



# Altered selection during language processing in individuals at high risk for psychosis

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## ABSTRACT

**Introduction:** Performance in the executive function (EF) domain has been linked to symptoms and functional outcomes in psychosis. Studies have found that UHR populations have difficulty with verbal fluency, which involves multiple facets of EF. Two potentially implicated EF facets were examined to explore whether these could be dissociated in UHR populations: selection among alternatives (measured by selection costs) and retrieval from semantic memory retrieval (measured by retrieval costs).

**Methods:** A total of 45 UHR individuals and 46 healthy controls (HVs) were assessed with a verb generation task. Differences in selection cost (RT difference between high and low selection demand conditions) and retrieval cost (RT difference between high and low retrieval demand conditions) were examined and participants were also assessed for clinical symptoms.

**Results:** The UHR group showed greater selection costs relative to HVs,  $F(1, 91) = 4.39, p = 0.039$ . However, there were no group differences on retrieval cost,  $F(1, 91) = 0.63, p = 0.43$ . A positive association ( $r = 0.41$ ) was found between disorganized and negative symptoms and selection costs (but not retrieval costs) in the UHR group. There was no significant association between selection costs and positive symptoms.

**Discussion:** Increased selection costs may reflect impaired performance in the neural inhibition domain of EF in the UHR population, potentially underlying a mechanistically distinct EF subdomain that affects the group's ability to efficiently select between competing options. Findings suggest that UHR individuals may exhibit impairment in selecting among alternatives, but not in retrieval from semantic memory.

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## 1. Introduction

Deficits in cognition are a core feature of psychosis (Dickinson, 2014; Fusar-Poli et al., 2012a; Fusar-Poli et al., 2012b; Fusar-Poli et al., 2007; Green et al., 2000; Reichenberg and Harvey, 2007), but the field is still only starting to understand how related functions may be affected in early stages and through illness progression (Dickson et al., 2012; Meier et al., 2014; Reichenberg and Mollon, 2016; Woodberry et al., 2008). Studies suggest that individuals at high risk for developing psychosis (UHR) exhibit performance impairments on a variety of cognitive tasks (Eastvold et al., 2007; Fusar-Poli et al., 2012a; Kim et al., 2011; Niendam et al., 2006; Pukrop et al., 2007; Reichenberg and Mollon, 2016). In this context, research suggests that studying executive

function (EF) in UHR individuals may be highly informative, especially given EF's critical role in individual goal pursuit and attainment, as well as in widespread day-to-day functions (Fusar-Poli et al., 2012b; Morey et al., 2005; Niendam et al., 2012; Schultze-Lutter et al., 2007; Snyder et al., 2015). Previous studies have found EF deficits in this population (Fusar-Poli et al., 2012b; Morey et al., 2005; Niendam et al., 2012; Schultze-Lutter et al., 2007); nonetheless, EF is not a unitary construct, and thus we would benefit from understanding distinct mechanisms within the EF domain in this group (Friedman and Miyake, 2017). Understanding specific EF functions that are altered has the potential of bringing us one step closer to separating affected processes in the disorder, and aids in informing current etiological models.

Executive function is an umbrella term for goal-oriented behaviors (Banich et al., 2009). Clinical EF research has often employed broad neuropsychological measures that mechanistically involve multiple facets of EF, as well as some non-EF abilities, thereby limiting our ability to understand specific underlying mechanisms within distinct facets (Snyder

