REINFORCEMENT LEARNING IN CHILDREN WITH FETAL ALCOHOL SPECTRUM DISORDER

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ABSTRACT

Background
It is often said that children with Fetal Alcohol Spectrum Disorder (FASD) have difficulty learning from reinforcement. However, there is little empirical evidence to support or deny this claim.

Objectives
To examine reinforcement learning in children with FASD, specifically: (1) the rate of learning from reinforcement; and (2) the impact of concreteness of the reinforcer.

Methods
Participants included 18 children with FASD (IQ $\geq$ 70), ages 11-17, and 18 age- and sex-matched controls. Participants each completed a novel reinforcement learning discrimination task that involved visual probabilistic learning (70% contingent feedback). The task was completed twice, once with tokens, and once with points (counterbalanced).

Results
The control group demonstrated significantly stronger overall reinforcement learning, although rates of improvement and effect of concreteness of the reinforcer (tokens vs. points) were not different between groups. The FASD group's responses were more likely to be guided by the most recent information, rather than based on integration of reward status over multiple trials.

Conclusions
Reinforcement learning does not appear to occur in a functionally different manner in children with FASD, but does take longer, and is more impacted by recent reward than an integration of overall reinforcement information. Children with FASD without an intellectual disability may be able to learn from reinforcement given sufficient consistent repetition. However, other failures associated with learning difficulties such as the complexity of the material, transfer of learning, or impulsivity were not addressed in this study.

Key Words: *Prenatal alcohol exposure; reinforcement learning; neuropsychology; behavior problems; behavioral interventions; Fetal Alcohol Spectrum Disorder*

Clinical wisdom suggests that children who are affected by prenatal alcohol exposure, even those with intelligence in the average range, do not appropriately alter their behavior in response to consequences. It is frequently stated that these children seem to make the same mistakes over and over despite being punished for "bad" behavior or rewarded for "good" behavior. This prevailing notion has had a profound impact on advice given to caregivers of individuals with Fetal Alcohol Spectrum Disorder (FASD) regarding the use of basic behavioral principles for learning, and yet has received surprisingly little research attention. Therefore, this study was designed to empirically examine learning from consequences in children with FASD compared to

non-affected peers. Neuropsychological studies have demonstrated that children with prenatal alcohol exposure recall less from their initial exposure to new material, but do pick up new information from repetition. They are able to hold information over time, but given their slow start, overall they learn and remember less than their peers.[1-5]

Reinforcement learning utilizes behavioral conditioning and involves discovering the actions which yield the most reward and the least punishment through exploration.[6] Prenatal exposure to alcohol has been demonstrated to impact the systems and structures in the brain most closely associated with reinforcement learning: the neurotransmitter dopamine[7-10], and the basal ganglia.[11-14] There is also strong support from the animal literature to support deficits in reinforcement learning associated with prenatal alcohol exposure[15-21], particularly when contingencies are altered, such in as reversal tasks, extinction, or fluctuating reward systems.[22-25]

There have been two studies of reinforcement learning in fetal alcohol exposed humans. A large study of newborn infants[26] demonstrated that, higher levels of alcohol combined with higher levels of nicotine consumption, were associated with slower operant learning (as measured by perseveration on a non-reinforced response during extinction). In the second study, Kodituwakku and colleagues[27] compared 20 children and adolescents with FASD (ages 7-19) to controls on a successive visual discrimination and reversal shifting task. The FASD group was significantly slower to learn to discriminate between abstract designs based on reinforcement (points), and when the contingencies were reversed, there was a significant group difference in number of reversals learned. Interestingly, participants in the FASD group showed a marked improvement in speed of learning when novel stimuli were later introduced, while children in the control group showed no improvement (likely due to a ceiling effect). The authors hypothesized that reversal deficits observed in this study were due to *deficient* (slow) processing skills, rather than problems with perseveration per se.

