Effects of Executive Functioning Abilities on Health Regimen Adherence

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Abstract

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Introduction: Adherence is the degree to which an individual accurately completes treatment recommendations, and is defined as a comparison between completed and prescribed events. Cognitively-mediated components of adherence have been identified in past research, and include comprehension of health information, ability to recall information at specific times, and consistency (i.e., regularity of recommendation completion). To date, no studies have explored the role of consistency in adherence for unstructured, behavioral recommendations, nor have any studies explored the association between consistency and complex executive functioning (EF).

Methods: The current study examined the relationship between consistency and adherence to a stress monitoring task in 33 healthy college students (M_{age}= 20.0, SD_{age}= 2.0; 63.6% Male). Participants were administered a battery of simple and complex EF measures, followed by a brief stress psychoeducation session. Participants subsequently tracked their stress online three times per day for seven days.

Results: Analyses revealed no association between consistency and adherence in this sample, r= -.08, p= .70. Results from sequential regression analyses indicated EF measures accounted for a significant proportion of variance in consistency, $F(6, 16)$= 4.62, p< .01, R^2_{adj}= 0.5 (large), but not adherence, $F(7, 25)$= .73, p= .65, R^2_{adj}= -.06 (no effect). Moreover, the contributions of simple EF measures to consistency were greater, R^2_{adj}= .54 (large), than complex EF, R^2_{adj} = .22 (medium).

Discussion: This study provides evidence that consistency is dissociable from overall adherence, and that this construct may rely on EF abilities. Given that past research has shown a relationship

between consistency and adherence in medically compromised populations, implications of the current study include identification of consistency as both a target for improving adherence and as a potential barrier to execution of treatment recommendations. Future research aims to explore this relationship in cognitively compromised populations, and to understand the impact of dysexecutive symptoms on consistency.

Effects of Executive Functioning Abilities on Health Regimen Adherence

Health regimen adherence is the extent to which a person's behavior is consistent with health care recommendations (Dunbar-Jacob & Mortimer-Stephens, 2001). Adherence to prescribed medical treatments is estimated to average only 50-80% among adults with a multitude of medical difficulties, and lack of adherence to medical recommendations has been found to reduce a patient's odds of good health outcomes significantly (DiMatteo, Giordani, Lepper, & Croghan, 2002; Haynes, McDonald, & Garg, 2006; Mackin & Arean, 2007). This lack of adherence to prescribed regimens (whether they be medication or behaviorally based) represents a significant source of mortality as well as healthcare cost in the United States, accounting for at least 10% of all hospitalization and nearly one quarter of all nursing home admissions among older adults (Miller, 1997; Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993). Non-compliance has been recognized as one of the most significant problems facing medical practice and accounts for more than $100 billion in medical costs annually to U.S. citizens (Miller, 1997; Haynes, Wang, & Da Mota Homes, 1987). For these reasons, identification and intervention for key factors contributing to poor adherence have become primary goals for clinicians and healthcare policy makers (Hawkins, Kilian, Firek, Kashner, Firek, & Silvet, 2012).

Patient non-compliance falls into three categories: Accidental, Triggered, and Intentional (Rajaei-Dehkordi & MacPherson, 1997). Though these forms of non-compliance were originally conceptualized for medication adherence (a form of health regimen adherence), they are easily extrapolated to apply to general health behavior recommendations (e.g., diet and exercise regimens) provided by medical professionals. Specifically, accidental non-compliance is defined as forgetting to take a dose of medicine or misunderstanding instructions and therefore failing to follow the prescribed regimen correctly (Rajaei-Dehkordi & MacPherson, 1997). Triggered non-compliance describes a situation in which an individual begins to feel better (or worse) and adjusts their level of adherence due to the belief that they no longer need the behavioral change or, alternatively, that the behavior change is doing no good (Coleman, 2005; Rajaei-Dehkordi & MacPherson, 1997). The third form of non-compliance is intentional. This is when a patient makes a conscious decision not to follow the regimen as recommended (Coleman, 2005; Rajaei-Dehkordi & MacPherson, 1997). Though this presents similarly to triggered non-compliance in clinical scenarios, the difference between these forms of non-adherence is in the patient's rationale for discontinuing their regimen. Critically, it is often the case in clinical practice that we have little insight into why individuals adhere poorly to the prescriptions they are provided, though it has been suggested that one frequently overlooked factor influencing compliance is the presence of cognitive impairment (Hawkins et al., 2012).

