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Deliberative Choice Strategies in Youths: Relevance to Transdiagnostic Anxiety Symptoms

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Abstract

Aberrant decision-making characterizes various pediatric psychopathologies; however, deliberative choice strategies have not been investigated. A transdiagnostic sample of 95 youths completed a child-friendly sequential sampling paradigm. Participants searched for the best offer by sampling a finite list of offers. Participants' willingness to explore was measured as the number of offers sampled, and ideal task performance was modeled using a Markov decision-process model. As in previous findings in adults, youths explored more offers when lists were long compared with short, yet participants generally sampled fewer offers relative to model-estimated ideal performance. Searching deeper into the list was associated with choosing better price options. Analyses examining the main and interactive effects of transdiagnostic anxiety and irritability symptoms indicated a negative correlation between anxiety and task performance ($p = .01$, $\eta_p^2 = .08$). Findings suggest the need for more research on exploratory decision impairments in youths with anxiety symptoms.

Keywords

decision-making, computational modeling, exploration, anxiety, irritability

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Decision-making difficulties occur in people affected by various pediatric psychopathologies (Paulus, 2007; Sonuga-Barke et al., 2016). On information-sampling tasks, deliberative choice strategies quantify individuals' willingness to explore to acquire additional information (Averbeck et al., 2013). Although ample research has been conducted on this construct in healthy adults (Costa & Averbeck, 2015; Vicario-Feliciano et al., 2019), no study has extended this to youths with psychiatric illness. Thus, it remains unknown whether deliberative choice strategies relate to pediatric clinical phenotypes. Such information may help to parse co-occurring symptom dimensions, such as anxiety and irritability (Brotman et al., 2017; Leibenluft, 2017; Pine, 2007), both of which have been linked with patterns of aberrant decision-making (Deveney, 2019; Miu et al., 2008; White et al., 2017). In the current study, we investigated associations between willingness to explore future

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choices and anxiety and irritability in a transdiagnostic pediatric sample.

Information sampling refers to a form of value-based decision-making that reflects an individual's willingness to explore unknown options to acquire information. Sequential sampling tasks mimic information sampling that occurs during real-world "best choice" problems, in which one must decide whether to accept or forgo known options. If an option is not chosen, an individual then explores in search of a better option. For example, when booking travel, one could select an available flight today for a known price or wait, hoping that the price will decrease but risking that it could increase. Thus, decision-making in the context of sequential sampling requires weighing the value of accepting current choices against the value of risky exploration of future options. Sequential-sampling paradigms have been used to quantify adults' behavioral performance and map neural circuitry related to choosing an available option compared with passing (to explore further; Costa & Averbeck, 2015; Furl et al., 2019; Vicario-Feliciano et al., 2019). Across species, willingness to explore is critical to survival by facilitating risk evaluation, foraging, and mate selection (Mehlhorn et al., 2015). Healthy adults deploy exploration strategies flexibly in a situation-dependent fashion (Wilson et al., 2014), and maturation of this skill comes in late adolescence (Somerville et al., 2016).

Parallels can be drawn between value-based decision-making in information-sampling tasks and decision-making in canonical risk-taking tasks such as the Balloon Analogue Risk Task (BART), in which participants must weigh the relative value of seeking potential reward against an increasing risk of failure (Lejuez et al., 2002). On these tasks, risky decision-making follows a quadratic developmental trajectory, peaking in adolescence before decreasing into adulthood (Braams et al., 2015). Prior evidence linking risk taking with forms of nonstrategic exploration suggests that risk tolerance in the context of explore-exploit paradigms may index one mechanism underlying willingness to explore (Somerville et al., 2016).

