Running title: Anhedonia in a transdiagnostic sample of help-seeking youth

Relations among anhedonia, reinforcement learning, and global functioning in help-seeking youth

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Abstract

Dysfunction in the neural circuits underlying salience signaling is implicated in symptoms of psychosis and may predict conversion to a psychotic disorder in youth at clinical high-risk (CHR) for psychosis. Additionally, negative symptom severity, including consummatory and anticipatory aspects of anhedonia, may predict functional outcome in individuals with schizophrenia-spectrum disorders. However, it is unclear whether anhedonia is related to the ability to attribute incentive salience to stimuli (through reinforcement learning, or RL) and whether measures of anhedonia and RL predict functional outcome in a younger, help-seeking population. We administered the Salience Attribution Test (SAT) to 33 participants who met criteria for either CHR or a recent-onset psychotic disorder and 29 help-seeking youth with non-psychotic disorders. In the SAT, participants must identify relevant and irrelevant stimulus dimensions and be sensitive to different reinforcement probabilities for the two levels of the relevant dimension ("adaptive salience"). Adaptive salience attribution was positively related to both consummatory pleasure and functioning in the full sample. Analyses also revealed an indirect effect of adaptive salience on the relation between consummatory pleasure and both role ($\alpha\beta = 0.22$, 95% CI [0.02, 0.48]) and social functioning ($\alpha\beta = 0.14$, 95% CI [0.02, 0.30]). These findings suggest a distinct pathway to poor global functioning in help-seeking youth, via impaired reward sensitivity and reinforcement learning.

Keywords: psychosis risk, salience, negative symptoms, depression

Background

Ample evidence suggests that negative symptoms such as anhedonia and avolition relate to poor functional outcome in individuals with schizophrenia-spectrum disorders[1,2], with research demonstrating that these symptoms typically emerge prior to the onset of psychosis[3]. In youth at clinical high risk (CHR) for psychosis, negative symptom severity is associated with functional impairment across many domains and with increased likelihood of conversion to a formal psychotic disorder[3-6]. Yet, few studies have specifically examined neural and psychological mechanisms of anhedonia across the psychosis continuum.

Prior studies have suggested that the overall anhedonia construct can be understood as having both consummatory and anticipatory aspects (i.e., "liking" and "wanting")[7,8] that are each associated with distinct neural mechanisms[9]. While patients with schizophrenia and healthy controls appear to evidence similar patterns of emotional reactivity to pleasant stimuli ("liking")[10-12], patients tend to show marked deficits in reward anticipation ("wanting") relative to controls[13-17]. These findings suggest that negative symptoms in schizophrenia may reflect difficulties in adaptively attributing incentive value, or salience, to reward-predicting stimuli (evoking "wanting")[18], rather than reduced sensitivity to experienced rewards ("liking"). The process of adaptive salience attribution is critical to the ability to adjust expectations and subsequent decision-making[19,20]. This process has been formally described in reinforcement learning (RL) models, and considerable evidence supports the idea that deficits in adaptive salience attribution (via RL mechanisms such as abnormalities in reward prediction error signaling[21]) contribute to decreased motivation and goal-directed behavior observed in schizophrenia and other serious mental illnesses[22-27].

Less is known about relations between anhedonia, RL, and functioning among younger, help-seeking populations, such as individuals with CHR or very early first episode psychosis. It is possible that deficits in adaptive salience attribution are an early marker of negative symptoms and also predictive of functional outcome at earlier stages of illness, where affective symptoms are prominent. Roiser and colleagues[28] found evidence of intact adaptive salience attribution in youth at CHR, but our previous work supports the link between adaptive salience attribution and negative symptom severity, as well as

impaired functioning in individuals with early psychosis spectrum symptoms or other psychopathologies (a subset of the present sample)[29]. We have also found that youth at CHR demonstrate RL deficits and reduced neural responses to rewards, relative to healthy controls[30]. Other studies examining reward responsivity in individuals at CHR have yielded mixed findings, though some have found that these youth display diminished subjective and neurophysiological emotional reactivity to pleasant stimuli[31], which is subsequently associated with comorbid depression and anxiety, and reduced social functioning[32]. This suggests that in contrast to schizophrenia, where RL and functional deficits seem to emerge from issues with anticipatory pleasure (or "wanting"), individuals with attenuated psychosis symptoms may also experience consummatory pleasure deficits that subsequently impact RL processes and functioning.

It is also possible that diminished response to reward, along with associated impairments in RL and functioning, is not specific to youth at CHR but is instead associated with depression and/or other co-morbid, non-psychosis-related mental health concerns that may impact reward related processes across a broader spectrum of help-seeking youth. Individuals at CHR represent a heterogenous group who often present with non-psychosis-related psychopathology[33], with most not developing threshold psychosis[34]. Given the apparent clinical overlap between youth at CHR and youth with other psychiatric conditions, it may be informative to examine anhedonia and related constructs across diagnoses and classifications.

This study sought to better understand potential factors contributing to functional impairment in help-seeking youth by examining relations among anhedonia, RL, and global functioning across a continuum of psychosis-risk to early psychosis symptoms. We predicted that poorer performance on experimental measures of adaptive salience attribution would be associated with: 1) greater clinician-rated negative symptom severity, 2) decreased self-reported consummatory and/or anticipatory pleasure, and 3) poorer global functioning in a combined sample of youth with CHR or very early first episode psychosis (CHR/EP) and help-seeking youth with other diagnoses (mainly depressive, anxiety, and behavioral disorders). Given the transdiagnostic nature of symptoms across these groups and evidence of RL abnormalities in affective illness[35], we did not anticipate significant differences between those at CHR/EP versus help-seeking youth with non-psychotic disorders. However, we explored whether relations

between self-reported pleasure, adaptive salience attribution, and global functioning found in the full sample would be present when controlling for important clinical and demographic covariates (i.e., dysphoric mood, age, and clinical status). Finally, we conducted exploratory analyses to test whether self-reported pleasure would have an indirect effect on global functioning through adaptive salience attribution.

Method

Participants

Participants were recruited through the Strive for Wellness clinic, affiliated with the YouthFIRST laboratory at the University of Maryland, Baltimore County, and with the Division of Child and Adolescent Psychiatry at the University of Maryland School of Medicine. Participants were referred to the study for either potential signs of early psychosis (EP) or other psychiatric concerns through various sources, including community providers and clinics in Maryland. From a larger, ongoing study on psychosis-risk, 66 help-seeking individuals consented to behavioral and neuroimaging procedures that included an experimental measure of salience attribution (results from other experimental measures have been reported elsewhere[29,30]). In addition to individuals at CHR (n = 28), the current study included those with EP (n = 6) and help-seeking youth with non-psychotic disorders who did not meet CHR or psychotic disorder criteria (n = 32), to better represent the dimensional nature of the psychosis spectrum.

The few participants with EP included in analyses represented youth who were initially referred for psychosis-risk-related or general mental health concerns but were not suspected to have crossed a diagnosable threshold for psychosis. Rather, these participants were ultimately determined as meeting criteria for full psychosis via their study participation and were very early in their first episode of psychosis. We opted to include these individuals in the current sample as various qualities (e.g., being specialty-treatment naïve, early in the course of symptom progression, and similar in age) suggest that these youth are likely more qualitatively similar to their peers at CHR in terms of clinical presentation and phenomenology than they are distinct.

General Procedures

Following the consent process, all participants completed a series of self-report questionnaires, clinician-administered psychodiagnostic interviews, and the computerized Salience Attribution Test (SAT). All assessments were administered by graduate-level staff. All procedures were approved by the Institutional Review Boards at the University of Maryland, Baltimore County, and the University of Maryland School of Medicine.

Measures

The Structured Interview for Psychosis-Risk Syndromes (SIPS). The SIPS[36] was administered by trained raters (interrater reliability ICC > .80) to determine clinical status (i.e., CHR, EP, or help-seeking youth with non-psychotic disorders) and to measure overall positive and negative symptom severity[36]. The SIPS assesses for the presence of three separate psychosis-risk syndromes and threshold-level psychosis[36]. The SIPS symptom items are divided into positive, negative, disorganized, and general symptom subscales. Each symptom is rated on a scale of 0-6, with higher scores reflecting greater severity. Participants meeting criteria for any of the three psychosis-risk syndromes were classified as at CHR, whereas the SIPS Presence of Psychotic Symptoms (POPS) criteria were used to determine EP status (see Supplementary Materials for additional details).

An overall positive symptom score was computed by summing the five SIPS positive symptom items (unusual thought content, suspiciousness, grandiosity, perceptual abnormalities, and disorganized communication). An overall negative symptom score was computed by summing the SIPS social anhedonia, avolition, 'expression of emotion', 'experience of emotions and self', and 'ideational richness' items. The remaining SIPS negative symptom item, occupational functioning, was not included in the score due to potential conflation with the outcome variables. Dysphoric mood was assessed using the SIPS 'dysphoric mood' item within the general symptom subscale, which measures feelings of depression, irritability, anxiety, and/or other instances of affective dysregulation.

