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Elementary Neurocognitive Function, Learning Potential and Everyday Life Skills in Schizophrenia: What is Their Relationship?

Matthew M. Kurtz, Ph.D.^{1,2}, Sarah B. Jeffrey, B.A.¹, and Jennifer Rose, PhD¹

¹Department of Psychology, Wesleyan University, Middletown, CT. U.S.A. 06459

²Schizophrenia Rehabilitation Program, Institute of Living, Hartford, CT. U.S.A. 06106

Abstract

Few studies have investigated relationships between static, elementary neurocognitive functions, dynamic measures of learning potential and functional status in schizophrenia, despite the putative role of learning potential in models of the relationship between static neurocognitive function and functional status (e.g., Green et al., 2000). The current study sought to clarify these relationships. One-hundred and twenty-five outpatients with schizophrenia were administered the California Verbal Learning Test-II (CVLT-II), as an index of learning potential, along with measures of sustained attention, verbal prose recall, working memory, problem-solving and processing speed, and a capacity measure of everyday life skills (Study 1). A subset of 48 outpatients with schizophrenia who were impaired on the Wisconsin Card Sorting Test (WCST) were also administered a test-train-test version of the WCST as a second measure of learning potential (Study 2). As expected, several static, elementary neurocognitive measures were linked to measures of everyday life skills in both samples. There was no evidence, however, that either measure of learning potential contributed unique variance beyond that explained by elementary cognitive skill to measures of everyday life skills. Learning potential was also tested as a mediator and moderator of the relationship between static neurocognitive function and measures of everyday life skills. Neither learning potential measure mediated the relationship between static measures of neurocognition and everyday life skills. Learning potential, as measured by the CVLT-II, was found to moderate the relationship of processing speed and everyday life skills. Taken together, these findings raise questions as to the explanatory value of measures of learning potential as predictors of functional status in schizophrenia.

Keywords

learning potential; neurocognition; everyday life skills; schizophrenia

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Address for correspondence: Matthew M. Kurtz, PhD, Department of Psychology, Wesleyan University, Judd Hall, 207 High Street, Middletown, CT. 06459 mkurtz@wesleyan.edu; Tel: (860) 685-2072, FAX: (860) 685-2761..

Contributors Matthew M. Kurtz, Ph.D., was responsible for initial conceptualization and design of the study, oversaw all data collection, wrote the Introduction and Conclusion sections of the paper, and wrote and/or edited all other portions of the manuscript.

Sarah B. Jeffrey, B.A., conducted the moderator analyses, helped interpret resultant findings and wrote portions of the Methods and Results sections of the paper as part of her undergraduate thesis submitted to the Honors College at Wesleyan University.

Jennifer Rose, Ph.D., was responsible for formulating the data analytic plan, helped conduct the moderator analyses, and provided support for interpreting the results of all statistical analyses. Dr. Rose wrote and edited portions of the Methods and Results sections of the paper.

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1. Introduction

A wealth of studies have revealed that elementary deficits in attention, verbal and non-verbal memory, working memory, language, early visual processing and psychomotor skills explain anywhere from 20–60% of the variance in measures of community function, analog measures of instrumental and social-skill, and progress in psychosocial rehabilitation programs in schizophrenia (Green et al., 2004; Green et al., 2000). Other studies have identified a link between measures of processing speed and competitive employment outcome (e.g., Gold et al., 2002). It remains unknown to what degree these links between elementary neurocognitive skills and functional status in schizophrenia are direct, or might instead be mediated by other variables. It also remains unknown what factors may explain the 40–80% of variance in functional status unaccounted for in these studies.

One concept that has been proposed to help clarify the relationship between elementary neurocognition and functional status in schizophrenia is “learning potential” (Fiszdon et al., 2006; Green et al., 2000; Sergi et al., 2005; Watzke et al., 2008; Wiedl, 1999; Vaskinn et al., 2008). Learning potential as a construct in schizophrenia has been measured through the use of dynamic assessments, a diagnostic approach that involves systematic learning experiences and provides important information about the remediability of cognitive functions above and beyond a person's manifest performance (e.g., Grigorenko & Sternberg, 1998). The concept focuses on latent abilities and places emphasis on within-subject variance in tests scores rather than between-subject differences in single test administrations (e.g., Zubin, 1950). Learning potential for individuals is typically measured through repeated test administrations, in a pretest-intervention/training-posttest approach, rather than a single test administration. Some investigators have formulated heuristic models that locate learning potential measurements as a variable more proximal to functional status than elementary neurocognitive skill, providing a direct index of the ability to acquire skills necessary for everyday-life that enable success across a variety of domains of outcome (e.g., Green et al., 2000). Despite these models, few studies have directly investigated the relationship of measures of static, elementary neurocognitive function, measures of learning potential and functional status in schizophrenia. The current study sought to clarify these relationships.