Irritability and anxiety are two common, burdensome, and co-occurring pediatric symptom dimensions (Brotman et al., 2017; Leibenluft, 2017; Pine, 2007). These symptom dimensions appear to involve distinct deficits in decision-making. Individuals with elevated anxiety tend to exhibit more cautious behavior when making decisions both naturalistically and on cognitive tasks. This is consistent with hypersensitivity to errors, decreased risk taking, and increased avoidance seen in both pediatric (Filippi et al., 2020; White et al., 2017) and adult samples (Ladouceur et al., 2000; Miu et al., 2008). This may further reflect altered processing of uncertainty and ambiguity (Grupe & Nitschke, 2013; Hartley & Phelps, 2012; Moser et al., 2013; Paulus, 2007). Cognitive biases in anxiety may exacerbate these effects such that a greater tendency to anticipate negative outcomes in the context of uncertainty leads to increased risk avoidance (Smith et al., 2016) independent of negative mood states (Maner et al., 2007). Indeed, across empirical studies, anxiety correlates with many signs of caution, including novelty aversion, greater anticipation of and response to negative outcomes, and risk avoidance (Hartley & Phelps, 2012; Moser et al., 2013). Collectively, this work suggests that individuals with anxiety may be less likely to engage in exploratory behaviors given the inherent uncertainty of outcomes and potential risk involved.

With respect to irritability, the literature on effects of uncertainty and ambiguity on decision-making is sparse. Studies of irritability have found reduced error monitoring (Deveney, 2019; Filippi et al., 2020) and atypical striatal prediction error signaling (Adleman et al., 2011; Deveney et al., 2013), patterns unlike those found for anxiety. In fact, research on phenotypes related to irritability has found signs of greater risk tolerance and impulsivity. For example, attention-deficit/hyperactivity disorder (ADHD) symptoms, which commonly co-occur with irritability (Eyre et al., 2019), include impulsive behaviors. However, findings for decision-making in ADHD are mixed, and there is evidence of both cautious (Humphreys et al., 2018) and risky behavior (Garon et al., 2006). Research on negative urgency may also provide insight. Negative urgency is characterized by impulsive and risky decision-making, particularly in the context of a heightened negative emotional state (Cyders & Smith, 2008). Although no study has directly linked negative urgency and irritability, both share associations with heightened amygdala activity to negative emotional stimuli (Gagnon & Rochat, 2017; Kircanski et al., 2018); thus, data on negative urgency may inform predictions regarding irritability and exploratory behaviors.

No study of either pediatric anxiety or irritability has examined willingness to explore unknown options to sample additional information within the context of an information-sampling task. In one prior study, pediatric psychopathology was broadly linked to reduced exploration (Humphreys et al., 2015). Because anxiety and irritability commonly co-occur (Brotman et al., 2006, 2017; Copeland et al., 2015; Leadbeater & Homel, 2015; Savage et al., 2015; Stringaris & Goodman, 2009), it is critical to assess both phenotypes to identify shared associations compared with specific associations.

In the current study, we modified a sampling task for use in youths (Costa & Averbeck, 2015; Vicario-Feliciano et al., 2019). First, we aimed to validate the developmental

feasibility of this adapted paradigm by attempting to replicate patterns observed in adults. We predicted that willingness to explore, as measured by individual differences in the number of choice options sampled before stopping and the comparison of participants' stopping behavior with a computational model-derived ideal performance (as estimated using a Markov decision-process [MDP] model; Costa & Averbeck, 2015), would be greater when participants were presented with a longer list of options compared with a shorter list of options. We also expected that willingness to explore would predict choosing the better priced option. Exploratory analyses were conducted to examine age effects.

Second, we examined how willingness to explore is associated with anxiety symptoms, irritability symptoms, and their interaction. We predicted that higher anxiety symptoms would be associated with reduced exploratory behavior and impaired performance on the task. Although few studies have examined decision-making in irritability, past research suggests alternative possibilities. Some studies suggest co-occurring irritability may index a more severe clinical presentation of anxiety (Cardinale, Kircanski, et al., 2019; Cornacchio et al., 2016; Hommer et al., 2014) such that the effect of anxiety (i.e., reduced exploratory behavior) would be accentuated in the context of higher irritability. In contrast, if irritability shares features with impulsivity and risk taking, it might be associated with excessive exploratory behavior and impaired performance on the task.