Salience Attribution Test (SAT). The SAT is a computerized speeded-response task which measures behavioral, or implicit (based on reaction times) and self-reported, or explicit (based on visual analogue scale ratings) measures of adaptive and aberrant salience.[26,37] During the task, participants were presented with an experimental stimulus consisting of one of four categories (blue animals, red animals, blue household objects, red household objects) which varied along two dimensions (color and form). Participants were then instructed to respond as quickly as possible to a probe (a green square around the stimulus) before receiving feedback. Feedback was provided in the form of points (5–100 points) on 50% of trials, with more points being awarded for faster responses. The probability of reward varied along one of the stimulus dimensions (task-relevant dimension, e.g., color, with blue stimuli rewarded 87.5% of the time and red stimuli rewarded 12.5% of the time), but not for the other (task-irrelevant dimension, e.g., object category, with both animal and household stimuli rewarded 50% of the time). *Explicit* measures of adaptive salience were derived by computing the difference between participants' subjective estimates of reward frequency for the high- versus low-probability levels of the relevant (e.g., color) dimension. Similarly, explicit measures of aberrant salience were derived by computing the difference between subjective estimates for high- versus low-probability levels of the irrelevant (e.g., object category) dimension. *Implicit* measures of adaptive and aberrant salience were derived by computing the difference between participants' mean reaction times to stimuli from the high- versus low-probability levels of the relevant and irrelevant dimensions, respectively (see Figure 1 for details).

Temporal Experience of Pleasure Scale (TEPS). Self-reported pleasure was assessed using the TEPS; a brief, 18-item self-report questionnaire designed to assess trait anticipatory (10 items) and consummatory (8 items) pleasure in both healthy and clinical populations[38]. Items are rated on a 6-point Likert scale ranging from 1 (very false) to 6 (very true), with higher scores reflecting greater pleasure (after reverse scoring is applied to one item). The TEPS demonstrated good reliability in our sample (α = .80).

Global Functioning Social and Role Scales (GF-S and GF-R). Global functioning was assessed using the GF-S and GF-R, clinician-rated measures designed to assess social activities and role performance in youth at CHR[39]. Each scale is rated from 1 to 10, with higher scores reflecting better functioning. The GF-S and GF-R have demonstrated good psychometric properties, with high interrater reliability ($\gtrsim .75$) and acceptable convergent and discriminant validity[39,40].

Figure 1 about here

Statistical Analyses. From the initial sample of 66 help-seeking participants, four were excluded due to missing data on the SIPS, TEPS, and/or functioning variables. The final analysis sample included 62 participants (27 CHR, 6 EP, and 29 help-seeking youth with non-psychotic disorders) with complete data sets, of which 26 participants performed two experimental sessions (64 trials each) and 36 participants performed one experimental session of the SAT. Given the relatively small number of participants with EP, this group was combined with the CHR group to represent a group of individuals with a broader spectrum of early-course positive symptom severity (CHR/EP). Participants ranged in age from 12 to 23 years old ($M = 16.60$, $SD = 3.27$), and were approximately 60% female ($n = 37$). Approximately 42% of participants identified as Black or African American ($n = 26$), 36% as White ($n = 22$), 11% as Asian ($n = 7$), and 11% as biracial or multiracial ($n = 7$).

Independent samples *t*-tests were used to examine between-group differences in the constructs of interest, and Pearson correlation and multiple regression analyses were used to test for systematic relations among measures in the full sample. Based on the results of these analyses, we then examined several possible indirect effect pathways using the bootstrapping technique via Hayes' PROCESS macro for SPSS[41]. All variables used in the analyses of indirect effects were treated as continuous and met assumptions of normality (defined as skewness and kurtosis values < 2)[42].

Results

Between-Group Differences in Symptom Severity, SAT Performance, Pleasure Ratings, and Global Functioning. Although the CHR/EP group presented with greater overall clinician-rated positive and negative symptom severity than did help-seeking youth with non-psychotic disorders, the two groups did not significantly differ in levels of self-reported consummatory or anticipatory pleasure, social or role functioning, or dysphoric mood (Table 1). There were also no significant between-group differences on any of the SAT measures, including both implicit and explicit measures of adaptive salience (all *t*-values <1.2; Figure S1A-B).

Table 1 about here

Figure 2 about here

Associations Between Measures. Correlation analyses primarily revealed significant relations between explicit adaptive salience, consummatory pleasure, and both role and social functioning (Table 2; Figure 2A-D). Specifically, poorer explicit adaptive salience attribution was associated with both decreased consummatory pleasure and poorer social and role functioning in the full sample. Relations among explicit adaptive salience, consummatory pleasure, and global functioning remained significant even after controlling for potential effects of dysphoric mood, age, and clinical status in linear regression models predicting a) explicit adaptive salience from consummatory pleasure, and b) social and role functioning from explicit adaptive salience, respectively (Tables S5-S7).

None of the SAT measures, including adaptive salience attribution, correlated significantly with clinician-rated negative symptom severity or self-reported anticipatory pleasure in the full sample, though greater negative symptom severity was correlated with poorer social and role functioning (Table 2)[†].

Table 2 about here

Indirect effects. Given that explicit adaptive salience attribution was significantly correlated with consummatory pleasure and social and role functioning, we tested whether consummatory pleasure would have an indirect effect on global functioning through explicit adaptive salience attribution. The ordering of variables in the model was based on theoretically increasing levels of complexity associated with various reward processes, with hedonic experience (i.e., consummatory pleasure) representing the most basic process and global functioning representing a more complex process involving the application of various higher order skills. Because tests of indirect effects, in some situations, can be statistically significant even when the total effect is not statistically significant[43,44], we elected to continue testing for the presence of an indirect effect despite the fact that no overall effect of consummatory pleasure on global functioning was found. As shown in Figure 3A, there was a significant indirect effect of consummatory pleasure on role functioning through explicit adaptive salience attribution, as the 95% confidence interval based on 5,000 bootstrapped samples did not overlap zero: $\alpha\beta = 0.22$, 95% CI [0.02, 0.48]. There was also a significant indirect effect of consummatory pleasure on social functioning through

[†] Additional analyses suggested that the relations observed among a) explicit adaptive salience, consummatory pleasure, and functioning, and b) clinician-rated negative symptoms and functioning, were not likely driven by any one particular group of participants (e.g., EP individuals). As can be seen in Tables S2-S4, similar patterns of findings were observed within the separate samples of CHR/EP, CHR only, and help-seeking youth with non-psychotic disorders. Relations among explicit adaptive salience, consummatory pleasure, and role functioning were also not attributable to the effects of psychotropic medications (see Tables S8-S11 for more information on differences in study variables by medication type).

explicit adaptive salience attribution, ($\alpha\beta$ = 0.14, 95% CI [0.02, 0.30]; Figure 3B). Further analyses revealed that these effects remained even after including participant group as a covariate in the models.‡

Figure 3 about here

Discussion

In this study of anhedonia and global functioning in a sample of help-seeking youth, deficits in task-derived adaptive salience attribution were associated with both decreased consummatory pleasure and impaired role and social functioning. While CHR/EP youth and help-seeking youth with non-psychotic disorders scored similarly on measures of adaptive salience, self-reported pleasure, and functioning, results revealed an indirect effect of consummatory pleasure on both role and social functioning through adaptive salience attribution in the full sample. This latter finding suggests that deficits in the ability to experience pleasure ("liking") may underlie deficits in RL in help-seeking youth, leading ultimately to functional impairment within this population.

As recent studies of reward processing and RL in adults with schizophrenia support the idea that these individuals have intact hedonic *experience* ("liking")[10,45], and that motivational deficits are more likely to be linked to the reduced *anticipation* of pleasure ("wanting")[45,46], our finding that consummatory, but not anticipatory, pleasure was associated with RL in help-seeking youth (including those at CHR) suggests that the nature of anhedonia may differ across diagnoses and/or illness stage. This notion has been supported by other studies reporting that consummatory pleasure deficits may be more common among youth at CHR compared to those with chronic schizophrenia, potentially due to the heterogenous nature of the CHR state[31,33,47]. In other words, consummatory pleasure deficits and associated impairments

‡ To provide further confidence that results were not disproportionately driven by the 6 participants with EP, all between-group, correlation, and indirect effect analyses were also performed excluding these individuals. The pattern of findings remained the same for all analyses.

in RL could be due to higher rates of comorbid symptoms such as depression and anxiety among this population relative to individuals with schizophrenia[48,49]. It is therefore possible that consummatory pleasure deficits play a larger role in motivation and behavior at earlier stages of illness or are otherwise associated with symptoms experienced by both youth at CHR and help-seeking youth with non-psychotic disorders[50,51].