Fiszdon et al. (2006) in a cross-sectional study of 50 outpatients with schizophrenia, compared the Matrix Reasoning subtest of the WAIS-III, an index of non-verbal reasoning, and a measure of learning potential derived from both standard and explicit task training on the CVLT-II, to a measure of rehabilitation readiness. Results revealed that dynamic assessments of verbal learning explained an additional 9% of variance in their index of rehabilitation readiness beyond that predicted by their static measure of non-verbal reasoning alone. The authors concluded that learning potential explains variance in readiness for rehabilitation beyond that explained by elementary neurocognitive measures

Similarly, Sergi et al. (2005) in a longitudinal study of 57 outpatients with schizophrenia assigned to one of two work-skill acquisition programs, evaluated the relationship of a measure of learning potential, the test-train-test version of the Wisconsin Card Sorting Test (WCST), to performance on a standard, single administration of the WCST for predicting accuracy and overall performance on work-skills tasks, after work-skills training. The test-train-test version of the WCST consisted of a standard administration phase (test), a training phase in which in which verbal instruction and feedback were offered to enhance task performance (train), and then a second test phase under standard instruction conditions to assess learning. Learning potential was measured by change in performance from the pre- to post-training assessment. Results yielded several interesting findings: first, static and dynamic assessments from the WCST were not related, suggesting these tasks measured independent neurocognitive skills,

despite using identical test stimuli. Second, an additional 15% of variance in accuracy on work-skills tasks at an immediate test, and 13% of variance in task accuracy at a 3-month follow-up was explained by the test-train-test version of the WCST, after accounting for variance explained by a single administration of the WCST.

These findings have been supported by other studies showing that scores from the test-train-test version of the WCST, as compared to scores from the standard administration of the WCST before training, explain a larger proportion of variance in: (1) a measure of problem-solving after a brief course of social-skills training (Wiedl et al., 2001), (2) work capability and vocational integration during and after vocational rehabilitation (Watzke et al., 2009), as well as (3) global ratings of psychosocial function and employment status (Weingartz et al., 2008) in samples of individuals with schizophrenia.

These studies all support the contention that measures of learning potential explain variance in outcome beyond that explained by static measures of neurocognitive function, despite utilizing very different methods for learning potential assessment. These studies however, were limited by: (1) including only a single measure of neurocognitive function (non-verbal reasoning or problem-solving), (2) not explicitly testing a variety of types of relationships such as moderating and mediating relationships between static elementary neurocognition, learning potential and functional status, and (3) controlling for overlap between symptom severity and estimated verbal IQ, learning potential and functional status.

The primary goal of the current study, then, was to investigate relationships between a range of measures of elementary neurocognitive function, two different measures of learning potential and a performance-based measure of everyday life-skill in the same sample of individuals diagnosed with schizophrenia or schizoaffective disorder. We predicted that; (1) a range of elementary neurocognitive measures would be linked to everyday life skills, and this relationship would be specific, evident even after estimates of verbal IQ and symptom severity measures were accounted for; (2) based on previous studies of the construct validity of learning potential measures, we predicted that elementary measures of executive-function, working memory and secondary verbal memory, would be closely linked to measures of learning potential (e.g., Wiedl et al., 2004), and (3) learning potential measures would be independent of static neurocognitive measures, and would have an additive relationship with elementary neurocognitive skill, predicting variance in everyday life-skill capacity beyond that explained by a range of elementary neurocognitive measures. We also investigated whether measures of learning potential mediated a causal relationship between elementary neurocognitive function and everyday life-skills. For example, would impaired attention influence measures of learning potential, which would in turn impact everyday life functioning? Alternatively, learning potential might moderate the relationship between elementary neurocognitive functions and everyday life skills. Thus, we assessed whether the relationship between attention, for example, and everyday life skills, depended upon whether measures of learning potential were high, medium or low.

2. Methods

Participants—One-hundred and twenty-five clinically-stable, community-dwelling individuals with schizophrenia or schizoaffective disorder participated. Diagnosis was confirmed by the patient form of the Structured Clinical Interview for DSM-IV (SCID; Spitzer, Williams, & Gibbon, 1996). Exclusion criteria for all potential participants were: (a) known neurological disease, (b) developmental disability, (c) current substance abuse, (d) mental retardation as evidenced by a history of services, or (e) lack of fluency in English. All patients provided written informed consent and all procedures met institutional ethical review. Data for this study were collected at entry to an ongoing study of the effects of cognitive remediation

on cognitive and social dysfunction in people with schizophrenia (Kurtz et al., 2007). Data from this sample was used for Study 1.

For Study 2, a subsample of forty-eight patients from the overall sample who achieved less than 5 categories on the 128-card paper-and-pencil version of the WCST (10th percentile or below for healthy participants between 20 and 39 years of age), were classified as impaired and thereby selected for further training and testing on the WCST. Table 1 describes the demographic and clinical characteristics of the entire sample used in Study 1, and the subsample receiving the test-train-test version of the WCST as part of Study 2.