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et al., 2015). One such EF facet requires individuals to be able to select among potential competing options in service of a goal, and this is the process on which the present paper focuses. Several studies have found that UHR individuals have difficulty with verbal fluency, which involves multiple facets of EF such as shifting between subcategories and working memory, as well as some non-EF abilities, such as semantic processing (Berberian et al., 2016; Docherty et al., 2011; Doughty and Done, 2009; Rende et al., 2002; Snyder et al., 2015). One investigation observed that verbal fluency scores in a UHR group did not significantly differ from scores of first episode psychosis patients, with both being significantly more impaired compared to healthy individuals (Becker et al., 2010). Another group found that compared to young individuals that had sought help at a specialized youth mental health center, UHR individuals exhibited lower semantic, but not phonological fluency (Magaud et al., 2010). This is notable especially in light of meta analytic evidence suggesting that semantic verbal fluency deficits are stronger in schizophrenia relative to phonological fluency deficits (Bokat and Goldberg, 2003). Even more interestingly, recent studies suggest that verbal fluency impairments serve as predictors of later transition to psychosis (Addington et al., 2017; Michel et al., 2014; Riecher-Rossler et al., 2009). Given this potential predictive power, along with the fact that among clinical populations those with psychosis disorders have among the largest reported EF deficits (Snyder et al., 2015), investigating distinct facets within the EF domain could be particularly valuable in aiding our understanding of specific underlying mechanisms, potentially increasing our ability to pinpoint processes that begin deteriorating prior to psychosis onset.

Indirect evidence suggests that selection during language processing may be a specific component of EF that exhibits impairment in UHR populations. Selecting words or other responses in order to respond efficiently to our environment requires the EF-mediated ability to resolve competition among competing representations (e.g., selecting among the responses “throw”, “kick”, “catch” etc. when generating a verb to go with “ball”) (Snyder and Munakata, 2008). Previous studies have hypothesized that impaired gamma-aminobutyric acid (GABA) function can negatively impact selection; these groups have shown that selection in healthy individuals can be boosted by GABA agonists, also observing positive links between GABA levels measured via spectroscopy and better selection abilities (de la Vega et al., 2014; Snyder et al., 2010). Given that impaired GABA function has been observed in psychosis (Egerton et al., 2017; Glausier and Lewis, 2017), a pattern of impaired selection may hold in groups at high risk of developing psychosis (Kang et al., 2014). This prediction is strengthened given observed verbal fluency deficits in UHR populations, as verbal fluency incorporates aspects of selection (e.g., selecting among all the possible animals to name next) (Snyder et al., 2015). However, because of the complexity of the tasks that have previously been used to study EF in this population, it is not possible to know whether selection specifically is impaired in a mechanistically distinct manner from executive aspects of semantic retrieval.

In language production, the difficulty of selecting among words has been described as a function of the number of alternatives, as well as the similarity in activation levels across alternatives (Botvinick et al., 2001; Snyder and Munakata, 2008). Snyder et al. hypothesized that cognitive control is exerted when individuals are needing to choose one response among multiple competing options. Under this framework, competing options that are equally salient slow down processing, thereby slowing selection. In a healthy sample, Snyder et al. (2010) used a computational model of selection during language processing, which predicted that competitive neural inhibition instantiated by GABAergic interneurons in prefrontal circuits is a key mechanism for selecting among alternatives during language processing. This prediction was supported by evidence that a GABA agonist improved selection, while increased selection costs due to highly competing options were linked with impaired prefrontal GABA function associated with anxiety (Snyder et al., 2010). In addition, greater lateral prefrontal cortex GABA concentrations in a general community sample predicted selection efficiency specifically, rather than general EF ability (de la Vega

et al., 2014). Previous studies have found deficits in latent inhibition in UHR individuals (Kraus et al., 2016); however, the literature of date has not isolated the selection domain of EF, and we have yet to learn whether selection constitutes a mechanistically distinct process within the umbrella of executive function in this population.

In order to investigate specificity to processes involving neural inhibition hypothesized to be impaired in UHR individuals, it is helpful to compare selection among competing alternatives to a second linguistic cognitive control process, controlled retrieval from semantic memory. Selection and retrieval processes both require cognitive control and rely on shared neural substrates in left ventrolateral prefrontal cortex (Snyder et al., 2011), but importantly, previous research and computational models suggest that only selection depends on neural inhibition (de la Vega et al., 2014; Snyder et al., 2011; Snyder et al., 2010). In contrast to the selection mechanisms described above, the effects of retrieval demands are a direct consequence of the strength of the associations (synaptic weights) between stimuli (e.g., nouns) and their associated representations (e.g., verbs): Weaker weights cause a slower build-up of activation, requiring more time to reach the threshold to make a response (Snyder et al., 2010). In addition, we speculate that sustained neuronal activation, enabled by recurrent connections in PFC networks, may support retrieval of weakly active representations. As predicted from this framework in which neural inhibition affects selection but not retrieval, the effects of the GABA agonist midazolam and anxiety (associated with decreased GABAergic function) were specific to impairments in selection, with no effects on retrieval (Snyder et al., 2010). Thus, retrieval from semantic memory serves as a control contrast in the current study, as it is cognitively demanding and relies on the same prefrontal areas but relies on distinct neural mechanisms not dependent on inhibition.