Method

Participants

Ninety-five youths ages 8 to 18 years (M = 13.04, SD = 2.50; 54.70% female) were recruited from the community. In our sample, age was normally distributed, $W(95)$ = 0.98, p = .104 (see Fig. S1 in the Supplemental Material available online). To obtain wide variability in levels of anxiety and irritability, we focused our recruitment on four diagnostic groups: youths with a primary diagnosis of an anxiety disorder (generalized, social, and/or separation anxiety disorder), disruptive mood dysregulation disorder (DMDD), or ADHD and youths with no psychiatric diagnosis (Table 1; see Table S1 in the Supplemental Material). Before participation, diagnostic status was assessed by a licensed doctoral- or master's-level clinician using the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime version (KSADS-PL; Kaufman et al., 1997) and was reviewed by a board-certified child and adolescent psychiatrist or clinical psychologist (D. S. Pine, M. A. Brotman, or E. Leibenluft) for consensus. IQ was assessed using the Wechsler Abbreviated Scale Intelligence (Wechsler, 2011). Exclusion criteria were IQ less than 70; diagnosis of an autism spectrum disorder, posttraumatic stress disorder, schizophrenia, or major depression; use of any (nonprescribed) substance with psychoactive effects within 3 months of participation; and neurological disorder. Patients with a primary anxiety disorder were recruited as part of a larger treatment

Table 1. Sample Characteristics

Variable	Value
Demographic variable	
Age (years)	M = 13.04 (SD = 2.50)
Sex (% female)	52 (54.70%)
IQ	M = 110.99 (SD = 13.04)
SES[a]	M = 37.16 (SD = 18.94)
Race	
White	62 (65.26%)
Asian	3 (3.16%)
Black or African American	17 (17.89%)
American Indian or Alaskan Native	2 (2.11%)
Multiple races	9 (9.47%)
Ethnicity	
Unknown	2 (2.11%)
Not Hispanic or Latino	86 (90.53%)
Hispanic or Latino	9 (9.47%)
Clinical measure	
ARI total score	M = 2.41 (SD = 2.95)
SCARED total score	M = 14.71 (SD = 14.70)
Diagnosis[b]	
ADHD	10 (10.53%)
Anxiety disorder	26 (27.37%)
DMDD	23 (24.21%)
None	36 (37.89%)
Medications[c]	
None	76 (80.00%)
SSRI	8 (8.42%)
Stimulant	9 (9.47%)
SGA	2 (2.11%)
AED	2 (2.11%)

Note: Values are ns with percentages in parentheses unless otherwise specified. ARI = Affective Reactivity Index (Stringaris et al., 2012); SCARED = Screen for Child Anxiety Related Disorders (Birmaher et al., 1997); ADHD = attention-deficit/hyperactivity disorder; DMDD = disruptive mood dysregulation disorder; SSRI = selective serotonin reuptake inhibitor; SGA = second-generation antipsychotic; AED = antiepileptic drugs.
[a]Socioeconomic status (SES) is based on current occupation and highest level education of the participant's parents. [b]Diagnosis refers to the primary diagnosis for which the participant was referred. Participants could have multiple diagnoses in addition to their primary diagnosis. [c]Participants could be taking more than one type of medication. For seven participants, no medication information was provided within 6 months of testing.

trial that had additional exclusionary criteria, including significant trauma-related or depressive symptoms or use of psychotropic medication. Before participation, written informed consent and assent were obtained from parents and youths, respectively. Participants received monetary compensation for participation. All study procedures were approved by the National Institute of Mental Health Institutional Review Board (IRB).

Symptom measures

Anxiety symptoms were assessed using the Screen for Child Anxiety Related Emotional Disorders (SCARED) parent- and youth-report forms (Birmaher et al., 1997). Irritability symptoms were measured using the Affective Reactivity Index (ARI) parent- and youth-report forms (Stringaris et al., 2012). Total scores were averaged across parent- and youth-report versions for each measure. In a subset of participants (n = 77), hyperactive-impulsive symptoms were assessed using the parent-report Conners Comprehensive Behavior Ratings Scale (CBRS) DSM Hyperactivity-Impulsivity subscale (Conners et al., 2011; M = 7.83, SD = 7.59).