Assessment Measures

Symptom Assessment—The Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987) was used to assess symptoms. This measure is a semi-structured interview that generates ratings of signs and symptoms on 30, 7-point Likert scale items. Symptom raters for the study maintained interrater reliability through periodic rater training sessions, and all raters were trained to a criterion reliability of .8 intraclass correlation coefficient (ICC), across four jointly viewed, but independently-rated interviews. The subscales for total positive and total negative symptoms were selected as the independent measures.

Neuropsychological Assessment—All participants were administered a neuropsychological test battery including the vocabulary subtest, and working memory and processing speed indexes (WMI and PSI respectively) from the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997), the Logical Memory subtest of the Wechsler Memory Scale-III (LM; Wechsler, 1997), the Penn Continuous Performance Test (PCPT; Kurtz et al., 2001) and the Penn Conditional Exclusion Test (PCET; Kurtz et al., 2004). For the PCPT, an efficiency score was calculated for each participant by dividing total true positives by the average reaction time. Since this variable is a proportion, an arcsine transformation was performed. For the PCET, the error score was selected for analysis. Measures were selected based on their relationships with functional status in previous studies of schizophrenia (e.g., Green et al., 2000; 2004; Gold et al. 2002).

Learning Potential Assessments—In addition to these static measures of neuropsychological abilities, two dynamic measures were utilized to assess the participants' learning potential. The California Verbal Learning Test-II (CVLT-II; Delis et al., 2000) was administered to all participants under standard instructions for the first assessment. In this test the participant is presented with a list of 16 word items from 4 semantic categories and is then asked to recall the items. This procedure is repeated five times using the same list of words in order to assess learning. This procedure has been selected in previous studies of learning potential (Green et al., 2000; Fiszdon et al., 2006).

The subgroup of the sample that achieved less than 5 categories (10th percentile or below for healthy participants between 20–39 years of age; Heaton et al., 1993) on the Wisconsin Card Sorting Task (WCST) were classified as impaired, and underwent the test-train-test protocol of the task, which has commonly been used to assess learning potential in schizophrenia (Sergi et al., 2005; Wiedl et al., 1999; Woonings et al., 2002). The WCST is a test of problem-solving that requires the subject to respond to rule changes and use feedback to guide future answers (Heaton et al., 1993). When this test is used to assess learning potential, it is administered three times. For the first trial the test is administered under standard conditions. For the second trial the participant is offered instruction, practice, and feedback on the task, and is then re-administered the task a third time under standard instructions. Training was conducted according to the commonly used approach described by Bellack et al. (1990) in which the task was explained, correct responses were modeled and card-by-card instruction was given for

cards 1–5 and 32–37. The progress made from the first to third administration has been measured an index of learning potential (Sergi et al., 2005).

For both measures, learning potential was calculated by a gain-score formula similar to that used by Sergi et al., (2005), and Vaskinn et al., (2008) in previous studies. This procedure permitted learning potential to be measured as a continuous variable. While a categorical approach has been selected for some studies of learning potential to identify “learners” or “non-learners” (e.g., Wiedl, 1999; Fiszdon et al., 2006), we selected a dimensional approach in the current study to provide greater statistical power. For the CVLT the gain score formula was: $(\text{Trial 5 score} - \text{Trial 1 Score}) / (16 - \text{Trial 1 score})$. This same formula was adapted to be applicable for the change in error score on the test-train-test version of the Wisconsin Card Sorting Task. In the denominator of the formula, the number of pre-training errors was subtracted from 6 because six errors represent the best score possible. The gain score formula for the test-train-test version of the WCST was: $(\text{Post-training errors} - \text{Pre-training Errors}) / (6 - \text{Pre-training Errors})$. In interpreting numbers yielded by the formula, a positive number indicates that the participant improved from trial one to the final testing trial. A negative number indicates that the participant's score declined from trial to trial. A score of 1 indicates improvement to perfect performance after training.

Functional Skills Assessment—(UPSA; Patterson et al., 2001): This standardized, performance-based instrument of everyday function provides information regarding patients' ability to plan trips to the beach and zoo (recreation planning), count out and provide change using actual domestic currency and write checks for bills (finance), ask for information and reschedule a doctor's appointment via the telephone (communication), plan a bus trip on the local bus system using relevant maps (mobility), and identify items necessary for a recipe that are missing from a simulated pantry (household management). Each of the five subscales was scored on a 1–20 scale, thus summing subtest scores results in a total score on a scale of 0 to 100.