The present study uses the predictions of a computational model of selection (Snyder et al., 2010) to explore whether UHR individuals exhibit higher selection costs relative to healthy volunteers, and whether those selection costs are affected independently of semantic retrieval. In addition, we examine whether selection costs are associated with specific symptom dimensions. Specifically, the current investigation seeks to focus in on the relationship of selection costs with negative and disorganized symptom domains, given the theoretically consistent pathophysiological underpinnings of these symptoms and EF (Bowley et al., 2011; Carrion et al., 2016; Gur et al., 2015; Xu et al., 2014).

## 2. Methods

### 2.1. Participants

Participants were recruited to the University of Colorado Boulder's Adolescent Development and Preventive Treatment (ADAPT) research program, totaling 46 healthy volunteers (26 female, 20 male, mean age 18.4, SD = 2.49) and 45 UHR individuals (21 female, 24 male, mean age 18.73, SD = 1.67). Exclusion criteria included presence of a neurological disorder, lifetime substance dependence, and presence or lifetime history of an Axis I psychotic disorder. Healthy volunteer exclusion criteria included presence of a psychotic disorder in a first-degree relative. All procedures were reviewed by the University of Colorado institutional review board. All participants spoke fluent English. Across the entire sample, 88% of participants were native English speakers (meaning English was the first language the participant learned, and also the preferred language). Of the individuals who were not native English speakers, the age in which English was learned ranged from ages 1 to 12, with a mean of age 4.3. Across the UHR sample, 91.2% of individuals were neuroleptic-free, with 8.8% (4) being on small atypical antipsychotic doses (mean CPZ equivalent dose = 152.1, SD = 57.85).

### 2.2. Clinical assessments

All participants were administered the Structured Clinical Interview for DSM-IV Axis I disorders (SCID), in order to rule out a psychosis

diagnosis for both groups, as well as to assess history of mood and anxiety disorders (First, 2012). The Structured Interview for Prodromal Syndromes (SIPS) was administered in order to diagnose UHR participants and rule out symptoms in healthy volunteers (Miller et al., 1999). In addition, the Wide Range Achievement Test (WRAT) was administered in order to control for overall cognitive ability (Wilkinson and Robertson, 2006). Self-reported anxiety was measured using the Beck Anxiety Inventory (BAI) (Osman et al., 1997).

### 2.3. Verb generation task

Participants completed a verb generation task measuring selection and retrieval of words from semantic memory. Participants were presented with a noun and instructed to say the first associated verb that came to mind (Snyder et al., 2010), and were given an example and 8 practice trials before starting the task. A fixation cross appeared for 500 ms, followed by a noun. Participants were then instructed to respond through a microphone that collected voice-triggered reaction times. Trial order was randomized across participants. Previous studies in non-clinical populations have shown that participants are slowed by higher selection demand (measured in terms of degree of competition between competing responses) and higher retrieval demand (measured in terms of association strength between the noun and correct verb response) (Snyder et al., 2010). Retrieval demand reflects association strength between the noun and the appropriate response, whereas selection demand reflects amount of competition between possible responses. For instance, in terms of retrieval demand, “scissors” would have low retrieval demand because it is strongly associated with “cut”, whereas “giraffe” would have high retrieval demand because it is only weakly associated with any verb. In terms of selection demand, “cat” has a high selection demand, because it brings to mind many competing verbs such as “purr”, “meow” and “lick”, whereas “scissors” has low selection demand because it generally brings to mind a single verb, “cut” (see Fig. 1) (Snyder et al., 2010). Verb generation stimuli were 100 nouns in a  $2 \times 2$  design crossing high and low selection and retrieval demand, where high and low association strength conditions were matched on competition, whereas low and high competition conditions were matched on association strength. Association strength (retrieval demand) for stimuli presented and competition between stimuli responses (selection demand) were calculated using latent semantic analysis to pre-categorize task stimuli into the 4 conditions, consisting