Given the dearth of research on reinforcement learning in children with FASD, useful information may be gathered from examining a population with significant overlap with FASD – Attention Deficit Hyperactivity Disorder (ADHD). Children with FASD are frequently co-diagnosed with ADHD.[28-30] Multiple lines of evidence suggest that like FASD, ADHD is also associated with dysfunction of the midbrain dopamine system.[31] Work by Holroyd and colleagues[32] suggests that children with ADHD may be more positively responsive to *in-hand* monetary reinforcement, and that this difference may be mediated by the midbrain dopamine system. Given their phenotypic and neurological similarity to children with ADHD, children with FASD might also be impacted by the tangibility of the reinforcer.

The goal of this study was to examine (1) the pattern of reinforcement learning in children and adolescents with FASD compared to controls, and (2) the impact of the concreteness of the reinforcer. Because children with FASD are known to take longer to learn new information in general, we hypothesized that the FASD group would learn less effectively overall (i.e., they would have lower overall scores). Further, it was hypothesized that the FASD group would demonstrate abnormal learning patterns, including slower within- and between-condition learning compared to the control group, and finally that concreteness of the reinforcer would affect reinforcement learning in the FASD group, but not the control group. This study was approved by the University of Victoria Human Research Ethics Board and was conducted as part of a larger study of reinforcement learning.

METHODS

Participants
Participants were recruited from the community and were tested by the first author. Children in the FASD group were required to have a diagnosis on the fetal alcohol spectrum based on confirmed alcohol exposure, and either evidence of facial features associated with exposure or indication of central nervous system dysfunction. Caregivers were asked to confirm the diagnosis, either by reviewing a diagnostic report or consulting with the diagnostician.

Exclusionary criteria for the FASD group included: visual impairment, hearing impairment, mental retardation, moderate to severe traumatic brain injury, stroke, psychotic disorder, bipolar

disorder, drug addiction, or other neurodevelopmental disorder. Prior to the testing session, written informed consent was obtained from participants and legal guardians.

Participants in the control group were chosen to match the FASD group based on sex and age. Exclusionary criteria for the control group included all of the previous conditions, as well as teratogenic medication or street drugs consumed during pregnancy, three or more standard alcoholic drinks consumed per week anytime during pregnancy (or the month prior to pregnancy recognition), unknown fetal alcohol exposure, suspected or confirmed diagnosis of ADHD, learning disability, epilepsy, or any known neurological or psychiatric disorder including anxiety or mood disorders. Furthermore, any participant (in either group) who was found during testing to have both a verbal and performance IQ below 70 was excluded.

A total of 39 participants (20 in the FASD and 19 in the Control group) participated in the study. Two participants in the FASD group were eliminated (one due to low IQ, one due to computer error), and one participant in the Control group was eliminated to equalize the groups. The mean age of the groups was not significantly different ($t(34)$ = -0.283, p = 0.78; *see Table 1*). Diagnoses in the FASD group included fetal alcohol syndrome (n = 6), partial fetal alcohol syndrome (n = 4), alcohol related neurodevelopmental disorder (n = 8), and alcohol related birth defects (n = 1). Six participants in the FASD group normally took psychostimulant medication, and four of these also normally took Risperidone. All but one of the participants were tested on their regular medications. In the control group, alcohol consumption during pregnancy was reported to occur in only two participants (in one, less than one drink per week; and in the other, maximum one to two drinks per week).

TABLE 1   Participant Demographic Features

	FASD	Control
Age in years (Mean [SD], Range)	13.98 (1.9), 11.7-17.5	13.81 (1.7), 11.2-17.5
Gender ratio (male: female)	10:8	10:8
K-BIT-2 FSIQ (Mean [SD], Range)	84.78 (10.2), 69-107	107.6 (12.1), 88-132
Ethnicity (number of children)		
Aboriginal	9	0
Black	0	1
Caucasian	6	17
Aboriginal & Caucasian	3	0

Tests and Measures
Probabilistic Reinforcement Learning
In this novel computerized task, the participant learned which stimulus within a pair of stimuli was associated with a higher probability of earning rewards. The stimuli consisted of two pairs of abstract multi-colored squares (3.5 x 3.5 cm., presented in the center of the computer screen with a 3.5 cm. space between stimuli). For each participant, one stimuli in each pair was

randomly assigned to be "correct." The task was presented in 12 continuous blocks of 10 trials each. Reinforcement was probabilistic, in that each stimulus was associated with a certain percentage likelihood of reward and/or response cost. Within each block, on 70% of the trials choosing the correct stimulus was rewarded, while on 30% of the trials choosing the correct stimulus was instead associated with a response cost.