Data Analysis

The Statistical Package for the Social Sciences (SPSS 15.0) was used for statistical analyses. Raw scores for each of the measures were converted to age-corrected z-scores using published or local normative data. For the learning potential assessment, for which no normative data was available, the data were converted to z-scores according to the mean and standard deviation from the current sample. The data analytic plan was conducted in two stages, and applied first to the overall sample that included the CVLT-II assessment of learning potential (Study 1), and then repeated for the subsample who received the test-train-test version of the WCST (Study 2). In stage 1, Pearson's product-moment correlations were calculated between each of the neurocognitive variables, estimated verbal IQ using WAIS-III vocabulary scaled scores, positive and negative symptom severity, one of the two learning potential assessments, and measures of everyday life-skills. In stage 2, a series of hierarchical regression models was tested using each of the static neurocognitive measures that were linked to everyday life skills in stage 1. In the first step of this model, estimated verbal IQ and symptom severity ratings, when linked to functional life skills in Stage 1 of the analysis, were entered into the equation. This ensured that relationships between specific, static neurocognitive measures and learning potential assessments with everyday life skills were not secondary to estimated verbal IQ or symptom severity. In step 2, a measure of static neurocognitive function linked to life skills in stage 1 was entered. In step 3, the results of the learning potential assessment was entered (CVLT-II learning, or the test-train-test version of the WCST). This step allowed us to both: (1) identify the unique contribution of learning potential to everyday functional life skills beyond elementary neurocognitive function, and (2) determine whether measures of learning potential mediated the relationship between elementary neurocognitive function and everyday

life skills. If learning potential could be conceptualized as a construct predicting variance in everyday life-skill separate from elementary neurocognitive function, we would expect a significant increase in explained variance when learning potential measures were added in step 3 of this regression, with elementary neurocognitive function remaining related to performance-based everyday life skills. Alternatively, if learning potential mediated the relationship between any of the neurocognitive variables and life-skills, we would expect that, according to the methods of Baron & Kenny (1986): (1) learning potential assessments would be related to everyday life-skills, (b) elementary neurocognitive function would be related to everyday life-skills, (c) learning potential would be related to elementary neurocognitive function, and (d) when learning potential was controlled for statistically the relationship between the elementary neurocognitive variable and everyday life-skill would be reduced or removed. In the fourth and final step of each regression, we entered the interaction term for the main effects of the elementary neurocognitive variable and learning potential assessment, to assess whether dynamic learning potential measures moderated the relationship between static, elementary neurocognitive function and everyday life-skills. Significant interactions were interpreted using methods outlined by Aiken and West (1991). Simple slope coefficients were calculated for the relation of neuropsychological functioning to functional capacity at low (-1 SD), medium (mean) and high ($+1$ SD) levels of learning potential (Aiken & West, 1991). All analyses were two-tailed and alpha was set at .01 to help adjust for multiple comparisons.

Results

Relationships Among the Study Variables

Correlations between standardized neuropsychological scores, estimated verbal IQ, symptoms, learning potential as measured by the CVLT-II (Study 1), and performance-based life-skills are presented in Table 2. Elementary neuropsychological measures, LM ($r = 0.44$, $p < .001$), WMI ($r = 0.57$, $p < .001$), PCET ($r = .41$, $p < .001$), and PSI ($r = 0.41$, $p < .001$) were all related to the UPSA Elementary neuropsychological measures, LM ($r = 0.51$, $p < .001$), WMI ($r = 0.39$, $p < .001$), and PSI ($r = 0.38$, $p < .001$) were all related to the CVLT-II assessment of learning potential. Learning potential, as measured by the CVLT-II, was also significantly related to the UPSA ($r = .29$, $p = .001$), as was estimated verbal IQ and negative symptom severity ($r = .55$, $p < .001$ and $r = -.23$, $p < .001$, respectively). For the subset of participants receiving the test-train-test version of the WCST (Study 2), correlations between standardized neuropsychological scores, estimated verbal IQ, symptoms, learning potential and performance-based life-skills are presented in Table 3. Elementary neurocognitive measures LM ($r = 0.50$, $p < .001$), WMI ($r = 0.48$, $p < .01$), and PSI ($r = 0.42$, $p < .01$) were all related to UPSA total score. The elementary neuropsychological measure WMI ($r = 0.42$, $p < .001$), was related to the test-train-test version of the WCST. The relationship of the test-train-test version of the WCST to everyday life skills was not significant in this analysis. Estimated verbal IQ, but not negative symptoms, was related to everyday life skills as well ($r = .47$, $p < .01$).

Specificity of the Association Between Elementary Neurocognitive Function and Everyday Life Skills

When estimated verbal IQ and negative symptoms were entered first into a series of hierarchical regressions for each elementary, static neurocognitive skill linked to everyday life skills in the correlational analysis for Study 1, only WMI remained a significant predictor of the UPSA ($t = 3.40$, $p < .002$), producing a significant change in $R^2 = .065$ ($F[1,109] = 11.61$, $p < .002$), and explaining 7% of the variance beyond that associated with estimated verbal IQ and negative symptoms. For Study 2, when estimated verbal IQ was entered first into a series of hierarchical regressions for each elementary neurocognitive skill linked to everyday life skill in the correlational analysis, only LM remained a predictor of the UPSA ($t = 2.96$; $p < .006$), producing

a significant change in $R^2=.13$, ($F[1,45]=8.75$, $p<.006$) and explaining an additional 13% of the variance beyond that associated with estimated verbal IQ.