of low/high competition and low/high association strength (Landauer et al., 2004; Snyder et al., 2011; Snyder et al., 2010). In regards to word stimuli used, concrete nouns (Kucera-Francis frequency range = 1–492, median frequency = 22, word length range = 3–9, median = 5) were divided into low and high selection demand groups, such that word frequency was not significantly different across low selection demand and high selection demand conditions. A word with high competition among alternatives will have a high selection demand because there are many options to choose from, whereas a word with few available responses, or low competition among alternatives, will have low selection demands because there are not as many options to choose from. A word with high association strength will have low retrieval demand, whereas a word with low association strength will be only weakly associated with suitable responses, and thus would have high retrieval demand, as it will be more difficult to elicit a response for that word, thus putting more of a strain on semantic retrieval processes. During task modeling, association strength was calculated as the average of (1) the strongest LSA cosine, (2) the LSA cosine for the most frequent response given by the norming sample, and (3) a weighted average of the LSA cosines for all verb responses given by the norming sample. Competition, in turn, was defined as entropy,  $[H = -\sum (p(i) \cdot \ln p(i))]$ , where  $p(i)$  is the cosine between the stimulus and each alternative response, divided by the sum of LSA cosines among all alternative responses (Snyder et al., 2010). In calculating entropy, a 0 value signified only one available response, and increasing values represented increasing available responses/increased competition among alternatives. For more information on task modeling, see Snyder et al. (2010) supplementary materials. Raw reaction times for each of the four conditions were obtained using time between stimulus presentation and participant voice response onset as detected by the microphone. Selection costs were calculated by subtracting the reaction time of low selection demand from that of high selection demand trials. Retrieval costs were calculated by subtracting the reaction time of low retrieval demand from that of high retrieval demand trials. Raw RTs were also natural log (ln) transformed, consistent with Snyder et al., 2010. The task was normed with a healthy sample such that stimuli with high selection/retrieval demand are more challenging than those with low selection/retrieval demand. Thus, calculations of selection costs (reaction time difference between high selection demand and low selection demand conditions) should be positive, or at the very least near zero. Negative values could indicate the individual did not

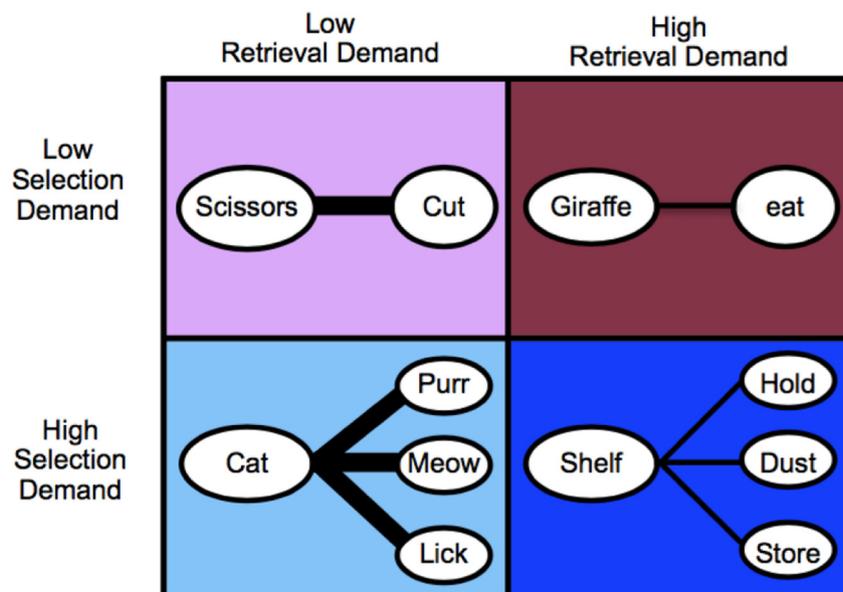


Fig. 1. Verb generation task design: selection demands (high vs low competition) are crossed with retrieval demands (high vs low association strength) (Snyder et al., 2010).