Elements of Regimen Adherence

Despite poor insight into individual adherence difficulties, many neuropsychologically-mediated functions have been posited to be involved in maintaining a health regimen. These include comprehension of health information (i.e., reading or auditory comprehension capabilities, level of schooling, and attention), the ability to encode any gained information into long-term memory (i.e., memory abilities), and the ability to recall this information at specific times (i.e., prospective memory abilities) wherein an individual must complete a step of their regimen (Rosen et al., 2003). An additional element of regimen adherence, particularly as it relates to medical outcomes is consistency. Though this has not been empirically supported as a major aspect of adherence, it is often cited as an area of importance and has been shown to be a predictor of outcomes in rehabilitation settings (Morris, Shaw, Mark, Uswatte, Barman, & Taub, 2006). Many studies have corroborated the fact that general cognitive functioning is important to medication and health regimen adherence, though these primarily include global measures of functioning such as mini mental state examinations or cognitive screeners (Feil, Pearman, Victor, Harwood, Weinreb, Kahle, & Unutzer, 2009; Hawkins et al, 2012; Vinyoles, De la Figuera, & Gonzalez-Segura, 2008). Fewer studies to date have examined the role of specific cognitive functioning in medication adherence, and even fewer have looked at the impact of executive functioning deficits on medication adherence.

In a study by Rosen and colleagues (2003), the neuropsychological correlates of adherence to prescribed medication in patients with type II diabetes was examined. This study included 79 male veterans prescribed anti-hyperglycemic medication (Metformin) and their adherence was tracked for 4 weeks following their initial consultation (Rosen et al, 2003). Critically, this study found that after controlling for demographic variables (age, race, years of education, and status of insulin prescription), time to complete Trailmaking Test Part B (TMT-B) as well as Stroop word score were significant predictors of adherence (as measured by number of successfully taken doses) in this sample. Moreover, TMT-B time to completion scores accounted for approximately 9% of the variance in adherence, whereas Stroop word score performance accounted for approximately 8% of the variance in adherence (Rosen et al., 2003). Both the TMT-B and Stroop tests have been related to executive functioning capabilities in past literature, and have been shown to be associated with frontal lobe functioning in adults (Reitan and Wolfson, 1995; Demakis, 2004). Therefore, these results suggest that frontal lobe functioning is important to adherence to medication prescriptions. The authors also found that consistency in adherence was related to overall cognitive functioning, as measured by the Mini-Mental State Exam (MMSE). Due to these findings, the authors suggest that neuropsychological functioning may play a more important role in medication adherence and that this may be elucidated with studies including greater variety in neuropsychological functioning or with lowered rates of adherence (Rosen et al., 2003).

Similarly, in studies looking at cardiovascular rehabilitation (CR) program adherence, it has been shown that lower cognitive functioning was associated with decreases in outcomes, namely, quality of life (QOL) in CR patients and is also associated with a decreased change in QOL between the onset and completion of CR (Cohen et al., 1999). Further, Cohen and colleagues (1999) found that CR patients struggled most with Verbal Fluency, which is an executive functioning task requiring individuals to flexibly generate words. This task has been shown to be sensitive to left prefrontal lobe functioning (Phelps et al., 1997).