Shopping task

Experimental design. Participants completed a sequential sampling paradigm, similar in structure to a task used previously in healthy adults (Costa & Averbeck, 2015; Vicario-Feliciano et al., 2019) but modified to be child-friendly (Fig. 1). The task proceeded in 28 randomized decision blocks. Participants were instructed that in each block, they would see a series of either eight or 12 sequential price options (trials) for a given item (e.g., icecream sundae, sneakers) and that participants' goal was to select the lowest price option for that item. Participants were informed at the start of each block whether it included eight or 12 options (14 blocks of each quantity). The locations of the lowest price option were pseudorandomized across blocks to ensure an equal distribution of trials with the best priced option. On each trial, participants could either accept or decline the presented price. If participants accepted the price, the block would end, and no additional price options would be shown. If participants declined the price, they were presented with the next option and could not return to the declined option. Thus, the task assessed participants' behavioral propensity to explore the price options. In each block, participants won \$1 for choosing the lowest (best) price option, \$0.50 for the second-best price option, and \$0.25 for the third-best price option. Participants could accumulate a maximum of \$28 during the task according to their performance (in addition to standard compensation for study participation). In accordance with institutional IRB procedures, participants could be compensated up to \$25 in task winnings following completion of the task; thus, actual compensation did not exceed \$25. Following completion of the task, participants self-reported levels of frustration and happiness using separate 5-point Likert scales.

Task behavior was quantified consistently with previous standards (Cohen et al., 2007; Costa & Averbeck, 2015; Vicario-Feliciano et al., 2019). *Mean choice rank* was used to index overall performance; a value of 1 indicated that the best price option was chosen per block, and a value of 8 or 12 (depending on the block) indicating that the worst price option was chosen per block. Lower mean choice rank indicated better overall performance. *Mean choice number* was used to index how many price options the participant typically sampled per block; a value of 1 indicated that the participant chose the first presented option and 8 or 12 (depending on the block length) indicating that the participant chose the last presented option. Thus, a lower mean choice number indicates less willingness to explore options to come.

Computational modeling. Task behavior was also indexed using a computational MDP model (Costa & Averbeck, 2015). The MDP model calculated the value of either accepting or declining each price for a given item. Value was operationalized as the expected reward value of the currently presented price compared with the expected value of continuing to sample options as a function of the probability that better options were to appear later. For details of the MDP model, see Supplemental Text and Figure S2 in the Supplemental Material, including the formal equations. These calculations were used to generate model-derived measures of exploration on the task, indicating the sampling behavior of an ideal strategy whereby the precise value of accepting or declining each price could be modeled.

Participants' stopping behavior on each block was compared with the point at which the MDP model would stop sampling and take the current price (i.e., the expected value of the current price exceeded the expected value of continuing to sample). For each participant, this difference was summarized as the *mean difference from ideal sampling* by calculating the difference, across all blocks shown to the participant, between the number trial at which the participant stopped sampling and the number trial at which the MDP model stopped sampling. A negative mean difference from ideal sampling would indicate that the participant chose to stop sampling earlier than the model-derived ideal, potentially reflecting less willingness to explore unknown options.