Salience attribution, self-reported anhedonia, and functional outcomes in help-seeking youth. While not the primary focus of this study, it is noteworthy that, unlike adaptive salience, *aberrant* salience attribution – which has been related to positive symptoms in both adults with schizophrenia[29] and youth at CHR[31] – was not statistically related to self-reported pleasure and global functioning in our sample. In addition, our finding that pleasure and functioning were related to the explicit, but not implicit, measure of adaptive salience attribution is consistent with prior findings from both our group[52,53] and others[25]. Prior research has demonstrated that explicit and implicit measures of adaptive salience may not always align or perform similarly in relation to other constructs, possibly due to different underlying cognitive processes[54-56], with the explicit measure potentially serving as a more sensitive measure of RL. Barch and colleagues[25] have also suggested that explicit measures of RL in particular may be more closely associated with psychiatric symptoms such as anhedonia.

Although we found a strong positive correlation between clinician-rated negative symptoms and global functioning in our sample, both adaptive salience attribution and self-reported consummatory pleasure were unrelated to overall clinician-rated negative symptom severity. Given that negative symptom ratings are typically meant to capture deficits in motivation and pleasure that would seemingly impact RL processes, these null findings were somewhat surprising (and unlikely to be due to insufficient power to detect effects, as the correlation effect sizes were small). Some have identified a number of potential limitations in using the SIPS to assess negative symptoms, including the fact that it does not distinguish primary from secondary negative symptoms, and the sole anhedonia item does not distinguish between consummatory versus anticipatory aspects of pleasure and may be more sensitive to behavior

than internal experience[3,57,58]. Our findings suggest that there may be a mismatch between interview-based and self-report assessments of anhedonia, and/or that conceptualizations of anhedonia operationalized by these two measures are not well-aligned[59]. Our findings highlight the need for a more thorough interview-based negative symptom assessment for help-seeking individuals at earlier stages of illness[3,58]. Future studies aiming to assess negative symptoms in youth at CHR should consider using the recently-developed Negative Symptom Inventory-Psychosis Risk (NSI-PR)[3,58], which accounts for some of the distinctions listed above and was specifically developed for use with younger age groups.

Limitations. Several factors may limit the generalizability of our results. The relatively small samples of participants in each group limited our power to detect small- and medium-sized effects. We did not include healthy controls in this study, limiting our ability to determine the extent to which participants' task performance and clinical presentation deviates from what would be expected in typically developing youth. Additionally, a wide range of general cognitive impairments, including impaired working memory[60,61], could impact the relations among consummatory pleasure, adaptive salience attribution, and global functioning. Although we did not have adequate data to fully assess this consideration, it is likely that our findings are a result of relations between consummatory pleasure and global functioning through RL, as well as general cognitive impairments. Future work parsing out variance explained by additional cognitive processes in the links between anhedonia, RL, and functioning is warranted. Furthermore, it is difficult to rule out effects of psychotropic medications on the relations observed, outside the context of controlled clinical trials, even when controlling for these variables in post-hoc analyses. Finally, assessing the effects of comorbid conditions would be best accomplished in larger samples, where subsets of youth at CHR and help-seeking youth with non-psychotic disorders with the same comorbid conditions could be compared.

Conclusions. Across our full sample of help-seeking youth, explicit adaptive salience attribution was related to consummatory pleasure, role functioning, and social functioning, with an indirect effect of

consummatory pleasure on functioning through salience attribution. Furthermore, we found that clinician-rated negative symptoms were related to role and social functioning. Our findings suggest that the nature and origins of anhedonia in help-seeking youth, including individuals at CHR, might be different than they are in adults with chronic schizophrenia, possibly due to an influence of mood symptoms such as depression. Specifically, these youth may experience genuine reductions in the *experience* of pleasure ("liking") that contribute to real-world functional deficits. As mood symptoms may be a natural part of the earliest stages of psychosis for many, longitudinal studies are needed to determine the extent to which changes in these symptoms are associated with anhedonia and unique RL impairments over time.

Figure Legends

Figure 1. Schematic of the Salience Attribution Test (SAT). (A) Example of experimental stimuli. **(B)** Participants viewed a fixation cross for 1 s, before a stimulus was presented for 3.5-4.5 s. Participants then responded as quickly as possible to a probe, which was displayed for a short window, before feedback was presented for 1.5-2.5 s. **(C)** After runs of the task, participants estimated reward probabilities for the different stimulus classes using visual analog scales.

Figure 2. Scatter plots illustrating significant relations between the explicit adaptive salience measure and **(A)** consummatory pleasure scores, **(B)** anticipatory pleasure scores, **(C)** role functioning scores, and **(D)** social functioning scores.

Figure 3. (A). Indirect effect model illustrating relations among consummatory pleasure, explicit adaptive salience, and role functioning in the full sample. The τ path represents the total effect of consummatory pleasure on role functioning, the α path represents the effect of consummatory pleasure on explicit adaptive salience, the β path represents the effect of explicit adaptive salience on role functioning controlling for consummatory pleasure, and the τ' path represents the direct effect of consummatory pleasure on role functioning (i.e., controlling for explicit adaptive salience). **(B).** Indirect effect model illustrating relations among consummatory pleasure, explicit adaptive salience, and social functioning. For both panels, * = $p < .05$, ** = $p < .01$.

Table 1. Demographic, clinical, functional, and self-report data from help-seeking youth with non-psychotic disorders groups.

	Help-seeking youth with non-psychotic disorders (*N*=29)	CHR/EP (*N*=33)		
	Mean (SD/%)	**Mean (SD/%)**	**Inferential Statistic**	***p***
Age	15.27 (2.63)	17.76 (3.37)	$t_{60} = -3.20$	.002
IQ	104.05 (16.08)	105.48 (13.80)	$t_{43} = 0.32$	.750
Diagnosis				
Depressive Disorder	12 (41%)	18 (55%)	$\chi^2 = 1.36$	.243
Bipolar Spectrum Disorder	3 (10%)	5 (15%)	$\chi^2 = 0.37$	.544
Anxiety Disorder	10 (34%)	22 (67%)	$\chi^2 = 6.40$	.011
Behavioral Disorder	22 (76%)	15 (45%)	$\chi^2 = 5.93$	.015
Trauma- and Stressor-Related Disorder	7 (24%)	13 (39%)	$\chi^2 = 1.64$	.200
Other Disorder	8 (28%)	11 (33%)	$\chi^2 = 0.24$	.624
SIPS				
Positive Symptom Total	4.55 (2.32)	12.55 (5.11)	$t_{60} = -7.74$	<.001
Negative Symptom Total	6.52 (4.09)	10.58 (6.11)	$t_{60} = -2.95$	.004
Dysphoric Mood	3.00 (1.64)	3.33 (1.73)	$t_{58} = -0.76$	.450
TEPS				
Anticipatory Pleasure	3.66 (1.05)	4.00 (1.01)	$t_{60} = -1.30$	.199
Consummatory Pleasure	4.60 (0.80)	4.19 (1.10)	$t_{59} = 1.64$	.106
Global Functioning				
Role	6.69 (1.71)	7.03 (1.65)	$t_{60} = -0.80$	.429
Social	7.07 (1.56)	6.55 (1.23)	$t_{60} = 1.48$	.144

Note. The Kiddie Schedule for Affective Disorders and Schizophrenia – Present and Lifetime (K-SADS-PL; Kaufman et al., 2013) was used to assess for non-psychosis-related mental health diagnoses. Anxiety disorders included general anxiety disorder (n = 15), social anxiety disorder (n = 10), separation anxiety disorder (n = 5), and panic disorder (n = 3). Behavioral disorders included oppositional-defiant disorder (n = 12), conduct disorder (n = 2), and attention-deficit hyperactivity disorder (n = 27). Other disorders included eating disorders (n = 8), tic disorders (n = 2), and obsessive-compulsive disorder (n = 8). The K-SADS-PL diagnoses were not mutually exclusive, and many participants had more than one diagnosis. N = 45 (22 help-seeking youth with non-psychotic disorders and 23 CHR/EP participants) for all analyses involving the IQ variable.

Table 2. Correlations between SAT measures and symptom measures across the full sample of help-seeking youth.

	Explicit Adaptive Avg	Implicit Adaptive Avg	Positive Symptom Total	Negative Symptom Total	Dysphoric Mood	Consummatory Pleasure	Anticipatory Pleasure	Role Functioning
Positive Symptom Total	-.05	.01						
Negative Symptom Total	-.16	-.07	**.49****					
Dysphoric Mood	.01	-.02	**.29***	**.54****				
Consummatory Pleasure	**.38****	-.01	.00	-.14	-.04			
Anticipatory Pleasure	-.19	.07	-.25	-.04	-.11	.24		
Role Functioning	**.38****	-.03	-.17	**-.50****	**-.36****	.19	-.16	
Social Functioning	**.31***	.11	-.24	**-.70****	**-.31***	.19	.02	**.51****

Note. **, $p < .01$; *, $p < .05$, $N = 62$

Avg = average score, $N = 60$ for all correlations involving the Negative Symptom Total and Dysphoric Mood variables.