Learning Potential as a Unique Contributor to Everyday Life Skills

The addition of measures of learning potential from the CVLT-II in Study 1 and the test-train-test version of the WCST in Study 2, did not explain variance in UPSA scores beyond that explained by each elementary neurocognitive measure, negative symptoms and estimated verbal IQ in Study 1, and each elementary neurocognitive measures and estimated verbal IQ in Study 2 (see Tables 4 and 5).

Learning Potential as a Mediator of the Relationship between Elementary Neurocognitive and Everyday Life Skills

In Study 1, the correlational analyses revealed the prerequisite relationships between learning potential, UPSA, WMI, LM and PSI for potential mediation. Mediation was tested with hierarchical regressions for each of these static neurocognitive measures (see Table 4, step 4). In two regressions, the relationship of the elementary neurocognitive measure and UPSA was no longer significant when estimated verbal IQ and negative symptoms were entered first into the regression model (LM and PSI; see Table 4). For the regression of WMI on UPSA, which remained significant after the entry of estimated verbal IQ and negative symptom severity, the relationship of WMI to UPSA was not reduced by entering the learning potential measure which suggested that learning potential did not mediate the relationship between WMI and UPSA. For Study 2, prerequisite correlational relationships for mediation were not evident for any of the elementary neurocognitive measures, learning potential assessments or UPSA (see Table 3). Consequently, no tests for mediation were conducted in Study 2.

Learning Potential Measures as a Moderator of the Relationship Between Elementary Neurocognitive and Everyday Life Skills

Results from the hierarchical regression analyses testing the moderating effects of two learning potential measures in the relationship between static measures of neurocognition and functional life skills found that the interaction term was only significant in the model including PSI ($t=-2.49$, $p=.01$; Tables 4 and 5). The interaction in the PSI model was plotted in Figure 1 using the simple slopes method described by Aiken and West (Aiken & West, 1991). PSI was significantly related to the UPSA at high and mean levels of learning potential, but not at low learning potential ($B=-0.17$, $p=0.91$; $B=2.38$, $p=0.04$; and $B=4.93$, $p=0.003$ at low, mean and high levels of learning potential, respectively). PSI was more strongly related to UPSA for participants with high learning potential compared to participants with average learning potential. No support was found for either measure of learning potential moderating the relationship between any of the other elementary neurocognitive variables and everyday life skills (Tables 4 and 5).

Discussion

This is the first study, to our knowledge, to evaluate a range of relationships, including mediation and moderation, between two different measures of learning potential, a range of measures of static elementary neurocognitive functions, and everyday life-skills in a sample of individuals with schizophrenia. Consistent with our first hypothesis and previous studies (e.g., McClure et al., 2007; Twamley et al., 2002) moderate relationships were evident between a range of elementary, static neurocognitive measures (prose recall, working memory, problem-solving and processing speed) and a measure of performance-based everyday life skills in both the larger sample of individuals receiving the CVLT-II learning potential assessment, and the sub-sample of clients receiving the test-train-test version of the WCST. The current findings also provide evidence for specificity of these relationships when verbal

IQ and/or symptoms are controlled: working memory in the larger sample given the CVLT-II remained linked to everyday life function after controlling for global verbal IQ and negative symptom severity, and verbal prose recall in the smaller sample administered the dynamic version of the WCST remained related to everyday life skills after controlling for global, verbal IQ.

Consistent with our second hypothesis, as well as previous construct validity studies of learning potential (Wiedl et al., 2004), the CVLT-II learning potential measure was linked to secondary verbal memory (Logical Memory from the WMS-III) and working memory. The test-train-test version of the WCST was linked to elementary neuropsychological measures of working memory, but not secondary verbal memory.

Results of the study did not support our third hypothesis: measures of learning potential in schizophrenia did not explain variance in everyday life skills unaccounted for by static measures of elementary neurocognitive function, estimated verbal IQ and negative symptom severity in people with schizophrenia. Two commonly used methods for assessing learning potential (gain scores from Trails 1–5 of the CVLT-II in Study 1 and a test-train-test version of the WCST in Study 2) failed to explain more than 1% of the variance in everyday life skill beyond that explained by global, verbal IQ and static measures of verbal prose recall, working memory, problem-solving and processing speed.