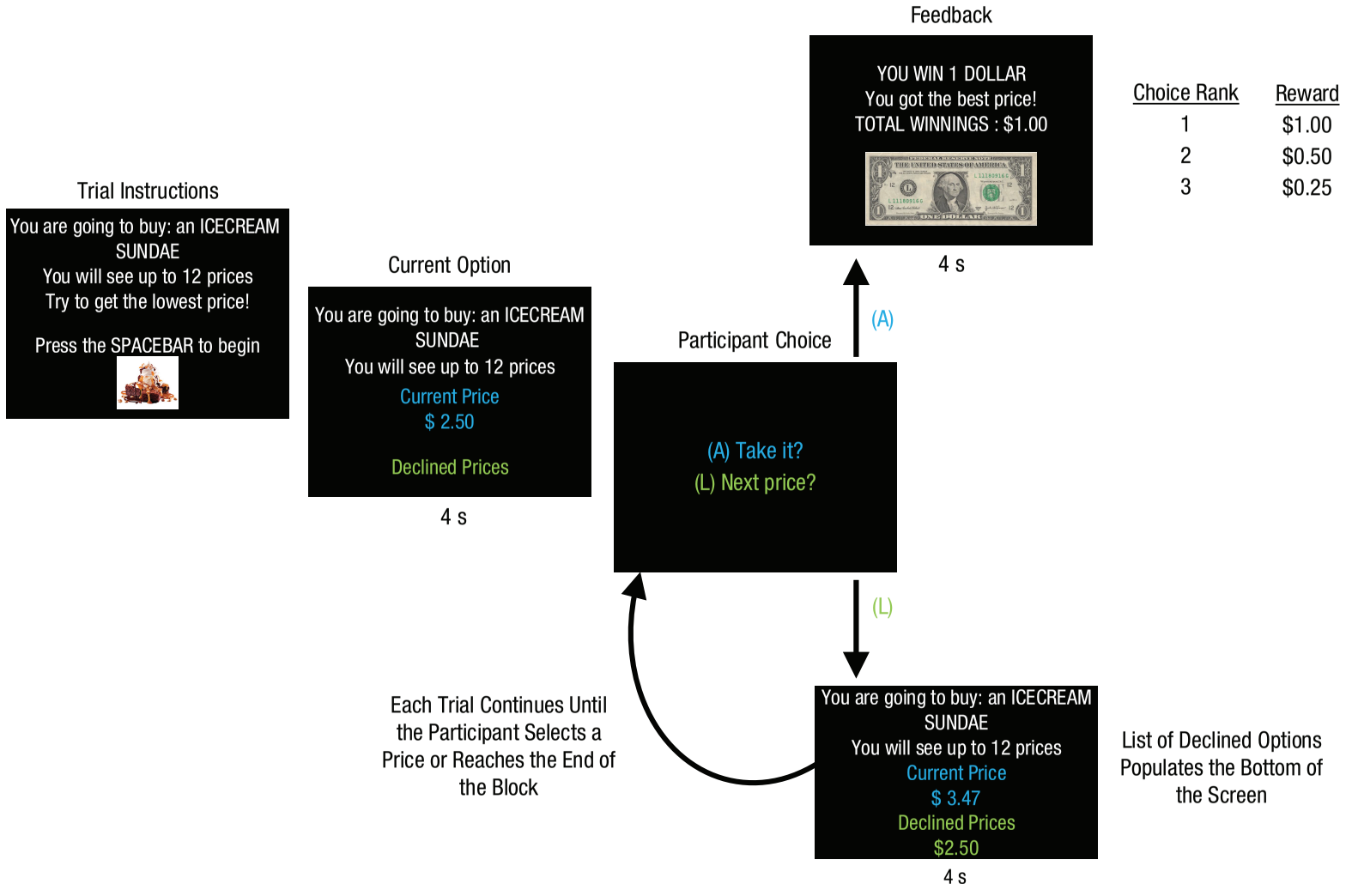

Fig. 1. Task schema for the sequential-sampling task.

Data analysis

To minimize undue influence of potential outliers, we first winsorized all clinical and task-performance variables. Values greater than 2.5 *SD* from the mean were set at the respective 2.5 *SD* value for each variable. Winsorizing the data affected 11 out of 950 data points across six of the 95 participants. Critically, taking this approach allows for the inclusion of these data points in analyses while minimizing the degree of leverage exerted on our linear models. Data were analyzed using IBM SPSS (Version 25). A series of repeated measures analyses of covariance (ANCOVAs) was used to examine task performance as a function of block type (eight vs. 12 price options) and SCARED average score, ARI average score, and their interaction. To investigate whether exploratory behavior was associated with the selection of better price options, we conducted separate linear mixed models with mean choice number and mean difference from ideal sampling predicting mean choice rank. For each model, block type was a within-subjects factor, and exploratory behavior (mean choice number or mean difference from ideal sampling) was a time-varying (i.e., block type) covariate.