References

1. Milev P, Ho BC, Arndt S, Andreasen NC. Predictive values of neurocognition and negative symptoms on functional outcome in schizophrenia: a longitudinal first-episode study with 7-year follow-up. *Am J Psychiatry.* 2005;162(3):495-506.
2. Green MF, Hellemann G, Horan WP, Lee J, Wynn JK. From perception to functional outcome in schizophrenia: modeling the role of ability and motivation. *Arch Gen Psychiatry.* 2012;69(12):1216-1224.
3. Pelletier-Baldelli A, Strauss GP, Visser KH, Mittal VA. Initial development and preliminary psychometric properties of the Prodromal Inventory of Negative Symptoms (PINS). *Schizophr Res.* 2017;189:43-49.
4. Piskulic D, Addington J, Cadenhead KS, et al. Negative symptoms in individuals at clinical high risk of psychosis. *Psychiatry Res.* 2012;196(2-3):220-224.
5. Corcoran CM, Kimhy D, Parrilla-Escobar MA, et al. The relationship of social function to depressive and negative symptoms in individuals at clinical high risk for psychosis. *Psychological medicine.* 2011;41(2):251.
6. Cressman VL, Schobel SA, Steinfeld S, et al. Anhedonia in the psychosis risk syndrome: associations with social impairment and basal orbitofrontal cortical activity. *NPJ Schizophr.* 2015;1:15020.
7. Berridge KC, Robinson TE. Parsing reward. *Trends Neurosci.* 2003;26(9):507-513.
8. Berridge KC, Robinson TE, Aldridge JW. Dissecting components of reward:‘liking’,‘wanting’, and learning. *Current opinion in pharmacology.* 2009;9(1):65-73.
9. Castro DC, Berridge KC. Advances in the neurobiological bases for food 'liking' versus 'wanting'. *Physiol Behav.* 2014;136:22-30.
10. Cohen AS, Minor KS. Emotional Experience in Patients With Schizophrenia Revisited: Meta-analysis of Laboratory Studies. *Schizophrenia Bulletin.* 2010;36(1):143-150.

11. Frost KH, Strauss GP. A Review of Anticipatory Pleasure in Schizophrenia. *Curr Behav Neurosci Rep.* 2016;3(3):232-247.

12. Castro MK, Bailey DH, Zinger JF, Martin EA. Late electrophysiological potentials and emotion in schizophrenia: A meta-analytic review. *Schizophr Res.* 2019;211:21-31.

13. Gold JM, Waltz JA, Prentice KJ, Morris SE, Heerey EA. Reward processing in schizophrenia: a deficit in the representation of value. *Schizophr Bull.* 2008;34(5):835-847.

14. Radua J, Schmidt A, Borgwardt S, et al. Ventral Striatal Activation During Reward Processing in Psychosis: A Neurofunctional Meta-Analysis. *JAMA Psychiatry.* 2015;72(12):1243-1251.

15. Mote J, Minzenberg MJ, Carter CS, Kring AM. Deficits in anticipatory but not consummatory pleasure in people with recent-onset schizophrenia spectrum disorders. *Schizophr Res.* 2014;159(1):76-79.

16. Schlosser DA, Fisher M, Gard D, Fulford D, Loewy RL, Vinogradov S. Motivational deficits in individuals at-risk for psychosis and across the course of schizophrenia. *Schizophr Res.* 2014;158(1-3):52-57.

17. Li Z, Lui SS, Geng FL, et al. Experiential pleasure deficits in different stages of schizophrenia. *Schizophr Res.* 2015;166(1-3):98-103.

18. Heerey EA, Bell-Warren KR, Gold JM. Decision-Making Impairments in the Context of Intact Reward Sensitivity in Schizophrenia. *Biological Psychiatry.* 2008;64(1):62-69.

19. Montague PR, Hyman SE, Cohen JD. Computational roles for dopamine in behavioural control. *Nature.* 2004;431(7010):760-767.

20. Schultz W. Dopamine reward prediction error coding. *Dialogues in clinical neuroscience.* 2016;18(1):23-32.

21. McClure SM, Daw ND, Montague PR. A computational substrate for incentive salience. *Trends Neurosci.* 2003;26(8):423-428.

22. Gold JM, Waltz JA, Matveeva TM, et al. Negative symptoms and the failure to represent the expected reward value of actions: behavioral and computational modeling evidence. *Arch Gen Psychiatry.* 2012;69(2):129-138.

23. Deserno L, Boehme R, Heinz A, Schlagenhauf F. Reinforcement learning and dopamine in schizophrenia: dimensions of symptoms or specific features of a disease group? *Frontiers in psychiatry.* 2013;4:172.

24. Heinz A, Schlagenhauf F, Beck A, Wackerhagen C. Dimensional psychiatry: mental disorders as dysfunctions of basic learning mechanisms. *J Neural Transm (Vienna).* 2016;123(8):809-821.

25. Barch DM, Carter CS, Gold JM, et al. Explicit and implicit reinforcement learning across the psychosis spectrum. *Journal of abnormal psychology.* 2017;126(5):694.

26. Roiser JP, Stephan KE, den Ouden HE, Barnes TR, Friston KJ, Joyce EM. Do patients with schizophrenia exhibit aberrant salience? *Psychol Med.* 2009;39(2):199-209.

27. Halahakoon DC, Kieslich K, O'Driscoll C, Nair A, Lewis G, Roiser JP. Reward-Processing Behavior in Depressed Participants Relative to Healthy Volunteers: A Systematic Review and Meta-analysis. *JAMA psychiatry.* 2020.

28. Roiser JP, Howes OD, Chaddock CA, Joyce EM, McGuire P. Neural and behavioral correlates of aberrant salience in individuals at risk for psychosis. *Schizophr Bull.* 2013;39(6):1328-1336.

29. Waltz JA, Demro C, Schiffman J, et al. Reinforcement Learning Performance and Risk for Psychosis in Youth. *J Nerv Ment Dis.* 2015;203(12):919-926.

30. Millman ZB, Gallagher K, Demro C, et al. Evidence of reward system dysfunction in youth at clinical high-risk for psychosis from two event-related fMRI paradigms. *Schizophr Res.* 2019.

31. Strauss GP, Ruiz I, Visser KH, Crespo LP, Dickinson EK. Diminished Hedonic response in neuroleptic-free youth at ultra high-risk for psychosis. *Schizophrenia research Cognition.* 2018;12:1-7.

32. Gruber J, Strauss GP, Dombrecht L, Mittal VA. Neuroleptic-free youth at ultrahigh risk for psychosis evidence diminished emotion reactivity that is predicted by depression and anxiety. *Schizophr Res.* 2018;193:428-434.

33. Millman ZB, Gold JM, Mittal VA, Schiffman J. The critical need for help-seeking controls in clinical high-risk research. *Clinical Psychological Science.* 2019;7(6):1171-1189.

34. Fusar-Poli P, De Micheli A, Patel R, et al. Real-World Clinical Outcomes Two Years After Transition to Psychosis in Individuals at Clinical High Risk: Electronic Health Record Cohort Study. *Schizophr Bull.* 2020.

35. Pizzagalli DA. Depression, stress, and anhedonia: toward a synthesis and integrated model. *Annu Rev Clin Psychol.* 2014;10:393-423.

36. Miller TJ, McGlashan TH, Rosen JL, et al. Prodromal assessment with the structured interview for prodromal syndromes and the scale of prodromal symptoms: predictive validity, interrater reliability, and training to reliability. *Schizophr Bull.* 2003;29(4):703-715.

37. Roiser JP, Stephan KE, den Ouden HE, Friston KJ, Joyce EM. Adaptive and aberrant reward prediction signals in the human brain. *Neuroimage.* 2010;50(2):657-664.

38. Gard DE, Gard MG, Kring AM, John OP. Anticipatory and consummatory components of the experience of pleasure: a scale development study. *Journal of Research in Personality.* 2006;40(6):1086-1102.

39. Cornblatt BA, Auther AM, Niendam T, et al. Preliminary findings for two new measures of social and role functioning in the prodromal phase of schizophrenia. *Schizophr Bull.* 2007;33(3):688-702.

40. Carrión RE, Auther AM, McLaughlin D, et al. The global functioning: social and role scales—further validation in a large sample of adolescents and young adults at clinical high risk for psychosis. *Schizophrenia Bulletin.* 2019;45(4):763-772.

41. Hayes AF. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach.* Guilford publications; 2017.

42. Curran PJ, West SG, Finch JF. The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological methods.* 1996;1(1):16.