Particular significance has been attached to relationships between learning potential, elementary neurocognitive function and functional status in light of theoretical models that suggest that latent skills that represent the ability to benefit from repeated task practice and instruction (learning potential) mediate relationships between manifest, static neurocognitive skills and psychosocial function in schizophrenia (e.g., Green et al., 2000). The current study failed to lend support to these models: neither measure of learning potential selected for our study mediated the observed relationships between static measures of verbal prose recall, working memory, problem-solving, and processing speed and everyday life skill. These findings are consistent with those of Vaskinn et al. (2008). The results of that study failed to find that learning potential, as measured by the test-train-test version of the WCST, mediated the relationship between a composite measure of neurocognitive function consisting of measures of verbal learning, executive-function and processing speed, and a role-play assessment of social-skill in 26 individuals with schizophrenia. The current findings replicate this study with a substantially larger sample of people with schizophrenia, and a second measure of learning potential, and extend these findings to a measure of everyday life skills that places larger demands on ADL skills and more modest demands on social interaction skills.

An important finding from the current study is that learning potential, as measured by the CVLT-II in Study 1, moderated the relationship between processing speed and everyday life skills: individuals with different levels of learning potential showed different relationships between processing speed and everyday life skills. More specifically, individuals with high learning potential showed a closer relationship between processing speed and everyday life skills than those with moderate levels of learning potential, while individuals with low levels of learning potential did not show a relationship between processing speed and everyday life skills. These latter findings suggest that strong processing speed is of little benefit to clients with low learning potential and argue that learning potential assessment may play an important role in understanding relationships between processing speed and functioning in people with schizophrenia

Only one cross-sectional study, to our knowledge, has shown that learning potential provides incremental validity for predicting a measure of functional status beyond that associated with elementary neurocognitive function. In that study (Fiszdon et al., 2006), two measure of

learning potential derived from the CVLT-II explained an additional 9% of variance in a measure of rehabilitation readiness over and above scores on a static measure of non-verbal reasoning. Potential explanations for the discrepancies in findings between this study and the current results include differences in outcome measures selected, and the control of estimated verbal IQ and negative symptom severity in the current study.

Caveats to the current study should be mentioned. First, we selected a capacity-based measure of everyday-life skills that provides an index of whether a client is capable of performing a specific life task in a clinic environment. Any number of motivational and environmental factors may influence whether this skills is actually expressed in a client's home environment. Thus, the relationship between capacity measures of life skills and actual community function remains unclear. Nonetheless, studies have shown that the capacity measure selected for the current study (UPSA) is closely related to a caretaker measure of physical functioning, personal care skills, interpersonal skills, social acceptability, community activity and work skills (Bowie et al., 2006), as well as actual residential independence (Mausbach et al., 2008) in individuals with schizophrenia. Second, sample size for the test-train-test WCST sample (Study 2) was moderate in size ($n=48$), and consequently this portion of the study may have been somewhat underpowered. Nonetheless, we note that: (1) measures of effect-size (change in R^2) showed that the test-train-test version of the WCST explained virtually no incremental variance in everyday-life skills, and (2) studies investigating emotion recognition as a mediator of elementary neurocognitive function and functional status have shown significant effects with even smaller samples (e.g., Vaskinn et al., 2008). Third, the formula for calculating gain-scores selected for the current study rewards those participants who score higher on the first trial of each learning potential measure, even when improvement across trials is identical. Thus, for example, participants recalling 14 words on Trial 1 of the CVLT-II, and then 16 words on Trial 5 will receive a gain score of 1.0, while a two-item improvement for participants' remembering only 12 words on Trial 1 of the CVLT-II will receive a gain index of only .5 even though both participants improved identically. There is also one recent report indicating that simple post-test scores and regression residual measures of change after training on the WCST have stronger reliability and construct validity than the gain-score measurements of learning potential selected for the present study (Weingartz et al., 2008). Fourth, as noted in the Introduction, while some researchers in this area have selected improvement on a verbal list learning measures as an index of learning potential (Green et al., 2000; Fiszdon et al., 2006), learning on the CVLT-II clearly does not measure the ability to benefit from instruction and feedback per se, which is a characteristic of many dynamic assessments of learning potential, and thus this approach may not have been ideal for measuring learning potential. Fifth, the first steps of each hierarchical regression most likely occupied substantial portions of the variance in learning potential measures, making it difficult to show incremental variance explained by the two learning potential measures.

Lastly, the current study investigated a variety of potential relationships between measures of learning potential, elementary neurocognitive function and everyday life skills, in the absence of specific behavioral interventions that place specific demands on learning processes. Thus, these findings do not speak to the utility of measures of learning potential to serve as an index of the ability to benefit from extended and targeted rehabilitation interventions in schizophrenia (Wiedl, 1999). Indeed, some longitudinal studies have already shown a link between measures of learning potential measured at baseline and progress in targeted behavioral interventions (e.g., Watzke et al., 2008; Sergi et al., 2005; but see Woonings et al, 2002). The current findings do suggest, however that establishing the incremental value of learning potential assessments for predicting response to treatment beyond that offered by traditional neuropsychological assessment, global verbal IQ measures and negative symptom severity will be important for assessing their ultimate value.