Due to its relationship with frontal lobe functioning, poor performance on verbal fluency tasks is generally associated with executive dyscontrol, which can significantly impact the ways in which individuals engage in rehabilitation regimens as well as their ability to act in accordance with motivation and to initiate and sustain effort during tasks (Cohen et al., 1999). In accordance with these findings, the authors suggest that clinicians should consider adjusting standard CR practices in accordance with the patient's level of cognitive functioning in order to account for the decreased trajectory of outcomes seen in individuals who have executive difficulties, though no direct recommendations are made (Cohen et al., 1999). Moreover, without a clear understanding of the relationship between executive functioning capacity and adherence, recommendations of this nature are impossible to anticipate.

In order to understand the relationship between executive functioning and rehabilitation outcomes, a recent study looked at 44 older adults (averaging 68 years old) who were enrolled in a CR program with a potential for 36 rehabilitation session (e.g., 3 times per week for 12 weeks)

(Kakos et al., 2010). Rehabilitation sessions consisted of one hours of exercise alongside 30 minutes of education, and adherence was the number of times individuals attended these sessions of the possible 36. They found that reduced executive functioning (as measured by the TMT-B) was associated with poorer outcomes following a CR regimen (Kakos et al., 2010).

The study also found a strong relationship between amount of CR received and improvements in cardiovascular variables as well as quality of life outcomes. Surprisingly, the authors did not find the relationship between cognitive factors and poor outcomes to be moderated by level of adherence. The authors suggest that further study is needed in this area, particularly as cognitive functioning may relate to compliance with recommended lifestyle changes occurring outside of the laboratory environment (e.g., changes in diet and exercise) necessary to truly adhere to the cardiac rehabilitation regimens put into place (Kakos et al, 2010). Critically, it is suggested by the authors that individuals with reduced cognitive function may also be expending less effort toward these health behaviors, therefore producing poorer outcomes despite attendance at scheduled sessions. Therefore it is suggested that the inability to adhere to prescribed lifestyle changes outside of the rehabilitation sessions may account for the reduced benefits seen by individuals involved in this form of therapy, though this portion of the CR regimen was not monitored (Kakos et al., 2010).

Another study found a similar pattern in individuals undergoing bariatric surgery (Spitznagel, Galioto, Limbach, Gunstad, & Heinberg, 2013). This study employed a web-based, abbreviated cognitive battery (WebNeuro; Silverstein, Berten, Olson, Paul, Williams, Cooper, & Gordon, 2007), which provides measures of multiple domains of cognitive functioning to include overall intellectual functioning, memory, attention, and executive functioning. The results revealed significant correlations between aspects of cognitive functioning (including memory, attention, and executive functioning abilities) and self-reported non-adherence on multiple health behaviors (Spitznagel et al., 2013). Specifically, poorer memory scores were associated with decreased total adherence rates and vitamin intake, reduced executive functioning skills were associated with decreased adherence to physical activity prescriptions (e.g., 30-60 minutes physical activity 5 days per week) as well as protein intake (e.g., eat 60-80g protein per day), and reduced attention was also associated with reduced physical activity (Spitznagel et al., 2013). Of note, the executive functioning measures in this study included both the Stroop task (number of errors) as well as a mazes task, which required participants to identify a hidden path through a grid with cues for correct and incorrect responses. Though the mazes task used here is not widely used in neuropsychology, this was the first use of a complex measure to look at the relationship between executive functioning and adherence.

Taken together, the literature as a whole identifies cognitive functioning as an important component of both medication and rehabilitation program adherence. The literature to date also suggests that an individual's overall cognitive functioning as well as their executive functioning appear to be important contributors to an individual's ability to adhere appropriately to prescribed behaviors. To date, the only measure of executive functioning found to be related to ability to adhere has been the TMT-B task, which is a measure of executive functioning that provides little information about the mechanism underlying the association between executive functioning abilities and adherence capacity.