**Table 1**  
Demographic characteristics by group.

	UHR (n = 45)	Healthy (n = 46)	p
Demographics			
Age	18.9 (1.6)	18.5 (2.4)	n.s
Gender	53.3% male	43.5% male	n.s
IQ	112.2 (11.6) <sup>a</sup>	104.5(12.0) <sup>a</sup>	2 > 1**
Parent education	12.3 (1.9) <sup>b</sup>	12.14 (2.6) <sup>b</sup>	n.s
Symptoms			
Positive	12.1 (4.5) <sup>c</sup>	0.57 (1.2) <sup>c</sup>	1 < 2**
Negative	9.2 (7.0) <sup>c</sup>	0.35 (0.67) <sup>c</sup>	1 < 2**
Disorganized	5.2 (3.4) <sup>c</sup>	0.22 (0.51) <sup>c</sup>	1 < 2**

Mean (SD), <sup>a</sup> = estimated by WRAT (Wide Range Achievement Test), <sup>b</sup> = average years of education of mother and father, <sup>c</sup> = Measured by SIPS battery.  
1 = Healthy volunteers, 2 = UHR, \*\* =  $p < 0.01$ .

fully understand the instructions, or that they were not trying to respond as quickly as possible, given that the conditions were normed such that low demand conditions take less time than high demand conditions. Therefore, negative values are indicative of a manipulation failure per the task design, and these individuals were excluded, consistent with what was done in the Snyder et al., 2010 study; 15 healthy volunteers and 16 UHR participants were excluded due to negative selection effects. The basic effects of task manipulation were highly robust, even when these individuals were included.

#### 2.4. Statistical analyses

Independent samples *t*-tests and chi square tests, when appropriate, were used to test for demographic differences between groups. Univariate ANCOVAs controlling for age and WRAT score were performed to assess differences in selection and retrieval costs between diagnostic groups. In addition, relationships between selection costs and positive, negative and disorganized symptoms were examined in the UHR group using partial correlations controlling for age and WRAT. Relationships between retrieval and selection costs and anxiety as assessed by the BAI were explored, in order to see whether links with anxiety in Snyder et al., 2010 were present in this sample as well (Tables 1 and 2).

### 3. Results

#### 3.1. Verb generation task

There was a significant effect of diagnosis on selection cost, such that UHR individuals exhibited increased selection costs,  $F(1, 91) = 4.39$ ,  $p = 0.039$  (see Figs. 2 and 3). However, there was no significant effect of diagnosis on retrieval cost,  $F(1, 91) = 0.63$ ,  $p = 0.43$ , which suggests the effect is independent of task engagement. As expected, selection cost scores were highly associated with retrieval costs ( $r = 0.49$ ,  $p < 0.001$ ).

In regards to reported anxiety as assessed by the BAI, the UHR group reported significantly greater anxiety levels relative to healthy volunteers,  $t(1, 91) = 7.729$ ,  $p < 0.001$ . Mean BAI scores for UHR group 22.23,  $SD = 12.67$ , for healthy volunteers 5.65,  $SD = 6.8$ . Reported

anxiety was not significantly associated with relevant outcome variables: it is worth noting that unlike the BAI measure, previous findings by Snyder et al., 2010 linking anxiety to performance were specific to anxious apprehension (e.g., worry).

#### 3.2. Correlations with symptoms

As hypothesized, selection costs were positively associated with total disorganized symptoms and total negative symptoms in the UHR sample, controlling for age and WRAT score, such that the higher the selection cost, the greater number of disorganized symptoms,  $r = 0.409$ ,  $p = 0.006$ , and the greater number of negative symptoms,  $r = 0.38$ ,  $p = 0.01$ . Total number of positive symptoms did not significantly correlate with selection costs ( $p = 0.15$ ). In order to gain some insight into the specificity of the association with disorganized symptoms, we ran exploratory correlations with each of the 4 sub-items comprising the composite score. Trouble with focus and attention yields the strongest association ( $r = 0.4$ ,  $p = 0.007$ ), as well as odd behavior or appearance ( $r = 0.26$ ,  $p = 0.048$ ), while impairment in personal hygiene ( $r = 0.2$ ,  $p = 0.056$ ) and bizarre thinking ( $r = 0.21$ ,  $p = 0.09$ ) are trending-level associations. In regards to negative symptoms, social anhedonia ( $r = 0.29$ ,  $p = 0.03$ ), avolition ( $r = 0.5$ ,  $p < 0.001$ ), ideational richness ( $r = 0.3$ ,  $p = 0.025$ ) and occupational functioning ( $r = 0.45$ ,  $p = 0.001$ ) are most strongly associated.