43. Holmbeck GN. Toward terminological, conceptual, and statistical clarity in the study of mediators and moderators: Examples from the child-clinical and pediatric psychology literatures. *Journal of consulting and clinical psychology.* 1997;65(4):599.

44. O'Rourke HP, MacKinnon DP. Reasons for testing mediation in the absence of an intervention effect: A research imperative in prevention and intervention research. *Journal of studies on alcohol and drugs.* 2018;79(2):171-181.

45. Gard DE, Kring AM, Gard MG, Horan WP, Green MF. Anhedonia in schizophrenia: distinctions between anticipatory and consummatory pleasure. *Schizophr Res.* 2007;93(1-3):253-260.

46. Kring AM, Barch DM. The motivation and pleasure dimension of negative symptoms: neural substrates and behavioral outputs. *Eur Neuropsychopharmacol.* 2014;24(5):725-736.

47. Wotruba D, Heekeren K, Michels L, et al. Symptom dimensions are associated with reward processing in unmedicated persons at risk for psychosis. *Front Behav Neurosci.* 2014;8:382.

48. Vargas T, Ahmed AO, Strauss GP, et al. The latent structure of depressive symptoms across clinical high risk and chronic phases of psychotic illness. *Transl Psychiatry.* 2019;9(1):229.

49. Weintraub MJ, Schneck CD, Walshaw PD, et al. Characteristics of youth at high risk for bipolar disorder compared to youth with bipolar I or II disorder. *Journal of Psychiatric Research.* 2020;123:48-53.

50. Cassidy CM, Lepage M, Harvey P-O, Malla A. Cannabis use and anticipatory pleasure as reported by subjects with early psychosis and community controls. *Schizophrenia Research.* 2012;137(1):39-44.

51. Rzepa E, Fisk J, McCabe C. Blunted neural response to anticipation, effort and consummation of reward and aversion in adolescents with depression symptomatology. *Journal of psychopharmacology.* 2017;31(3):303-311.

52. Waltz JA, Frank MJ, Wiecki TV, Gold JM. Altered probabilistic learning and response biases in schizophrenia: behavioral evidence and neurocomputational modeling. *Neuropsychology.* 2011;25(1):86-97.

53. Waltz JA, Xu Z, Brown EC, Ruiz RR, Frank MJ, Gold JM. Motivational Deficits in Schizophrenia Are Associated with Reduced Differentiation between Gain and Loss-Avoidance Feedback in the Striatum. *Biol Psychiatry Cogn Neurosci Neuroimaging.* 2018;3(3):239-247.

54. Smieskova R, Roiser JP, Chaddock CA, et al. Modulation of motivational salience processing during the early stages of psychosis. *Schizophr Res.* 2015;166(1-3):17-23.

55. Katthagen T, Dammering F, Kathmann N, et al. Validating the construct of aberrant salience in schizophrenia — Behavioral evidence for an automatic process. *Schizophrenia Research: Cognition.* 2016;6:22-27.

56. Neumann SR, Linscott RJ. The relationships among aberrant salience, reward motivation, and reward sensitivity. *International Journal of Methods in Psychiatric Research.* 2018;27(4):e1615.

57. Azar M, Pruessner M, Baer LH, Iyer S, Malla AK, Lepage M. A study on negative and depressive symptom prevalence in individuals at ultra-high risk for psychosis. *Early intervention in Psychiatry.* 2018;12(5):900-906.

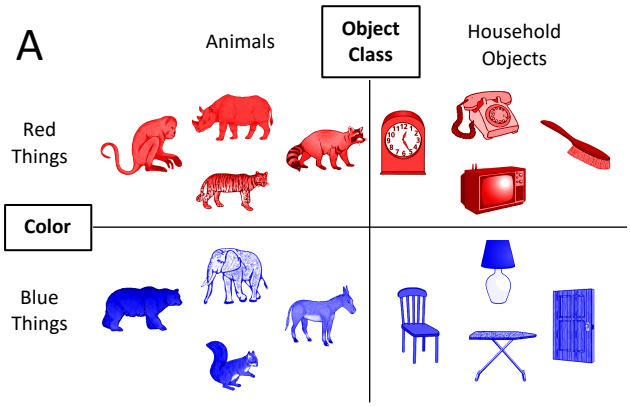
58. Strauss GP, Pelletier-Baldelli A, Visser KF, Walker EF, Mittal VA. A review of negative symptom assessment strategies in youth at clinical high-risk for psychosis. *Schizophr Res.* 2020.

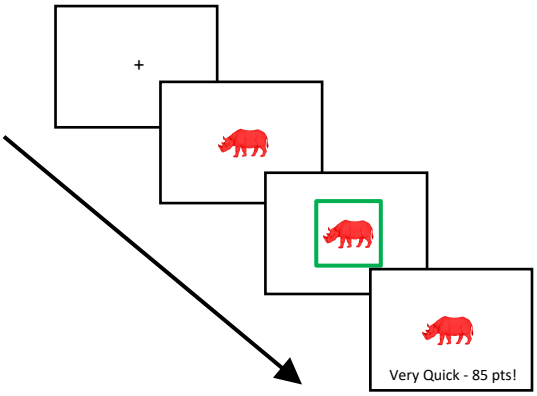
59. Strauss GP, Gold JM. A new perspective on anhedonia in schizophrenia. *Am J Psychiatry.* 2012;169(4):364-373.

60. Collins AG, Brown JK, Gold JM, Waltz JA, Frank MJ. Working memory contributions to reinforcement learning impairments in schizophrenia. *J Neurosci.* 2014;34(41):13747-13756.

61. Collins AGE, Albrecht MA, Waltz JA, Gold JM, Frank MJ. Interactions Among Working Memory, Reinforcement Learning, and Effort in Value-Based Choice: A New Paradigm and Selective Deficits in Schizophrenia. *Biological Psychiatry.* 2017;82(6):431-439.

Figure 1. Salience Attribution Task.





C

Press the left arrow to go left
Press the right arrow to go right
Press the down arrow to make rating
Press the up arrow to make changes

Blue animals 90%

Red animals 75%

Blue household objects 15%

Red household objects 30%

Figure 2. Relations between Explicit Adaptive Salience scores and measures of anhedonia and global functioning in the entire sample.

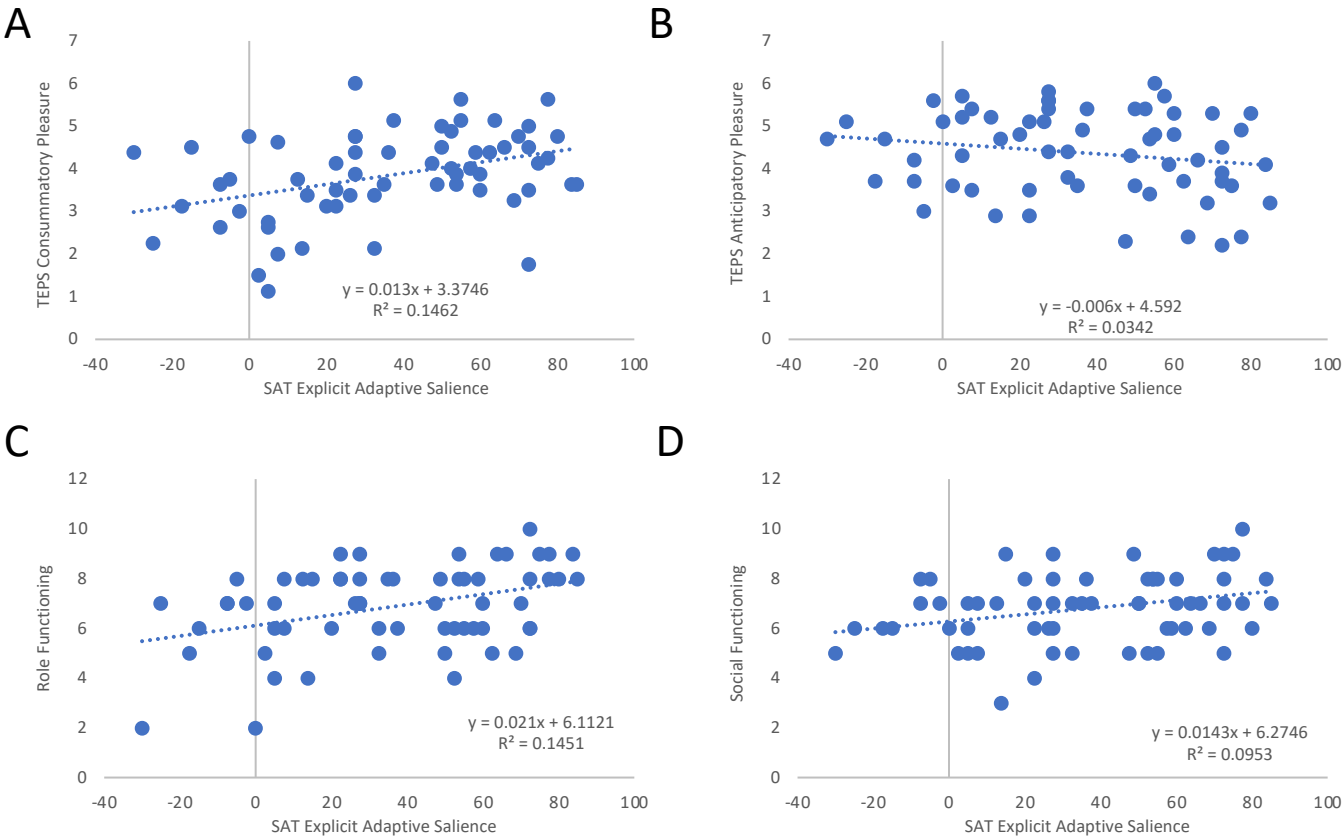
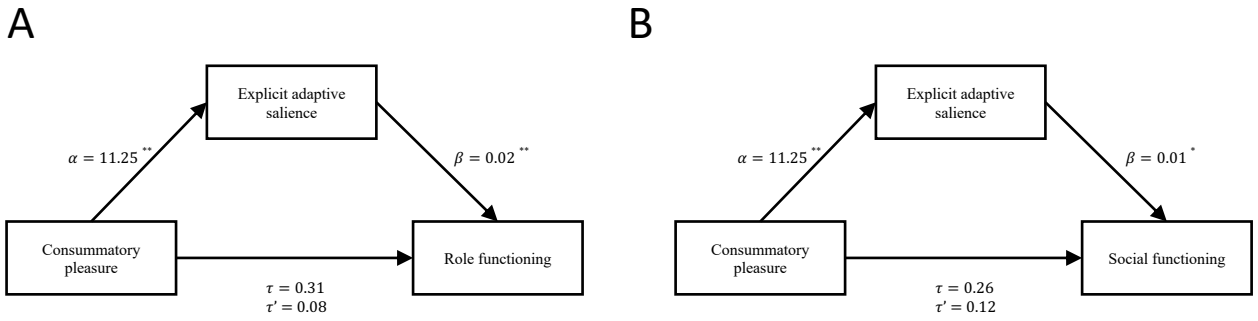