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Figure 1.
The moderating effect of learning potential, as measured by the CVLT-II, on the relationship between UPSA scores and processing speed.

Table 1

Demographic and clinical characteristics of overall sample receiving CVLT-II learning potential assessment (Study 1; n=125) and the subsample receiving the WCST learning potential assessment (Study 2; n=48).

	Study 1	Study 2
Variable	Mean (SD; range)	Mean (SD; range)
Age	33.0 (11.3; 19–59)	34.7 (12.2; 19–59)
Sex (% male)	75	71
Education	12.9 (2.1; 8–18)	12.1 (1.9; 8–16)
#of Hospitalizations	4.1 (3.2; 0–20)	4.6 (2.6; 1–13)
Illness Duration (years)	10.1 (10.0; 1–40)	12.2 (11.1; 1–40)
WAIS-III Vocabulary (Scaled Scores)	10.0 (3.8; 1–19)	7.7 (3.3; 1–13)
PANSS Positive	18.3 (5.3; 8–32)	18.2 (4.6; 9–27)
PANSS Negative	20.0 (5.0; 9–32)	20.5 (4.7; 9–28)

Note: SD: standard deviation; WAIS-III: Wechsler Adult Intelligence Scale-III; PANSS=Positive and Negative Syndrome Scale.

Table 2

Intercorrelations of variables for Study 1 (n=125).

Measure	1	2	3	4	5	6	7
<u>Neurocognitive</u>							
1. PCPT	--	--	--	--	--	--	--
2. LM	.23	--	--	--	--	--	--
3. WMI	.23	.39*	--	--	--	--	--
4. PCET	.13	.22	.46*	--	--	--	--
5. PSI	.43*	.37*	.48*	.24*	--	--	--
<u>Learning Potential</u>							
6. CVLT-II learning	.25	.51*	.39*	.09	.38*	--	--
<u>Everyday Life Skill</u>							
7. UPSA Tot	.23	.44*	.57*	.41*	.41*	.29*	--
<u>Verbal IQ</u>							
8. WAIS-III Vocab	.12	.46*	.64*	.38*	.41*	.36*	.55*
<u>Symptom Severity</u>							
9. Positive	-.07	.10	-.04	-.17	-.07	-.03	-.06
10. Negative	-.19	-.15	-.08	-.04	-.27*	-.04	-.23*

Note: PCPT: Penn Continuous Performance Test; LM: Logical Memory subtest from the Wechsler Memory Scale-III; WMI: Working Memory Index from the Wechsler Adult Intelligence Scale-III; PCET: Penn Conditional Exclusion Test; PSI: Processing Speed Index from the Wechsler Adult Intelligence Scale-III; CVLT-II: California Verbal Learning Test-II; UPSA: UCSD Performance -Based Skills Assessment; WAIS-III: Wechsler Adult Intelligence Scale-III.

* = $p \leq .01$.

Table 3

Intercorrelations of variables for Study 2 (n=48).

Measure	1	2	3	4	5	6	7
<u>Neurocognitive</u>							
1. PCPT	--	--	--	--	--	--	--
2. LM	.36	--	--	--	--	--	--
3. WMI	.19	.27	--	--	--	--	--
4. PCET	-.01	.10	.37*	--	--	--	--
5. PSI	.36	.40*	.32	.16	--	--	--
<u>Learning Potential</u>							
6. WCST gain score	.11	.19	.42*	.19	.08	--	--
<u>Everyday Life Skill</u>							
7. UPSA Tot	.19	.50*	.48*	.18	.42*	.26	--
<u>Verbal IQ</u>							
8. WAIS-III Vocab	.04	.36*	.59*	.27	.30	.31	.47*
<u>Symptom Severity</u>							
9. Positive	.00	-.02	.02	-.12	.03	-.20	-.20
10. Negative	-.02	-.21	.03	.10	-.15	-.08	-.19

Note: PCPT: Penn Continuous Performance Test; LM: Logical Memory subtest from the Wechsler Memory Scale-III; WMI: Working Memory Index from the Wechsler Adult Intelligence Scale-III; PCET: Penn Conditional Exclusion Test; PSI: Processing Speed Index from the Wechsler Adult Intelligence Scale-III; CVLT-II: California Verbal Learning Test-II; UPSA: UCSD Performance -Based Skills Assessment; WAIS-III: Wechsler Adult Intelligence Scale-III.

* =p≤.01

Table 4

Multiple regressions for the prediction of everyday life skills by each elementary neurocognitive measure, learning potential (as measured by the CVLT-II), and the interaction of each neurocognitive measure and learning potential (n=125). Vocabulary scaled scores and the sum of negative symptoms were entered in the first step of each regression to control for their effects on everyday life skills.