Results

Participant demographic and clinical characteristics are shown in Table 1. There was no significant association of SCARED or ARI score with age, IQ, or sex, all *p*s > .05 (see Table S2 in the Supplemental Material). Participants, on average, reported high levels of happiness (M = 4.36, SD = 0.85) and low levels of frustration (M = 1.61, SD = 0.91) following completion of the task. Participant winnings ranged from \$3.00 to \$25.00 (M = \$11.82, SD = \$3.19). With respect to the task-performance variables, mean choice rank ranged from 1.95 to 6.10 (M = 3.46, SD = 1.00), mean choice number ranged from 1.75 to 6.18 (M = 3.75, SD = 0.82), and mean difference from ideal ranged from −3.54 to 1.05 (M = −1.57, SD = 0.94). Lower mean choice rank (i.e., better performance) was associated with higher IQ, $r(92) = -0.21$, $p = .049$ (see Table S2 in the Supplemental Material). There was no significant association between task performance and self-reported frustration or happiness (all *p*s > .10).

Task performance

Results of repeated measures analyses of variance indicated that, as expected, participants sampled fewer options when eight options were available (M = 3.35, SD = 0.70) than when 12 options were available (M = 4.14, SD = 1.13), $F(1, 94) = 65.31$, $p < .001$, $\eta_p^2 = .41$. Block types did not differ significantly in mean choice rank (eight options: M = 3.41, SD = 0.82; 12 options: M = 3.52, SD = 1.38), $F(1, 94) = 0.93$, $p = .337$, $\eta_p^2 = .01$. With respect to mean difference from ideal, participants stopped sampling relatively earlier compared with ideal sampling when 12 options were available (M = −2.33, SD = 1.31) than when eight options were available (M = −0.81, SD = 0.77), $F(1, 93) = 206.58$, $p < .001$, $\eta_p^2 = .69$.

Results of separate linear mixed models indicated significant main effects of both mean choice number, $F(1, 185) = 14.97$, $p < .001$, and mean difference from ideal, $F(1, 180) = 19.05$, $p < .001$, on mean choice rank such that increased sampling predicted choices of lower/better overall price options. There was no significant interaction between block type and mean choice number, $F(1, 117.09) = 3.45$, $p = .066$, or mean difference from ideal, $F(1, 117) = 1.79$, $p = .183$, indicating that this association did not differ by block type (see Fig. S3 in the Supplemental Material).

Associations with age

Separate repeated measures ANCOVAs examined participant age in relation to task performance. Results revealed no significant main effect of age on mean choice rank, $F(1, 93) = 0.42$, $p = .521$, $\eta_p^2 = .004$; mean choice number, $F(1, 93) = 0.27$, $p = .602$, $\eta_p^2 = .003$; or mean difference from ideal, $F(1, 92) = 0.003$, $p = .957$, $\eta_p^2 < .001$. In addition, there was no significant interaction between age and block type on mean choice rank, $F(1, 93) = 0.63$, $p = .428$, $\eta_p^2 = .01$; mean choice number, $F(1, 93) = 0.17$, $p = .683$, $\eta_p^2 = .002$; or mean difference from ideal, $F(1, 92) = 0.21$, $p = .648$, $\eta_p^2 = .002$.

Associations with clinical symptoms

Next, we examined associations between task performance and clinical symptoms (see Fig. S4 in the Supplemental Material). Results of repeated measures ANCOVAs revealed a significant main effect of SCARED score predicting mean choice rank, $F(1, 85) = 7.04$, $p = .010$, $\eta_p^2 = .08$, such that higher SCARED scores were associated with choosing worse/higher priced options on average (i.e., worse ranked options; see Fig. S5 in the Supplemental Material). A trend-level main effect of higher SCARED score predicting lower mean choice number also emerged, $F(1, 85) = 3.80$, $p = .055$, $\eta_p^2 = .04$, whereby higher SCARED scores trended with a lower mean choice number, indicating less exploration of future options. There were no significant main effects of ARI score, *p*s > .10. Examining interactions between SCARED and ARI scores, we observed only a trend-level effect in predicting mean choice rank, $F(1, 85) = 3.76$,

$p = .056$, $\eta_p^2 = .04$ (see Table S3 in the Supplemental Material).

Given the association between mean choice rank and IQ, we repeated the analysis including IQ as a covariate. Inclusion of IQ in the model did not affect the significant main effect of SCARED score, $F(1, 82) = 8.59$, $p = .004$, $\eta_p^2 = .10$, or the interaction effect between SCARED and ARI scores, $F(1, 82) = 3.36$, $p = .070$, $\eta_p^2 = .04$, which remained only a trend-level effect (see Table S4 in the Supplemental Material).