### 4. Discussion

This study is among the first to examine in more detail neural inhibition aspects of EF in UHR youth as assessed by selection during language processing. Present findings indicate that UHR participants exhibit increased selection costs relative to healthy volunteers, when controlling for age and overall cognitive performance, potentially indicating impaired ability in the domains of cognitive control and neural inhibition. There was no overall group difference in retrieval costs, suggesting that this effect is not driven by task engagement or other aspects of EF required for the task. Rather, the results suggest a mechanistically distinct impairment in selection in UHR individuals relative to healthy volunteers. In addition, a positive association was found between selection costs, negative and disorganized symptoms. If increased selection costs entail decreased prefrontal GABAergic function (Snyder et al., 2010), this would be in line with multiple theories linking both executive function deficits and disorganized symptoms to GABA dysfunction in psychosis (Egerton et al., 2017; Glausier and Lewis, 2017; Minor and Lysaker, 2014; Phillips and Silverstein, 2013).

Previous research has found that selection and retrieval processes are differentiated through neural inhibition: selection, but not retrieval, depends on neural inhibition, perhaps due to GABAergic interneuron-mediated competitive lateral inhibition aiding in suppressing competing options (Phillips and Silverstein, 2003; Snyder et al., 2011). In line with previous studies finding that agonist-induced increased GABAergic function aids selection but not retrieval, our findings lend support to the notion that this distinct facet of neural inhibition is affected, as opposed to common EF (Snyder et al., 2011; Snyder et al., 2010). Taken together, results indicate that this population may exhibit an impaired ability to

**Table 2**  
RTs per condition and diagnosis.

	Low retrieval demand		High retrieval demand	
	Mean RT (SD)	Log RT (SD)	Mean RT (SD)	Log RT (SD)
Healthy volunteer				
Low selection demand	1835.5 (1400.9)	7.36 (0.5)	2958.2 (4613.3)	7.69 (0.67)
High selection demand	2325.2 (2288.2)	7.54 (0.57)	3559.8 (4599.7)	7.84 (0.72)
UHR				
Low selection demand	2163.7 (2446.8)	7.45 (0.58)	3336.0 (4185.6)	7.79 (0.71)
High selection demand	2927.8 (3758.3)	7.65 (0.71)	4138.5 (5689.2)	7.93 (0.79)

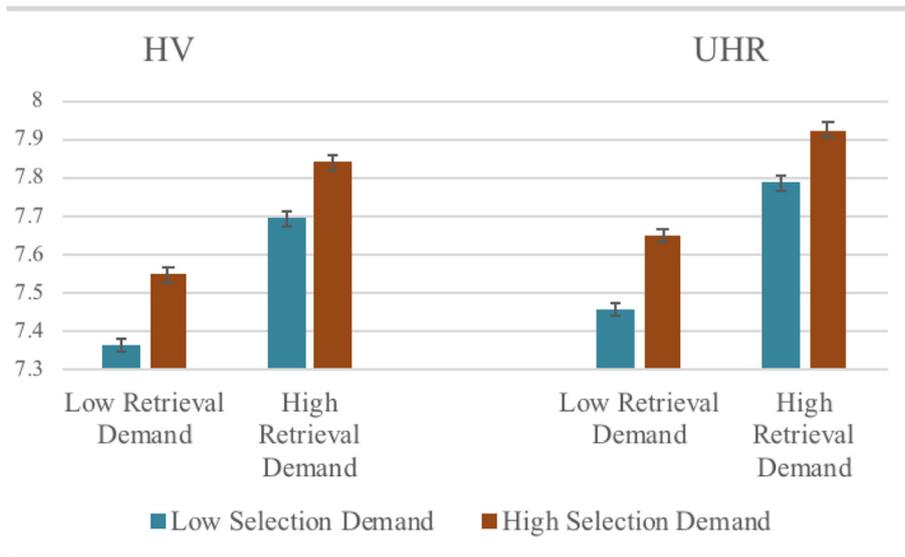


Fig. 2. Log RT across conditions per diagnosis, estimated marginal means of log RT controlling for age and WRAT score.