Measure	Step 1	Step 2	Step 3	Step 4	F-value	R ²
<u>LM</u>						
WAIS-III Vocabulary	.52 p=.000	.43 p=.000	.42 p=.000	.42 p=.000	25.64 p=.000	.32
Negative Symptoms	-.19 p=.020	-.15 p=.052	-.16 p=.048	-.16 p=.048		
LM		.21 p=.019	.18 p=.064	.44 p=.008	19.70 p=.000	.35
LP (CVLT-II)			.07 p=.470	-.09 p=.464	14.84 p=.000	.36
LMxLP				-.27 p=.050	12.98 p=.000	.38
<u>WMI</u>						
WAIS-III Vocabulary	.52 p=.000	.31 p=.002	.30 p=.003	.32 p=.001	26.00 p=.000	.32
Negative Symptoms	-.19 p=.020	-.18 p=.021	-.18 p=.020	-.19 p=.012		
WMI		.33 p=.001	.31 p=.003	.62 p=.000	22.88 p=.000	.39
LP (CVLT-II)			.08 p=.333	.04 p=.707	17.39 p=.000	.39
WMIxLP				-.35 p=.019	15.64 p=.000	.42
<u>PCET</u>						
WAIS-III Vocabulary	.58 p=.000	.52 p=.000	.47 p=.000	.47 p=.000	32.82 p=.000	.39
Negative Symptoms	-.21 p=.007	-.21 p=.006	-.21 p=.006	-.22 p=.006		
PCET		.17 p=.039	.18 p=.026	.23 p=.140	24.07 p=.000	.42
LP (CVLT-II)			.10 p=.233	.08 p=.396	18.49 p=.000	.43
PCETxLP				-.05 p=.737	14.69 p=.000	.43
<u>PSI</u>						
WAIS-III Vocabulary	.52 p=.000	.45 p=.000	.43 p=.000	.44 p=.000	26.0 p=.000	.32
Negative Symptoms	-.19 p=.020	-.14 p=.064	-.16 p=.054	-.17 p=.036		
PSI		.19 p=.031	.16 p=.074	.51 p=.003	19.51 p=.000	.35
LP (CVLT-II)			.10 p=.253	-.23 p=.146	15.00 p=.000	.36
PSIxLP				-.43	13.83	.39
				p=.014	p=.000	

Note: LM: Logical Memory subtest from the Wechsler Memory Scale-III; WMI: Working Memory Index from the Wechsler Adult Intelligence Scale-III; PCET: Penn Conditional Exclusion Test; PSI: Processing Speed Index from the Wechsler Adult Intelligence Scale-III; CVLT-II: California Verbal Learning Test-II; UPSA: UCSD Performance -Based Skills Assessment; WAIS-III: Wechsler Adult Intelligence Scale-III; LP=learning potential.

Table 5

Multiple regressions for the prediction of everyday life skills by each elementary neurocognitive measure, learning potential (as measured by the test-train-test version of the WCST), and the interaction of each neurocognitive measure and learning potential (n=48).

Measure	Step 1	Step 2	Step 3	Step 4	F-value	R ²
<u>LM</u>						
WAIS-III Vocabulary	.47 p=.001	.33 p=.014	.31 p=.029	.38 p=.008	13.06 p=.001	.22
LM		.38 p=.005	.37 p=.006	.81 p=.002	12.01 p=.000	.35
LP (WCST, test-train-test)			.10 p=.451	-.51 p=.115	8.12 P=.000	.36
LMxLP				-.72 p=.043	7.64 p=.000	.42
<u>WMI</u>						
WAIS-III Vocabulary	.47 p=.001	.29 p=.073	.28 p=.081	.27 p=.089	13.06 p=.001	.22
WMI		.31 p=.055	.29 p=.090	.70 p=.034	8.88 p=.001	.28
LP (WCST test-train-test)			.05 p=.718	-.38 p=.241	5.85 p=.002	.29
WMIxLP				-.49 p=.141	5.07 p=.002	.32
<u>PSI</u>						
WAIS-III Vocabulary	.47 p=.001	.38 p=.006	.34 p=.017	.34 p=.019	13.06 p=.001	.22
PSI		.31 p=.022	.31 p=.021	.36 p=.127	10.01 p=.000	.31
LP (WCST test-train-test)			.13 p=.319	.048 p=.885	7.01 p=.001	.32
PSIxLP				-.10 p=.785	5.17 p=.002	.33

Note: LM: Logical Memory subtest from the Wechsler Memory Scale-III; WMI: Working Memory Index from the Wechsler Adult Intelligence Scale-III; PSI: Processing Speed Index from the Wechsler Adult Intelligence Scale-III; CVLT-II: California Verbal Learning Test-II; UPSA: UCSD Performance -Based Skills Assessment; WAIS-III: Wechsler Adult Intelligence Scale-III; LP=learning potential.