Also within each block, the "incorrect" stimulus was associated with a response cost on 70% of the trials and a reward instead on 30% of the trials. The pairs were presented in semi-random order, with no more than two in a row of the same pair. Within each pair, the "correct" stimuli were presented with equal frequency on the left and on the right. There was a 500 millisecond inter-stimulus interval between trials during which the result of the previous trial was presented. Feedback consisted of seeing the phrase "You won/lost 1 point (or token)," along with a pleasant/unpleasant sound.

The first condition was preceded by a 40-item practice trial with a single pair of unique stimuli. During this trial, points accumulated on the screen, though they did not count towards the final tally. Next, the participant began one of two randomly selected conditions: points or tokens. In the points condition, the participant earned and lost points, which accumulated on the screen in a running tally. In the tokens condition, the participant earned and lost physical tokens, which were distributed by the examiner into a small box lid situated next to the mouse. In each condition, the participant was given 5 points or tokens to start. Task instructions, presented before the practice trial, alerted participants to the probabilistic nature of the task (the rewarded stimuli might not always get the reward), and clarified that direction (right-left) was not important.

The primary outcome score for this task was the percentage of trials on which the correct stimulus was chosen. Supplemental scores were calculated to provide a more meaningful analysis of performance:

1. mean difference in percent correct between the first and second halves of the conditions (within-condition learning or *rate of learning*);
2. mean difference in the percent correct between the first and second conditions (between-condition learning or *learning savings*); and
3. *feedback sensitivity* - described by Chamberlain and colleagues[33] - calculated as the likelihood that the participant switched from a correct to an incorrect response after receiving misleading negative feedback (i.e., when the correct stimulus was associated with a response).

The type of reinforcers used in this study were chosen for ease of comparison with typical reinforcers used in the daily lives of children, as well as in research settings. A more direct method of addressing the importance of concreteness in reinforcement might utilize first order reinforcers such as candy or coins rather than points and tokens. While this would be an interesting research question, its value in terms of external validity is questionable (a typical behavioral intervention is not likely to use candy or money as a reinforcer). Therefore, points and tokens were chosen both for their functional equivalency (they were "worth" the same amount towards a prize) and their applicability to everyday settings.

Intelligence

Intelligence was measure using the Kaufman Brief Intelligence Test – Second Edition (K-BIT-2).[34] This three-subtest test measures both verbal and nonverbal intelligence and took about 20 minutes to complete.

Procedure

Before testing began, participants were told that if they earned "enough" tokens and points, they would be given their choice of one of the large prizes rather than a small prize. The amount required for a large prize was deliberately withheld to ensure that all participants gave their fullest effort throughout the tasks. When testing was complete, all participants were given their choice of a large prize, regardless of the number of tokens and points earned.

Testing typically lasted about one hour. The order of tasks was counterbalanced so that half of the participants completed the probabilistic reinforcement learning task first, while the other half completed another task (not reported here) first. Within the probabilistic task, half of the participants completed the points condition first, while the other half completed the tokens condition first. The image sets used were also varied, so that half of the participants received one image set in the points condition, while the other half received that set in the tokens condition. The K-BIT-2 subtests were administered between the experimental tasks, in their standardized order (Verbal Knowledge, Matrices, Riddles).

RESULTS

Overall Performance

In order to examine overall performance differences between groups, each participant's scores were collapsed across conditions to create an overall mean score (*see Table 2*). Although the data were not perfectly normally distributed (kurtosis: -1.211; skew: -0.043; *Shapiro-Wilk*: 0.939(36), *p* = .046), deviation was not sufficient to violate the model's assumption of normality. As hypothesized, a t-test revealed that the mean score of the control group was significantly higher than the FASD group (*t* = 3.328(35), *p* = 0.002, *d* = 1.11, all statistical tests use alpha .05). Overall task performance was not significantly correlated with age (*r* = -0.028, *p* = 0.870), and there was no

significant difference between the performance of male and female participants (*t*(34) = 0.086, *p* = 0.932). Overall performance was significantly positively correlated with full scale IQ (FSIQ) in both the FASD group (*r* = .768, p < .001) and the control group (*r* = .542, p = .02).