Figure 3. Tests of Indirect Effects.



Supplementary Materials for:

Relations among anhedonia, reinforcement learning, and global functioning in help-seeking youth

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Supplementary Methods:	358 words
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Supplementary Methods

Recruitment, Eligibility, and Determination of CHR status. Recruitment strategies included outreach activities, flyers, and internet advertisements encouraging individuals (or their providers) to contact us about new or unusual symptoms, disturbances in mood or sleep, sudden changes in functioning, and/or other mental health difficulties. Notably, individuals formally diagnosed with a psychotic disorder at the time of recruitment were excluded from the study. Youth under Department of Social Services guardianship were also excluded from participation.

In order to be eligible, participants needed to be engaged in mental health services at the time of participation and/or suspected of experiencing attenuated psychosis symptoms, between the ages of 12 and 25 years old, and able to provide informed consent (or written assent, if under the age of 18). Participants who scored a 3-5 and met frequency criteria on any of the SIPS positive symptoms received a diagnosis of Attenuated Positive Symptom Syndrome (APSS). Participants met criteria for Genetic Risk and Deterioration Syndrome (GRD) if they had either a first-degree relative with psychosis or a diagnosis of schizotypal personality disorder and had experienced a significant decline in functioning within any 12-month period. A score of 6 on any of the positive items indicated full threshold psychosis, with the exception of Brief Intermittent Psychotic Syndrome (BIPS), in which symptoms met psychotic-level intensity but were considered transient and/or not sufficiently disorganizing or dangerous enough to meet criteria for full psychosis. Each participant evaluation was reviewed in weekly group supervision meetings, in order to establish diagnostic and symptom-level consensus among research team members.

Of note, our criteria resulted in some participants who were initially referred for suspected psychosis-risk symptoms being categorized as youth with non-psychotic disorders after not meeting SIPS criteria for psychosis-risk/psychosis. Therefore, participants in our help-seeking youth with non-psychotic disorders group may have had higher levels of attenuated psychosis symptoms than other help-seeking samples in the general population. Note also that non-psychotic disorders, such as mood disorders, are in and of themselves predictive of later psychosis[1,2]. Thus, the help-seeking youth with non-psychotic

disorders group can be thought of as carrying some risk for psychosis, though less so than those with observable emerging attenuated psychosis symptoms.

Supplementary Results

Between-group Differences in SAT Performance: 3 Subsamples. When we separated the 6 EP individuals from the 27 CHR participants, we continued to observe no group differences on either adaptive salience measure (explicit: $F_{2,59} = 0.73$, $p = .489$; implicit: $F_{2,59} = 1.20$, $p = .308$). While we did observe a main effect of group on implicit (but not explicit; $F_{2,59} = 0.79$, $p = .457$) aberrant salience scores ($F_{2,59} = 6.43$, $p = .003$), with EP individuals having higher mean scores (38.2) than either CHR (15.1; $p = .001$) or help-seeking youth with non-psychotic disorders (18.2; $p = .003$), this finding aligns with prior research demonstrating elevated implicit aberrant salience scores in individuals with greater positive symptom severity[3].

Correlation analyses in subsamples. Table S2 shows that significant relations among negative symptoms, dysphoric mood, and global functioning were also present in the sample of 33 CHR/EP only. As shown in Table S2, significant relations among explicit adaptive salience, consummatory pleasure, and role functioning were also present in the sample of 33 CHR/EP only. Significant relations among negative symptoms, dysphoric mood, and global functioning were also present in the sample of 27 CHR individuals only (with the 6 EP individuals excluded; Table S3). Furthermore, the significant correlation between explicit adaptive salience and consummatory pleasure held for the sample of 27 CHR individuals only (with the 6 EP individuals excluded; Table S3). As shown in Table S4, significant relations between negative symptoms and global functioning were present in the sample of 29 help-seeking youth with non-psychotic disorders only, but the relations among dysphoric mood and positive and negative symptoms, and between dysphoric mood and global functioning, were not significant in this group (although correlation effect sizes were moderate). As shown in Table S4, significant relations among explicit adaptive salience, consummatory pleasure, and global functioning were present in the sample of 29 help-

seeking youth with non-psychotic disorders only. These results provide further evidence that these significant relationships were not driven by differences in the measures due to attenuated/early psychosis status.

Tests of Psychotropic Medication Effects. Proportions of participants on different types of psychotropic medications are shown in Table S1. Independent samples *t*-tests comparing participants taking vs. not taking different medications are shown in Tables S8-S11. With regard to antidepressant medications, participants taking antidepressants had higher ratings for dysphoric mood (t_{58} = -2.00; p = .050) and lower scores for anticipatory pleasure (t_{59} = 2.25; p = .028), consistent with partially-, but not completely-remitted depression. No significant effects of stimulant medications were observed (all t's < 2). As expected, participants taking antipsychotic medications had higher ratings for positive symptoms (t_{60} = 3.02; p = .004). No other effects of antipsychotic medications were observed (all t's < 2).

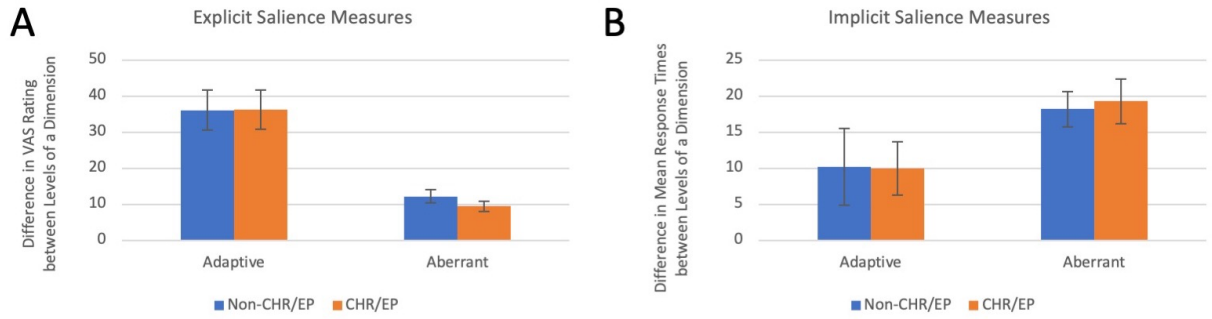

Figure S1. Salience Attribution Test Performance in Participant Subgroups. (A) Explicit Salience measures. **(B)** Implicit Salience measures. *Abbreviations: VAS, Visual-Analog Scale; CHR/EP, Clinical High-Risk/Early Psychosis; Non-CHR/EP, Non-Clinical High-Risk/Early Psychosis (help-seeking youth with non-psychotic disorders).*

Table S1. Demographic, clinical, functional, and self-report data from help-seeking youth with non-psychotic disorders, CHR, and EP groups.

