ with most of the OTB

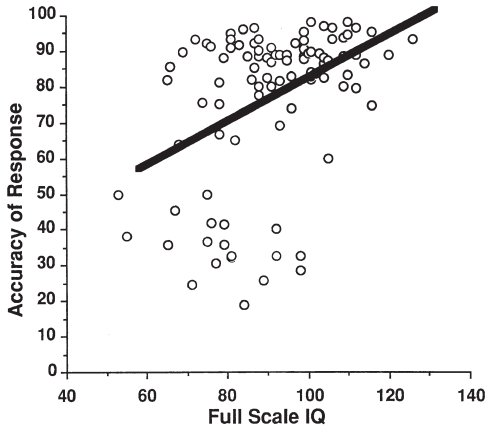

FIG. 4. Short-Term Memory and Attention Task: correlation between Full Scale IQ and performance (accuracy) in the short-term memory and attention (delayed matching-to-sample) task. There was a highly significant correlation between these measures ($R = 0.442$, $p = 0.0001$).

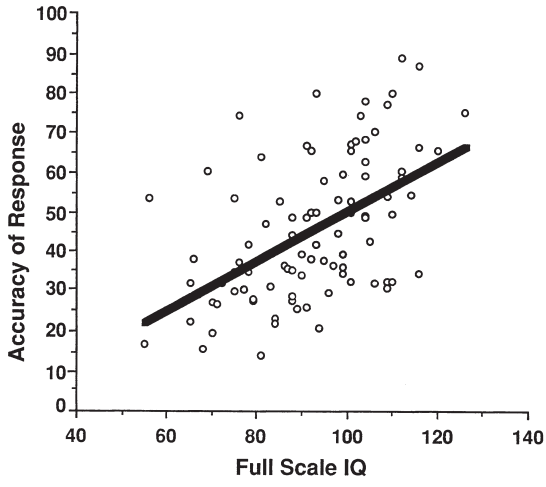

FIG. 5. Learning Task: correlation between Full Scale IQ and performance (accuracy) in the learning (incremental repeated acquisition) task. There was a highly significant correlation between these measures ($R = 0.532$, $p = 0.0001$).

variables. Correlations between Full-Scale IQ and performance accuracy in the time estimation, short-term memory and attention, and learning tasks are shown graphically as representative data in Fig. 3–5.

DISCUSSION

Performance on many of the operant tasks that were used in this research was significantly correlated with IQ in children; thus, it would appear that many endpoints in these tasks are influenced to some degree by intelligence. It is interesting to note that those tasks whose performance correlated with intelligence were those thought to model short-term memory (delayed matching-to-sample), learning (incremental repeated acquisition), color and position discrimination (conditioned position responding), and time estimation (temporal response differentiation), whereas performance of the task thought to be more associated with aspects of motivation did not correlate at all with IQ in these children. Thus, performance of the motivation task by children with IQs of around 50 was generally indistinguishable from that of children with IQs of about 120.

The correlations that were significant suggest that behavior in several of the tasks in the NCTR OTB should be predictive of IQ in human subjects. In fact, artificial intelligence techniques employing "modified rough sets" approaches have been applied to the data set obtained in the present study and algorithms for estimating children's IQ from OTB data have been developed (23). In that effort, it was determined that, using OTB data only, the IQ of subjects could be accurately predicted to within 20 points in approximately 70% of cases. The same algorithm was also applied to provide, by analogy, estimates of nonhuman primate equivalents of IQ (23). The plausibility of such an analogy is made even more intriguing by the observation that OTB behavior of children (given both verbal and visual instructions on now to perform the OTB tasks) is generally indistinguishable from that of well-trained rhesus monkeys (44).

Even though the correlations between many of the OTB behavioral variables and the "global measurements of intelligence obtained using traditional IQ tests are highly significant (see Table 2), the correlation coefficients describing such associations are never any greater than 0.58, and are usually much less. This suggests that there are factors that influence OTB performance that may not be related to those captured in a global IQ index score. These observations are important for at least two reasons. 1) They demonstrate that behavioral measures used routinely in the animal laboratory have direct relevance for important aspects of human brain function and, thus, serve to validate their use in both situations. 2) They demonstrate that many operant measures also provide information about complex brain function that may not be obtained from traditional assessments of intelligence. Although it is not suggested that OTB performance replace traditional IQ assessments, it is important to acknowledge that such instruments—readily adaptable to the animal laboratory—can provide valuable, relevant information about important aspects of brain function.