In the subset of participants with parent-report CBRS scores ($n = 77$), hyperactive-impulsive symptoms were associated with both ARI, $r(73) = 0.38$, $p = .001$, and SCARED, $r(77) = 0.24$, $p = .037$, scores but were not significantly related to measures of task behavior (all $|r|$s $< .13$, all ps $> .10$). Note that the inclusion of CBRS hyperactivity-impulsivity score as a covariate in the repeated measures ANCOVA did not mitigate the significant main effect of SCARED score in predicting mean choice rank, $F(1, 65) = 5.46$, $p = .022$, $\eta_p^2 = .07$.

Discussion

The current study is the first to investigate willingness to explore within the context of an information-sampling paradigm in relation to pediatric psychopathology. Results suggest that our modified, child-friendly sequential-sampling task generates expected patterns of performance. Task effects were consistent with those observed in adults, and no age effects emerged in the current sample. Thus, willingness to explore as measured by this task specifically may remain stable from middle childhood into adulthood. Furthermore, higher anxiety symptoms correlated with poorer task performance. Below we discuss these findings with respect to previous empirical work along with future extensions.

As in adults (Costa & Averbeck, 2015), participants exhibited strong block type effects. Specifically, participants sampled fewer options when presented with eight-option lists compared with 12-option lists. They also sampled fewer options than an ideal strategy would have (as estimated by the MDP model), and this difference was greater when searching through 12-option lists compared with eight-option lists. However, there was no difference in mean choice rank between block types given that youths chose options with an average rank of approximately 3.5 in both block types.

Note that we were able to apply the MDP model developed in adults (Costa & Averbeck, 2015) to youths. This computational approach enables modeling of the comparative value of accepting an option compared with declining an option on each task trial. The MDP defines the optimal choice strategy for the task, providing a computationally derived benchmark for participants' behavior. Applying this model to the current sample, we were able to extract a measure of exploration relative to ideal sampling, and this variable demonstrated consistent task effects as observed in adults. Further providing confidence in the application of the MDP model in the current sample, our evaluation of model output (see Fig. S2 in the Supplemental Material) confirmed comparable patterns with those previously observed in adults. Costa and Averbeck (2015) used this same model to map the associated neural circuitry; they found that activity in the insula, dorsal anterior cingulate, striatum, and frontoparietal regions related to choosing an available option compared with passing (to explore further). Given the developmental feasibility of this modified task and MDP model, future studies may extend this work to the neural substrates of deliberative choice strategies in developmental psychopathology.

As predicted, higher levels of anxiety symptoms were associated with choosing worse price options (mean choice rank). Furthermore, we observed a trend-level effect in which higher anxiety symptoms were associated with less willingness to explore (mean choice number). There were no significant main or interactive effects of irritability symptoms on any task-behavior variables. Given these findings and the robust association between exploratory behavior and choosing better price options across the sample, it may be that this study is underpowered to detect potential associations between anxiety and more nuanced measures of exploration compared with the global measure of task performance. In addition, specific characteristics of anxiety disorders, for example, degree of avoidance behavior, may show more robust associations with task-assessed exploration compared with overall anxiety symptom severity.

Findings for anxiety in the current study demonstrate consistent patterns with other studies of decision-making. These patterns link anxiety to a cautious approach to decision-making. Thus, poor decision-making associated with reduced exploration manifests in the current study on an information-sampling task, whereas other studies have found alternative signs of cautious approach, such as hypersensitivity to errors. Further work should examine whether reduced willingness to explore in this task relates to other potentially important variables, such as avoidance behavior.