	Help-seeking youth with non-psychotic disorders (*N*=29)	CHR (*N*=27)	EP (*N*=6)		
	Mean (SD/%)	Mean (SD/%)	Mean (SD/%)	Inferential Statistic	*p*
Age	15.27 (2.63)	17.96 (3.47)	16.87 (2.97)	$F_{2,59} = 5.41$	.007[a]
IQ	104.05 (16.08)	106.00 (14.50)	103.00 (11.17)	$F_{2,42} = 0.12$	.891
Diagnosis					
Depressive Disorder	12 (41%)	16 (59%)	2 (33%)	$\chi^2 = 2.14$	.343
Bipolar Spectrum Disorder	3 (10%)	3 (11%)	2 (33%)	$\chi^2 = 3.27$	.195
Anxiety Disorder	10 (34%)	19 (70%)	3 (50%)	$\chi^2 = 7.22$	.027[a]
Behavioral Disorder	22 (76%)	13 (48%)	2 (33%)	$\chi^2 = 6.38$	.041[a]
Trauma- and Stressor-Related Disorder	7 (24%)	10 (37%)	3 (50%)	$\chi^2 = 2.02$	.364
Other Disorder	8 (28%)	8 (30%)	3 (50%)	$\chi^2 = 1.85$	.397
SIPS					
Positive Symptom Total	4.55 (2.32)	11.85 (4.05)	15.67 (8.21)	$F_{2,59} = 34.07$	<.001[abc]
Negative Symptom Total	6.52 (4.09)	9.81 (6.21)	14.00 (4.60)	$F_{2,57} = 6.10$	.004[bc]
Dysphoric Mood	3.00 (1.64)	3.26 (1.81)	3.67 (1.37)	$F_{2,57} = 0.43$	.655
TEPS					
Anticipatory Pleasure	4.60 (0.80)	4.10 (1.14)	4.58 (0.92)	$F_{2,58} = 1.96$	.150
Consummatory Pleasure	3.66 (1.05)	4.14 (0.90)	3.40 (1.33)	$F_{2,59} = 2.19$	.121
Global Functioning					
Role	6.69 (1.71)	7.56 (1.12)	4.67 (1.63)	$F_{2,59} = 9.84$	<.001[abc]
Social	7.07 (1.56)	6.67 (1.27)	6.00 (0.89)	$F_{2,59} = 1.66$	.199
Psychotropic Medications					
Antidepressant	12 (41%)	9 (33%)	2 (33%)	$\chi^2 = 0.43$	.807
Stimulant	12 (41%)	11 (41%)	0 (0%)	$\chi^2 = 1.36$	.506
Antipsychotic	1 (3%)	4 (15%)	3 (50%)	$\chi^2 = 9.74$	.008
None	9 (31%)	10 (37%)	1 (17%)	$\chi^2 = 0.97$	.616

Note. The Kiddie Schedule for Affective Disorders and Schizophrenia – Present and Lifetime (K-SADS-PL; Kaufman et al., 2013) was used to assess for non-psychosis-related mental health diagnoses. Anxiety disorders included general anxiety disorder (n = 15), social anxiety disorder (n = 10), separation anxiety disorder (n = 5), and panic disorder (n = 3). Behavioral disorders included oppositional-defiant disorder (n = 12), conduct disorder (n = 2), and attention-deficit hyperactivity disorder (n = 27). Other disorders included eating disorders (n = 8), tic disorders (n = 2), and obsessive-compulsive disorder (n = 8). The K-SADS-PL diagnoses were not mutually exclusive, and many participants had more than one diagnosis.

Significant between-group differences in *italics*. For between-group differences: a = help-seeking youth with non-psychotic disorders vs. CHR, b = help-seeking youth with non-psychotic disorders vs. EP, c = CHR vs. EP. $N = 45$ (22 help-seeking youth with non-psychotic disorders, 19 CHR, and 4 EP participants) for all analyses involving the IQ variable. Participants were on the following antipsychotic medications: asenapine ($n = 1$), quetiapine ($n = 1$), aripiprazole ($n = 2$), quetiapine + risperidone ($n = 1$), clozapine + risperidone ($n = 1$), unknown ($n = 2$).

Table S2. Correlations between SAT measures and symptom measures in youth at CHR/EP.

	Explicit Adaptive Avg	Implicit Adaptive Avg	Explicit Aberrant Avg	Implicit Aberrant Avg	Positive Symptom Total	Negative Symptom Total	Dysphoric Mood	Consummatory Pleasure	Anticipatory Pleasure	Role Functioning
Positive Symptom Total	-.05	.19	-.01	.30						
Negative Symptom Total	-.22	.13	.14	.32	.42*					
Dysphoric Mood	.00	.17	.11	.21	.32	**.64****				
Consummatory Pleasure	**.35***	-.24	-.16	**-.55****	-.09	-.24	-.08			
Anticipatory Pleasure	-.27	-.02	-.04	.07	-.18	.02	-.10	.19		
Role Functioning	**.38***	-.26	-.19	-.34	**-.42***	**-.67****	**-.38***	.19	-.18	
Social Functioning	.26	-.06	-.20	-.31	-.12	**-.74****	**-.44****	.15	-.04	**.50****

Note. **, $p < .01$; *, $p < .05$, $N = 33$

Avg = average score.

Table S3. Correlations between SAT measures and symptom measures in youth at CHR only.

	Explicit Adaptive Avg	Implicit Adaptive Avg	Explicit Aberrant Avg	Implicit Aberrant Avg	Positive Symptom Total	Negative Symptom Total	Dysphoric Mood	Consummatory Pleasure	Anticipatory Pleasure	Role Functioning
Positive Symptom Total	.20	.03	-.06	.045						
Negative Symptom Total	-.05	.01	.11	.15	.24					
Dysphoric Mood	-.00	.26	-.04	.15	.30	**.70****				
Consummatory Pleasure	**.38***	.19	-.11	-.27	.15	-.14	-.01			
Anticipatory Pleasure	-.31	-.18	-.03	-.03	-.11	.03	-.06	.30		
Role Functioning	.17	-.11	-.28	.15	-.15	**-.65****	**-.57****	.01	-.12	
Social Functioning	.13	.12	-.24	-.17	.11	**-.71****	**-.48***	.01	-.02	**.46***

Note. **, $p < .01$; *, $p < .05$, $N = 27$
Avg = average score.

Table S4. Correlations between SAT measures and symptom measures in help-seeking youth with non-psychotic disorders only.

	Explicit Adaptive Avg	Implicit Adaptive Avg	Explicit Aberrant Avg	Implicit Aberrant Avg	Positive Symptom Total	Negative Symptom Total	Dysphoric Mood	Consummatory Pleasure	Anticipatory Pleasure	Role Functioning
Positive Symptom Total	-.15	-.28	.20	-.08						
Negative Symptom Total	-.11	-.33	-.13	-.10	.34					
Dysphoric Mood	.01	-.19	.01	.09	.38	.35				
Consummatory Pleasure	**.43***	.17	-.13	.18	**-.40***	-.10	-.03			
Anticipatory Pleasure	-.06	.19	.01	.06	-.05	.13	-.03	**.46***		
Role Functioning	**.39***	.16	.09	.00	-.23	**-.53****	-.36	.16	-.09	
Social Functioning	**.38***	.23	.12	.18	-.28	**-.64****	-.14	.31	-.01	**.58****

Note. **, $p < .01$; *, $p < .05$, $N = 29$

Avg = average score, $N = 27$ for all correlations involving the Negative Symptom Total and Dysphoric Mood variables.

Table S5. Multiple Regression Model Predicting Explicit Adaptive Salience from Consummatory Pleasure.

Explicit Adaptive Salience				
Overall Model	R^2	F	df	p
	0.26	4.71	4, 55	.002
Predictors	b	t	p	f^2
Consummatory Pleasure	7.99	2.16	.035	0.09
Dysphoric Mood	1.08	0.51	.612	0.00
Age	3.40	2.77	.008	0.14
Clinical Status[a]	-9.97	-1.31	.196	0.03

Note. $N = 60$

[a] Coded as (0 = help-seeking youth with non-psychotic disorders, 1 = CHR/EP).

Table S6. Multiple Regression Model Predicting Role Functioning from Explicit Adaptive Salience.

Role Functioning				
Overall Model	R^2	F	df	p
	0.27	5.02	4, 55	.002
Predictors	b	t	p	f^2
Explicit Adaptive Salience	0.02	2.80	.007	0.14
Dysphoric Mood	-0.36	-3.19	.002	0.19
Age	-0.01	-0.17	.862	0.00
Clinical Status[a]	0.46	1.09	.279	0.02

Note. $N = 60$

[a] Coded as (0 = help-seeking youth with non-psychotic disorders, 1 = CHR/EP).