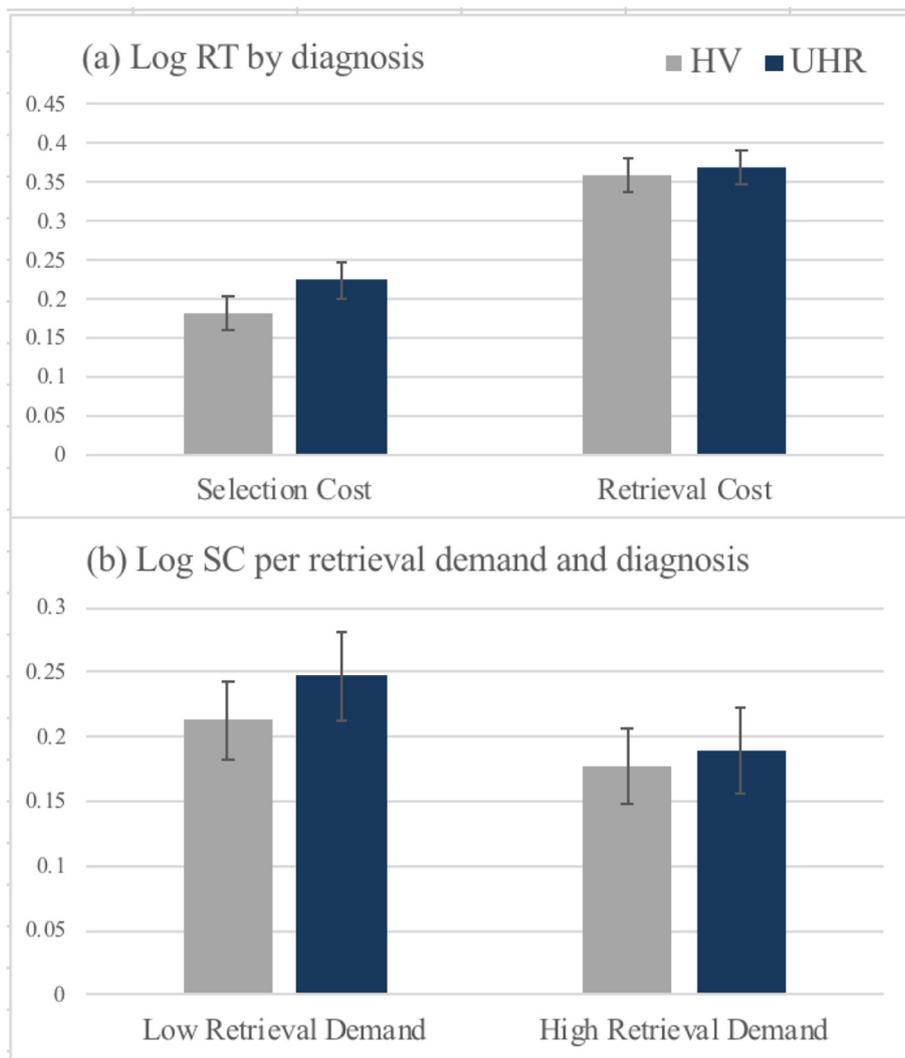


Fig. 3. Log RT selection and retrieval costs per diagnosis, estimated marginal means of log RT controlling for age and WRAT score.

efficiently choose among options when competition among alternatives is high, independent of cognitive ability and overall EF. Further, results indicated that selection cost reaction times were strongly associated to disorganized symptoms in the UHR sample, which is consistent with previous studies finding that executive function is most closely linked with disorganized symptoms, and may share underlying mechanisms (Bowie et al., 2011; Phillips and Silverstein, 2013).