To examine the question of whether order (beginning with points vs. beginning with tokens) impacted performance, a 2 (Order: Points first vs. Tokens first) X 2 (Condition: Points vs. Tokens) mixed factor repeated measures ANOVA was conducted. With both groups together, there was no significant effect of Condition (*F*(1,34) = 0.001, *p* = .972), Order (*F*(1,34) = 1.369, *p* = .250), or interaction of Condition by Order (*F*(1,34) = 0.011, *p* = .915).

TABLE 2   Probabilistic Learning Percent Correct by Group

	FASD		Control	
Condition	*M*	*SD*	*M*	*SD*
Tokens	68.8	18.0	79.8	17.3
Points	63.6	17.8	84.7	15.7
First Task	65.1	16.4	83.0	15.6
Second Task	67.3	19.6	81.5	17.8
Overall	66.2	15.0	82.2	13.9

Rate of Learning and Learning Savings

Learning savings was examined using a 2 (Group: FASD vs. Controls) X 2 (Order: 1st condition vs. 2nd condition) mixed factor repeated measures ANOVA. There was no effect of Order (*F*(1,34) = 0.012, *p* = .915), nor was there an interaction between Group and Order (*F*(1,34) = 0.304, *p* = .585). Planned comparisons revealed that the groups were significantly different in both the first (*t*(34) = 3.340, *p* = .002) and second (*t*(34) = 2.287, *p* = .029) conditions.

Both groups showed a similar rate of learning. The control group showed a significant (*t*(17) = -

4.033, *p* = .001) mean improvement of 10.6 percent (*sd* = 11.2), while the FASD group showed a significant (*t*(17) = -4.458, *p* < .001) mean improvement of 8.4 percent (*sd* = 8.0). The group difference in improvement was not significant (*t*(34) = 0.672, *p* = .506).

Concreteness of the Reinforcer

Probability reinforcement learning using points versus tokens was compared to assess whether there was a difference between learning under abstract reinforcers (points) versus more concrete reinforcers (tokens), both of equal "worth." To

examine this question, a 2 (Group: FASD vs. Controls) X 2 (Condition: Tokens vs. Points) mixed factor repeated measures ANOVA was conducted. The dependent variable was defined as the percent correct choices. Contrary to the predicted outcome, FASD and Control children did not have a differential pattern of responses to the type of reinforcer. Neither Condition ($F(1,34) = 0.001$, $p = .971$) nor Condition by Group interaction ($F(1,34) = 2.625$, $p = .114$) were significant (*see Figure 1*; bars represent 95% confidence interval). Planned comparisons using

paired t-tests revealed that neither the control group ($t(17) = 0.1.168$, $p = .259$) nor the FASD group ($t(17) = -1.127$, $p=.275$) showed a significant difference between the points and tokens conditions. Interestingly, planned post-hoc independent samples t-test showed a significant mean group difference between controls and participants with FASD in the points condition ($t(34) = 3.765$, $p = .001$), but failed to reach significance level in the tokens condition ($t(34) = 1.865$, $p = .071$).