Table S7. Multiple Regression Model Predicting Social Functioning from Explicit Adaptive Salience.

Social Functioning				
Overall Model	R^2	F	df	p
	0.25	4.02	4, 55	.006
Predictors	b	t	p	f^2
Explicit Adaptive Salience	0.01	2.35	.023	0.10
Dysphoric Mood	-0.24	-2.48	.016	0.11
Age	-0.02	-0.40	.692	0.00
Clinical Status[a]	-0.52	-1.49	.141	0.04

Note. $N = 60$

[a] Coded as (0 = help-seeking youth with non-psychotic disorders, 1 = CHR/EP).

Table S8. Differences in symptoms, functioning, and SAT performance by medication type (antidepressant vs. no antidepressant), in full sample

	Antidepressant (*N* = 23)	**No Antidepressant (*N* = 39)**		
Symptom Variables	*M* (*SD*)	*M* (*SD*)	*t*(df)	*p*
Positive Symptom Total	8.35 (5.74)	9.08 (5.71)	0.484 (60)	.630
Negative Symptom Total	8.43 (5.26)	8.92 (5.89)	0.322 (58)	.749
Dysphoric Mood	3.76 (1.41)	2.87 (1.75)	-2.004 (58)	.050
Consummatory Pleasure	3.79 (1.03)	3.88 (1.05)	0.298 (60)	.767
Anticipatory Pleasure	4.02 (0.93)	4.59 (0.98)	2.253 (59)	.028
Functioning Variables				
Role Functioning	6.83 (1.97)	6.90 (1.50)	0.161 (60)	.873
Social Functioning	6.83 (1.67)	6.77 (1.25)	-0.153 (60)	.879
SAT Variables				
Explicit Adaptive Avg	33.91 (34.18)	37.53 (28.35)	0.450 (60)	.655
Implicit Adaptive Avg	12.61 (16.42)	8.56 (28.86)	-0.616 (60)	.540
Explicit Aberrant Avg	10.33 (6.44)	10.99 (10.47)	0.276 (60)	.783
Implicit Aberrant Avg	17.94 (12.52)	19.25 (17.29)	0.318 (60)	.752

Table S9. Differences in symptoms, functioning, and SAT performance by medication type (stimulant vs. no stimulant), in full sample

	Stimulant (*N* = 23)	**No Stimulant (*N* = 39)**		
Symptom Variables	*M* (*SD*)	*M* (*SD*)	*t*(df)	*p*
Positive Symptom Total	8.48 (5.36)	9.00 (5.93)	0.35 (60)	.730
Negative Symptom Total	7.48 (5.11)	9.44 (5.85)	1.29 (58)	.201
Dysphoric Mood	2.76 (1.64)	3.41 (1.68)	1.44 (58)	.156
Consummatory Pleasure	3.53 (1.02)	4.03 (1.01)	1.86 (60)	.067
Anticipatory Pleasure	4.22 (1.02)	4.47 (0.97)	0.98 (59)	.331
Functioning Variables				
Role Functioning	7.00 (1.28)	6.79 (1.88)	-0.46 (60)	.645
Social Functioning	6.74 (1.42)	6.82 (1.41)	0.22 (60)	.828
SAT Variables				
Explicit Adaptive Avg	33.15 (29.87)	37.98 (30.97)	0.60 (60)	.550
Implicit Adaptive Avg	5.47 (29.41)	12.78 (21.77)	1.12 (60)	.268
Explicit Aberrant Avg	11.96 (8.03)	10.03 (9.75)	-0.80 (60)	.427
Implicit Aberrant Avg	18.16 (14.59)	19.12 (16.34)	0.23 (60)	.818

Table S10. Differences in symptoms, functioning, and SAT performance by medication type (antipsychotic vs. no antipsychotic), in full sample

	Antipsychotic (*N* = 8)	**No Antipsychotic (*N* = 54)**		
Symptom Variables	*M* (*SD*)	*M* (*SD*)	*t*(df)	*p*
Positive Symptom Total	14.13 (7.14)	8.02 (5.06)	-3.02 (60)	.004
Negative Symptom Total	9.25 (5.20)	8.67 (5.74)	-0.27 (58)	.790
Dysphoric Mood	4.00 (1.41)	3.06 (1.70)	-1.49 (58)	.142
Consummatory Pleasure	4.17 (0.53)	3.80 (1.08)	-0.96 (60)	.342
Anticipatory Pleasure	4.16 (1.10)	4.41 (0.98)	0.62 (59)	.537
Functioning Variables				
Role Functioning	6.25 (2.52)	6.96 (1.58)	1.13 (60)	.264
Social Functioning	6.38 (1.06)	6.85 (1.45)	0.90 (60)	.374
SAT Variables				
Explicit Adaptive Avg	40.78 (33.45)	35.51 (30.22)	-0.46 (60)	.651
Implicit Adaptive Avg	7.35 (17.56)	10.47 (25.91)	0.33 (60)	.744
Explicit Aberrant Avg	8.91 (6.96)	11.02 (9.43)	0.61 (60)	.546
Implicit Aberrant Avg	17.79 (12.19)	18.91 (16.13)	0.19 (60)	.852

Table S11. Differences in symptoms, functioning, and SAT performance by medication type (antipsychotic vs. no antipsychotic), in CHR/EP group only

	Antipsychotic (*N* = 7)	**No Antipsychotic (*N* = 26)**		
Symptom Variables	*M* (*SD*)	*M* (*SD*)	*t*(df)	*p*
Positive Symptom Total	15.14 (7.06)	11.85 (4.37)	-1.55 (31)	.132
Negative Symptom Total	9.57 (5.53)	10.85 (6.33)	0.48 (31)	.632
Dysphoric Mood	3.71 (1.25)	3.23 (1.84)	-0.65 (31)	.519
Consummatory Pleasure	4.20 (0.56)	3.95 (1.10)	-0.56 (31)	.578
Anticipatory Pleasure	4.16 (1.10)	4.20 (1.13)	0.08 (31)	.935
Functioning Variables				
Role Functioning	6.29 (2.43)	7.23 (1.35)	1.36 (31)	.182
Social Functioning	6.14 (0.90)	6.65 (1.29)	0.98 (31)	.336
SAT Variables				
Explicit Adaptive Avg	39.12 (35.76)	35.53 (30.55)	-0.27 (31)	.792
Implicit Adaptive Avg	7.26 (18.97)	10.67 (22.11)	0.37 (31)	.713
Explicit Aberrant Avg	9.11 (7.49)	9.57 (8.39)	0.13 (31)	.896
Implicit Aberrant Avg	19.94 (11.41)	19.12 (19.24)	-0.11 (31)	.915

References

1. Guloksuz S, Pries L-K, ten Have M, et al. Association of preceding psychosis risk states and non-psychotic mental disorders with incidence of clinical psychosis in the general population: a prospective study in the NEMESIS-2 cohort. *World psychiatry : official journal of the World Psychiatric Association.* 2020;19(2):199-205.
2. Plana-Ripoll O, Pedersen CB, Holtz Y, et al. Exploring Comorbidity Within Mental Disorders Among a Danish National Population. *JAMA Psychiatry.* 2019;76(3):259-270.
3. Roiser JP, Stephan KE, den Ouden HE, Barnes TR, Friston KJ, Joyce EM. Do patients with schizophrenia exhibit aberrant salience? *Psychol Med.* 2009;39(2):199-209.
4. Chen C. Intelligence moderates reinforcement learning: a mini-review of the neural evidence. *Journal of Neurophysiology.* 2014;113(10):3459-3461.
5. Collins AGE. The Tortoise and the Hare: Interactions between Reinforcement Learning and Working Memory. *Journal of cognitive neuroscience.* 2018;30(10):1422-1432.
6. Collins AG, Brown JK, Gold JM, Waltz JA, Frank MJ. Working memory contributions to reinforcement learning impairments in schizophrenia. *J Neurosci.* 2014;34(41):13747-13756.
7. Collins AGE, Albrecht MA, Waltz JA, Gold JM, Frank MJ. Interactions Among Working Memory, Reinforcement Learning, and Effort in Value-Based Choice: A New Paradigm and Selective Deficits in Schizophrenia. *Biological Psychiatry.* 2017;82(6):431-439.
8. Green MF. Cognitive impairment and functional outcome in schizophrenia and bipolar disorder. *J Clin Psychiatry.* 2006;67(10):e12.
9. Bowie CR, Reichenberg A, Patterson TL, Heaton RK, Harvey PD. Determinants of real-world functional performance in schizophrenia subjects: correlations with cognition, functional capacity, and symptoms. *Am J Psychiatry.* 2006;163(3):418-425.