Clinical Implications of Improving Health Regimen Adherence

As suggested previously, an individual's level of executive functioning may not only affect their ability to comprehend necessary information and perform tasks required for partaking in long-term treatment, but may also affect an individual's adherence directly through a decline in capacity for effort and a decreased ability to act in accordance with motivational factors (Kakos et al., 2010). In turn, individuals with lower cognitive abilities (particularly executive functioning abilities) show poorer outcomes, which renders them a group who is at risk of reduced benefit from planned health interventions. Due to their status, it is important to understand how executive dysfunction might affect individuals in treatment and, further, attempt to correct for these deficiencies in practice settings (Conn et al., 2009). Once we understand the level of risk an individual faces for poor adherence due to their cognitive abilities, we can begin to cater rehabilitation plans (e.g., momentary assessment and prompting) to their needs in order to provide the best quality of care for our patients.

The Current Study

The current study aimed to further investigate the relationship between executive functioning and health regimen adherence and better define aspects of executive functioning (e.g., problem solving, planning, ability to shift set, etc.) which contribute most to one's ability to consistently adhere to a health behavior in the absence of a laboratory setting.

Though a relationship has been shown between medication adherence and performance on simple executive functioning measures, this study includes both simple executive functioning measures (e.g., TMT-B) as well as more complex measures of executive functioning with the goal of introducing a problem-solving component rarely seen in literature of this nature. This is an important addition as it is currently unclear how executive functioning impacts regimen adherence. The current study utilized multiple measures of this broad cognitive facet in an effort to provide information regarding the mechanisms underlying relationships seen in previous literature. Moreover, this is the first study to investigate the relationship between neuropsychological performance and adherence to behavioral prescriptions performed in an unstructured environment (e.g., at home), rather than in a laboratory or medical center.

Primary Aims and Hypotheses

The primary aim of this study was to systematically confirm the relationship between executive functioning skills and regimen adherence.

Hypothesis 1: Scores on executive functioning tasks will be correlated with overall health regimen adherence (HRA).

Hypothesis 2: Executive functioning (EF) skills will account for a significant amount of variance in HRA above and beyond years of education.

Hypothesis 3: Complex EF skills will be a better predictor of HRA than are Simple EF skills.

A second aim was to investigate the relationship between health regimen consistency (HRC) and executive functioning.

Hypothesis 4: EF performance will be correlated with HRC performance.

Hypothesis 5: EF skills will account for a significant amount of variance in HRA above and beyond years of education.

Hypothesis 6: Complex EF skills will be a better predictor of HRA than are Simple EF skills.

Exploratory Aims and Hypotheses

Exploratory aims were to understand the ways in which consistency in decision making (DMC) relates to HRA and HRC. It was hypothesized that DMC would be associated with both measures, such that increased consistency in decision making would be associated with increased consistency and overall adherence during the SMT. Similarly, the relationship between executive functioning and consistency in decision making was explored, with the expectation that increased executive functioning skills would be associated an increased consistency in decision making.

METHODS

Participants

A total of 33 healthy college students were recruited (63.6% Male). Healthy college students were utilized as they traditionally have heightened stress levels, and therefore are likely to have moderate levels of motivation to reduce their stress. The demographic information for participants in this study may be viewed in Table 1.

<<INSERT TABLE 1>>

Inclusion criteria:

- 4-item PSS score greater than 7. Given that motivation was a significant concern with regard to regimen adherence, having a minimum stress score for inclusion was a means of controlling for potential motivation to reduce stress. A score of 8 (the minimum acceptable for this study) indicates that the individual endorsed at least experiencing occasional stress for each item. See Appendix A for the 4-item perceived stress scale included on recruitment flyers to screen participants.
- Between the ages of 18 and 50. Individuals under 18 were not included as they were unable to provide consent independently, and individuals over the age of 50 were excluded in order to reduce variability due to aging effects.
- Able to speak English fluently. Many cognitive measures required a verbal component, and therefore participants must have been able to speak and understand English well.