The current investigation suggests that cognitive deficits inform our understanding of symptoms in UHR populations, and may potentially possess converging underlying mechanisms. Examining distinct EF processes may aid our understanding of symptom presentation, as well as overall social and role function in the UHR population, especially given that disorganized and negative symptoms in tandem with poor neurocognitive function have been shown to predict poor social and role functioning in UHR populations (Carrion et al., 2013; Minor and Lysaker, 2014; Xu et al., 2014). Our findings are in line with previous studies implicating disorganized symptoms as having greater associations with neurocognition and social cognition relative to positive and negative symptoms (Minor and Lysaker, 2014), as well as with studies linking disorganized symptoms to impaired executive function (Xu et al., 2014) and functional outcomes (Carrion et al., 2013). Thus, selection during language processing may be informative in helping us gauge the convergence between disorganized symptoms and executive function deficits in psychosis. Given that cognitive deficits constitute a cardinal feature of the disorder (Eastvold et al., 2007; Meier et al., 2014; Pukrop et al., 2007; Reichenberg and Harvey, 2007; Reichenberg and Mollon, 2016; Woodberry et al., 2008), understanding cognitive impairments that are also associated with symptom progression is a promising avenue to further understanding etiology. As studies in healthy populations suggest, prefrontal alterations in GABA-ergic inhibitory neuronal function may lead to dysfunctional recruitment of prefrontal network activity during executive aspects of selection (de la Vega et al., 2014). Future studies exploring whether these same mechanisms are indeed directly implicated in some of the symptoms observed in formal thought disorder and disorganization symptoms more generally, would be highly informative in furthering this line of research. Future investigations should further explore UHR neural inhibition using other modalities such as fMRI or MRS in order to determine neurological underpinnings.

As noted, the present study's findings of increased selection costs among the UHR group were independent of general cognitive ability and another aspect of EF performance (i.e., executive aspects of memory retrieval), supporting the notion that the observed selection impairment may constitute a mechanistically distinct EF subdomain. Several of the current limitations also provide important lessons for future research. Specifically, including a broader battery designed to assess different components of EF would be valuable and an important next step. Given that selection during language processing has not been previously studied in UHR populations, future studies are needed to confirm present findings that selection costs are impaired in this population. An equivalent number of individuals in the UHR and healthy volunteer groups were excluded due to inadequate engagement with the task. Future studies with better attended task performance across groups would be ideal, as well as studies recruiting a larger number of participants in each group.

Given the amount of subjects that had to be excluded, there is a possibility that the current task paradigm was challenging for a clinical population. Future studies may devote more focus to making the paradigm more manageable for clinical populations, such as giving more thorough task instruction and practice trials, as well as offering rewards for engaged responses to give participants positive reinforcement and greater motivation to perform to the best of their ability. Having the experimenter in the room monitoring the participant may also aid in eliciting optimal performance. These techniques could also be applied to healthy volunteer groups, in order to increase motivation to perform well on the task and remain attentive.

Finally, the Snyder 2010 study found that administering the GABA agonist midazolam improved selection in a non-clinical population, concluding that GABA agonists may be effective not only in treating the affective symptoms of anxiety disorders, as they are often used, but also in treating the cognitive control and decision-making deficits implicated in anxiety (Snyder et al., 2010). Thus, another promising future direction could be to administer GABA agonists to UHR populations to see if this would aid in easing disorganization symptoms, anxiety levels, and bettering selection cost performance. In addition, longitudinal studies tracking disorganized symptom development with cognitive deterioration in the cognitive control and decision-making domains would be informative. Examining how development in these domains may predict social function or conversion risk would also be a promising future direction.

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#### Contributors

Dr. Vijay Mittal and Teresa Vargas conducted literature review and drafted the manuscript. Dr. Snyder and Dr. Banich helped with editing the manuscript and were consulted for data analysis questions. Dr. Shankman and Dr. Strauss were also consulted for help with writing the manuscript and data analysis. Rae Newberry helped with preparing the data for analysis, as well as with the quality checking of the data.

#### Conflicts of interest

V.A.M. is a consultant to Takeda Pharmaceuticals. No other authors have any disclosures.

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