FIG. 1   Probabilistic Learning: Points vs. Tokens
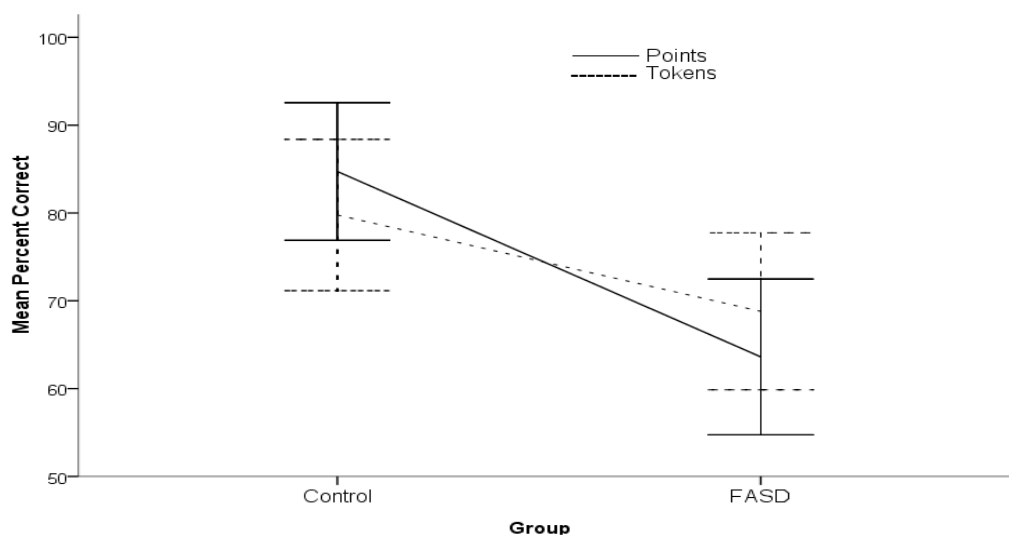
Response to Misleading Feedback

A trial was defined as providing misleading feedback if the participant chose the correct stimulus, but received a response cost rather than a reward. *Percent switches following misleading trials* were defined as the percent of misleading trials where the participant chose the incorrect stimulus on the next trial with the same image pair. The median percent of switches following

misleading trials was 8.9 in the Control group (range: 1.4 – 79.8), and 37.0 in the FASD group (range: 3.0- 58.5). Due to the highly skewed nature of this variable, the non-parametric Mann-Whitney test was used to examine group differences. This difference was significant ($U = 74.50$, $N_1 = 18$, $N_2 = 18$, $p = .006$).

Within the FASD group, percent switches following misleading trials was significantly

negatively correlated with FSIQ (r_s = -.504, p = .033), and approached significance in controls (r_s = -.433, p = .073). The majority (78%; n = 14) of participants in the FASD group made this type of error on greater than 25% of the trials. In contrast, a minority (22%; n = 4) of control participants made this type of error on greater than 25% of trials. Neither group showed a large improvement in response to misleading feedback between the first and second halves of the tasks (Control group mean improvement: 6.57(sd = 12.61); FASD group mean improvement: 3.92 (sd: 14.29); t (34) = 0.589, p =.560).

Furthermore, utilizing a repeated measures ANOVA, children with FASD and Controls had a significantly different response in mean reaction time in the trial directly following a misleading response (F(34) = 4.155, p = 0.049). Controls in general showed a trend toward slowing of reaction times following unexpected feedback (i.e., post-error slowing), while children with FASD showed the opposite trend.

DISCUSSION

Results from the current study showed that overall probabilistic reinforcement learning was significantly slower in the FASD group who overall exhibited more responses that were incorrect. The effect size for this group difference was large, suggesting a meaningful difference between the groups. However, if individuals with FASD have a true dysfunction of the reinforcement learning system, probabilistic reinforcement learning might be expected to reveal a different pattern of learning (e.g., very slow learning curve, flat learning curve). Taking a closer look at probabilistic reinforcement learning in the current study, the groups actually showed similar rates of improvement from the first to the second halves of the probabilistic tasks (rate of improvement), while neither group showed significant improvement between the first and second probabilistic conditions (learning savings). Together, these findings suggest that probabilistic reinforcement learning in these children with FASD proceeds in a manner similar to general learning: while learning is slower, evidence does not support that the process is abnormal. One significant difference between the groups is that children with FASD were less likely than children

in the control group to learn by synthesizing information over multiple trials. Rather, reinforcement learning in children with FASD appeared to be more strongly influenced by the most recent information. This is consistent with animal research which suggests particular difficulty for fetal alcohol exposed animals with alterations in the pattern of contingencies (e.g., changes in the rate of reinforcement, reversal learning).[15-25]