With respect to development, age was uncorrelated with behavior on this sequential-sampling task. Combined with the observation of expected task effects, these results suggest relative stability in task-related behavior from middle childhood to late adolescence. Prior developmental work that identified age-related effects in exploratory behaviors differs from the current study in two critical aspects (Somerville et al., 2016). First, prior work involved samples that ranged from

early adolescence to young adulthood, whereas the current study includes a younger sample; differences in age distribution may affect detection of developmental effects. Although the current study benefits from inclusion of a broad age range, a larger sample may be necessary to detect any small to moderate developmental effects across this age range. Second, past research studied exploration in the context of the explore-exploit dilemma, in which decisions to gather information regarding unknown potential rewards are pitted directly against decisions to exploit known rewards. Such tasks rely on learning multiple reward distributions, potentially amplifying age effects, whereas the current task does not. Even in prior work, only specific measures of exploration were associated with age, such as those in which decisions were made to optimize information gathering (e.g., strategic directed exploration). This suggests that different measures of exploration may follow distinct developmental trajectories. Finally, extensive longitudinal work is needed to draw any clear conclusions regarding developmental trajectories of these exploration behaviors.

Several limitations of the current study warrant discussion. First, we measured decision-making on a single task. Thus, findings may be driven by task-specific effects and not generalize to other contexts. Future work should measure willingness to explore across additional developmentally appropriate tasks. This would allow for factor analytic approaches that could be used to derive a latent variable of exploratory behavior across tasks (Cardinale, Subar, et al., 2019). Second, participants received monetary reward only for the three best ranked options, thus our measure of mean choice rank captures a wider range of options than those that received monetary reward. Future versions of the task might consider more fully dispersing rewards across the ranked options. Third, the study design did not allow for examination of any impact of affective state on task performance. On average, posttask ratings indicated high levels of happiness and low levels of frustration. Future work might consider task modifications that could induce specific mood states such as state anxiety and assess affect dynamically throughout the task. Fourth, although the current sample cuts across several psychiatric diagnoses, both irritability and anxiety are present across an even wider range of diagnoses than are included here (Cornacchio et al., 2016; Stoddard et al., 2014). Thus, future work should aim to recruit a broader transdiagnostic sample, such as depressive disorders (Stringaris et al., 2013; Vidal-Ribas et al., 2016; Zisner & Beauchaine, 2016). Fifth, although we were able to examine the influence of hyperactive-impulsive symptoms as a covariate in a subset of the sample, further work is needed in samples optimized for impulsivity to thoroughly evaluate its potential relations with exploratory behaviors. Finally, our patient sample included some youths with severe impairment such that their clinical symptoms necessitated medication. As a result, we were unable to exclude patients because of the use of psychotropic medications.

In sum, these results indicate the utility of a modified best choice sequential-sampling task in a developmental sample with varying degrees of clinical symptoms. Results also demonstrate that although anxiety and irritability commonly co-occur in youths, they are dissociable with respect to performance on the task such that anxiety, but not irritability, was associated with impaired performance. This novel task lays the groundwork for further investigation into potential decision-making dysfunction in anxious youths. If the results are replicable, it may be fruitful to consider adapting the sequential sampling task here to train and incentivize information sampling in the service of increasing exploratory behaviors under uncertainty in youths with anxiety disorders. Such an approach may serve as a promising computer-based intervention or adjunct to cognitive behavioral therapy in which youths with anxiety symptoms would receive targeted interventions or incentives aimed at increasing willingness to explore. Such an approach could have downstream effects on cognitive processes such as a decreased likelihood of anticipating negative outcomes under uncertainty. Of course, further work examining associations between changes in exploratory behaviors and such cognitive processes is needed. With respect to precision therapeutics, the current study suggests that targeting broadly diminished performance related to unwillingness to explore may be a promising avenue for future intervention in pediatric anxiety.

Transparency

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Author Contributions

E. M. Cardinale and D. Pagliaccio contributed equally to this work. D. Pagliaccio, V. Costa, B. Averbeck, M. A. Brotman, D. S. Pine, and E. Leibenluft developed the study concept. D. Pagliaccio, V. Costa, B. Averbeck, D. S. Pine, and K. Kircanski contributed to study design. Testing and data collection were performed by D. Pagliaccio and C. Swetlitz. E. M. Cardinale, D. Pagliaccio, and V. Costa performed data analysis and interpretation under the supervision of B. Averbeck, M. A. Brotman, D. S. Pine, E. Leibenluft, and K. Kircanski. E. M. Cardinale, D. Pagliaccio, H. Grassie, and K. Kircanski drafted the manuscript. All of the authors provided critical revisions and approved the final manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/2167702621991805

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