Others have also adapted oft-used animal behavioral procedures such as delayed matching-to-sample tasks (5,41), concurrent object discrimination (28,30) and delayed non-matching-to-sample tasks (28), maze tasks (36,46), and other cognitive function tasks (50) for use in humans. Some of these instruments [e.g., visuospatial memory and learning tasks, and DMTS (51,52)] have been useful in demonstrating differences between certain clinical entities (e.g., Parkinson's and Alzheimer's disease) and controls (51,52). Conversely, some human assessment methods, such as those used in visual function assessments, have been adapted for use in animals (8). The data from the present study, however, go beyond previous studies by demonstrating the utility of an automated operant test battery that consists of multiple tasks and by demonstrating that specific measures of operant behavior are related to intelligence in humans.

In cases where comparable data are available for humans and laboratory animals (rhesus monkeys, in the present case), it has been demonstrated that acute drug effects on OTB performance in animals are often similar to, and thus predictive of, drug effects in humans. For example, the ability of delta-9-tetrahydrocannabinol (THC, thought to be the major psychoactive constitutent of marijuana) to alter time perception is similar in both monkeys (54) and humans (24). In this case, predominant effects appear as an overestimation of the passage of time: subjects tend to prematurely indicate that a specific duration has elapsed (i.e., 8 s is reported as 10 s). Marijuana smoke, while also affecting timing behavior in much the same way as THC (55), has effects on short-term memory performance in the monkey at the same or even lower doses than those needed to impact timing behavior (55). In accord with these findings in monkeys, others have reported that marijuana exposure decreases performance accuracy in short-term memory tasks in humans (1,6). The dopaminergic antagonist, chlorpromazine, affects monkey OTB behavior primarily by slowing response rates, generally by increasing response initiation times (9) and these data are similar to those obtained in humans where decreases in task initiation have been observed after both acute (62) and chronic (61) treatment. The effects of diazepam on rhesus monkey OTB behavior to decrease accuracy of learning and short-term memory task performance (58) are also similar to those reported in humans (17,25) where decreases in accuracy occur at doses lower than those necessary to cause detectable motoric (i.e., response rate) effects. Morphine primarily decreased response rates while having little or no effect on accuracy in the majority of OTB tasks in monkeys (57), suggesting, as in humans (18,29), a more general effect of the drug to cause sedation and motor incoordination rather than specific disruptions in cognition. The muscarinic cholinergic antagonist atropine (53) was shown to disrupt monkey performance of the OTB learning task at doses that generally had no effect on performance of the other tasks and these effects were similar to those reported for human subjects performing a similar repeated acquisition task (26). For the barbiturate, pentobarbital, the monkey OTB data were characterized by disruptions in timing behavior indicative of an overestimation of the passage of time, a finding analogous to data from humans given secobarbital where subjects underestimated the length of time between the presentation of two stimuli: a "time flying" phenomenon (21).

In a relatively large-scale study of the effects of chronic marijuana smoke exposure on OTB behavior in the rhesus monkey (40), an amotivational syndrome, evidenced by suppressed responding in the motivation (progressive ratio) task during, and for several weeks after exposure, was observed. This observation mirrored the findings of several reports in the human literature of a marijuana-associated amotivational syndrome [e.g., (32,59,60)] and again demonstrated the comparability of drug effects between monkeys and humans. Whether drug effects will be identical between the two species when exactly the same behavioral tasks are used in the comparisons remains to be determined, but where comparable data exist, it seems clear that the monkey model provides re-

sults that are remarkably similar to those obtained in humans. Additionally, although the predictive utility of other animals capable of OTB performance has not yet been explored in any depth, there is every reason to believe that a variety of species will prove useful.

The data presented here clearly demonstrate the relevance of specific operant behavioral endpoints to intelligence (IQ) in humans. The use of these same or similar measures in well-controlled experiments in the animal laboratory should reduce the uncertainty associated with extrapolation of such animal data to humans and, thus, provide important methods for predicting outcomes associated with drug and/or other chemical exposures.

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