Concreteness of Reinforcers
The token economy is a behavioral management system frequently employed with individuals with special needs such as intellectual disability, ADHD, autism, and behavioral disorders. In this system, individuals earn and may also lose tokens based on a formal set of rules. Tokens are typically traded for rewards including tangible goods or privileges. Furthermore, systems of rewards and punishments are frequently advocated for typically-developing children to promote prosocial behavior and reduce unwanted behavioral problems. [35, 36] In addition to formal contingency management systems, successful navigation of everyday life requires learning from one's own mistakes and successes based on both tangible/concrete (e.g., being given a cookie for doing a chore, burning your hand after touching a hot stove) and intangible/abstract (e.g., praise, disapproving looks) reinforcement.

One goal of the present study was to test whether speed of probabilistic reinforcement learning differed based on the abstract/concreteness of the reinforcers. It was hypothesized that children with FASD would respond differently to the two conditions, while the control group would not. The direction of the hypothesis was not specified, as a dysfunctional reinforcement learning system could cause impairment in either direction.

As expected, the control group showed equivalent performance regardless of the abstractness of the reinforcers. Unexpectedly, the FASD group also showed no difference between the two conditions. Interestingly, the control group demonstrated a slightly higher mean score in the points condition compared to the tokens condition, while the FASD group showed the opposite pattern. This does raise the possibility that with a larger sample size, significant findings may emerge. However, lack of within-group differences in either group suggests that the

current study must conclude that neither type of reinforcement is more effective than the other. Although individuals with FASD are frequently noted to have difficulty with abstract concepts, this difficulty did not appear to extend to abstractness of reinforcers in this study. Overall, findings from the study support the notion that reinforcement learning mechanisms in individuals with FASD are not fundamentally different from those of matched controls.

Limitations and Directions for Future Research
The reinforcement learning task in this study included both reward and response cost. Research from patients with Parkinson's disease has shown that increasing levels of dopamine facilitated learning from rewards, while the natural decreased levels of dopamine associated with the disease may actually facilitate learning from response costs.[37] As the current study was not designed to compare methods of reinforcement, there is no way to know whether using both types of reinforcement might obscure deficits in learning from one or the other.

This study was designed to investigate various aspects of reinforcement learning, both within and between groups. As such, there was no condition without reinforcement. A no-reinforcement baseline condition would be very useful in separating learning in general from reinforcement learning. However, given that a no-reinforcement condition could be seen as withdrawal of reward (i.e. punishment), this type of study may be best examined using subgroups, each assigned to separate conditions. With the small sample size in the current study, this type of design was not feasible.

An important limitation to the generalizability of this study is the representativeness of the groups. For instance, all participants in the FASD group lived in stable home situations at the time of testing (with only one child in their current home less than four years). In order to minimize self selection of only children from the most stable families, and to make participation open to the broadest range of children, testing was frequently conducted in the family's home, or in a location close to their home. Nonetheless, the practicalities of participating in research in the community meant children in stable homes were more likely to participate. Furthermore, given the

inclusion criteria, it is clear that all participants had some confirmed prenatal alcohol exposure, but the levels of exposure were not consistent across the FASD participants and not all participants were necessarily exposed to high levels of alcohol. This inconsistency could limit the ability to find group differences.

Individuals with FASD are a diverse group with varying levels of cognitive ability. The current study included participants with all diagnoses on the fetal alcohol spectrum, but without significant intellectual deficits. This served to increase generalizability across the fetal alcohol spectrum and helped assure that any differences were not due to a lack of understanding the task directions. However, the current findings do not necessarily generalize to individuals with FASD who have intellectual disabilities. Due to the small sample size and the fact that the groups were not matched for IQ, this study was unable to determine if the findings were due to prenatal alcohol exposure or merely lower IQ in the FASD group. Covarying is one method for dealing with group differences in IQ. However, it has been argued that IQ should not be used as a covariate in neurodevelopmental disabilities[38] as intellectual disability is characteristic of FASD, and therefore removing the effects of lower intelligence removes some of the true effects of prenatal alcohol exposure. Future studies should examine reinforcement learning in children with FASD and IQ-matched controls without alcohol exposure to determine if the learning difference is alcohol related or is simply a function of lower IQ. Another important limitation to this sample was that the groups were not matched for ethnicity. Future studies would benefit from matching for ethnicity in order to ensure that group differences are not influenced by ethnic differences.

Although their exact mechanism is unknown, psychostimulant medications which facilitate release and block re-uptake of the neurotransmitters norepinephrine and dopamine have been found to be effective in treating ADHD[39,40], frequently comorbid with FASD. It has been suggested that psychomotor stimulants alter the neurochemistry of the striatum causing behavior to come under increasing control by reinforcement contingencies.[41]

Also, psychostimulants may improve response to reinforcement indirectly through increased

attention and concentration. In contrast, Risperidone, the atypical antipsychotic prescribed to four participants in the FASD group (in combination with psychostimulants in every case, although one had abstained for 24 hours), is a dopamine antagonist with high affinity for D2 dopaminergic receptors.[42] Medication status of participants in the FASD group could have impacted performance on the reinforcement tasks in this study. Unfortunately, previous research does not provide sufficient guidance to predict how these medications might or might not impact reinforcement learning. Ideally, medication status would have been consistent across participants. Alternatively, with a larger sample size, medication status could be examined as a variable of interest.

The current study was designed to tap into basic reinforcement learning mechanisms in a laboratory setting. This type of research takes place in a highly controlled environment, with specific task instructions, one-on-one interactions, and generally a lack of distractions. Therefore, it would be interesting to examine responses to behavioral consequences in a natural environment. Given the large amount of inter-individual variation in children with FASD, an A-B-A design, where the target behavior is measured for each individual before, during and after an intervention, would be appropriate. Having children with FASD serve as their own control group would also be useful due to the difficulty of matching children with FASD to peers with similar family, ethnic, and socio-economic backgrounds.

Clinical Implications
Reinforcement learning was chosen as a focus for this study because it is a function often cited as deficient in individuals with FASD, but which has received minimal research attention in the human population. Outside of reinforcement learning, there is strong evidence from research into learning in general that although individuals with FASD are typically slow to encode new information, learning with repetition does occur, and retention of learned information is generally intact. The current study raises the possibility that

reinforcement learning may operate similarly: reinforcement learning may be slower, but is effective for learning. In this sample of children with FASD, there was no evidence that reinforcement learning mechanisms were fundamentally altered, though response to reinforcement seemed to be more likely to be impacted by the most recent information rather than integration of information over the long-run.

There is much variability under the fetal alcohol spectrum, and thus this study must not be over-generalized to apply to all individuals with FASD. For example, given the within-group positive correlation between probabilistic reinforcement learning and intellectual function, the findings may not apply to individuals with FASD who have intellectual impairments.

Although it is not possible to generalize this study to all children with FASD, it is worthwhile to explore the possible clinical implications. First, this study supports the notion that individuals with fetal alcohol exposure *can* learn from the consequences of their behavior. As such, behavioral interventions should not be ruled out or avoided as an option for intervention. However, the second and equally important conclusion is that *learning from reinforcement will take individuals with FASD more repetition and consistency.* Without this knowledge, frustration and hopelessness (and giving up) may set in before learning takes place.

Another important caveat is that reinforcement learning is only one piece of what is required for successful behavioral interventions. Behavioral interventions could fail for a number of reasons, even in the context of intact reinforcement learning. For example, there could be problems with the application of the intervention. Children with FASD often experience chaotic environments, multiple home placements, or other challenging situations which could be associated with inconsistent reinforcement, unclear expectations, unrealistic expectations, etc. In addition, children with FASD are frequently cited as having difficulty with transfer of learning, as can be seen in McInerney (unpublished manuscript 2007). Therefore, learning consequences in one particular environment (the classroom), may not generalize to another environment (a different classroom or the playground).

Furthermore, problems with impulsivity may mean that learned consequences do not always successfully guide behavior. Finally, children may have difficulty applying learned consequences to complex situations with multiple demands. Clearly, the findings from this study are but one piece of the puzzle in understanding reinforcement learning mechanisms in children with FASD.

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