Exclusion criteria:

- Participants taking psychotropic medications or steroids. These medications are known to have a significant effect on cognition, particularly executive functioning, and therefore would have skewed results.
- History of learning disability. Given the potential for all cognitive tests to be compared to norms of typically developed individuals, individuals with a history of learning disability were excluded from the current study.
- Significant motor or sensory deficits (e.g., no or poor arm/hand use or vision impairment). Many of the tasks administered could not be altered to accommodate these deficits.

All participants were recruited via three methods: (1) Drexel University's SONA system, (2) classes at the Drexel University campus, and (3) flyers placed in common gathering areas at Drexel University. All individuals participating in the study were awarded four points of extra-credit through the SONA system as payment for their participation.

All measures and questionnaires that could be administered on the computer were administered using Inquisit study software. When possible, tasks in the study were automated and had the capability of being administered on a tablet. Every effort was made to minimize external distractions, and all sessions took place in the Applied Neurotechnologies Laboratory on Drexel University's Main Campus.

Procedures

After individuals indicated interest in the study, individuals were contacted by phone or email to conduct an initial screening. During this communication, potential participants were quickly screened for inclusion and exclusion criteria in order to determine their eligibility for the study and were provided information about the structure of the study. After an individual's eligibility was confirmed and they continued to express interest in the study, an appointment in the laboratory was scheduled in order to complete the laboratory portion of the experiment.

Laboratory Session:

The study consisted of a 90-minute laboratory visit, during which time study procedures were fully explained to the participant and consent was obtained. After obtaining consent, participants completed the demographic questionnaire, the Perceived Stress Scale (PSS), and the Health Behaviors Questionnaire. Participants were then administered the cognitive battery, which lasted approximately 45 minutes, and the order of which was randomly counterbalanced.

After this, participants were provided with approximately 10 minutes of psychoeducation regarding the biological and psychological effects of stress, focused on the college student population, and were then informed of the specifics of the Stress Monitoring Task (SMT) and provided with a hand out including formal instructions as well as written information about how to access the reporting site. Participants were also provided with a link to the SMT monitoring survey via email and were shown the portal in session. They were then given an opportunity to ask questions. Means and standard deviations on relevant outcome measures from questionnaires, cognitive measures, and the SMT may be seen in Table 2.

<<INSERT TABLE 2>>

Follow-Up:

After completing the week-long SMT, individuals received a follow-up email indicating the completion of the week, regardless of their overall adherence. In this email, a de-identified graph of their tracked stress and affect levels was attached (made in excel and transferred to a word document) along with the feedback survey. Participants were informed during the consent process that they must complete the feedback survey prior to distribution of their final SONA credit. Final distribution of SONA credit was completed within 24 hours of an individual's completion of the feedback survey. If an individual did not complete the feedback survey, they were given a reminder email 1 week later. If, after 2 weeks they had not completed the feedback survey, participants who had completed at least 1 adherence event were awarded their final SONA credit. In all instances where individuals completed at least 1 adherence event or the feedback survey after the laboratory session, the final credit was disbursed.

Measures

Stress Monitoring Task (SMT). Participants in this study were asked to complete the Stress Monitoring Task (SMT), which is a health regimen wherein individuals track their stress online for a 7-day period. Prior to beginning the SMT, the effects of acute and chronic stress on biological, psychological, and cognitive functioning was explained to participants. The script for this session is provided in Appendix B.

After completing this brief psychoeducational session, participants were provided with instructions for tracking during the SMT, and were told that their regimen would begin the following morning. Scheduling responses was left up to the participant, though a morning, noon, and night schedule was suggested. They also received the following restrictions: (1) responses could not occur within two hours of one another and (2) all responses for a given day must have occurred before midnight (e.g., at or before 11:59 pm) of that day.

To complete a reporting event, individuals were provided with the link for an online survey (created using Qualtrics), which they could access via computer or smart phone. The same link was used throughout the entire week. The survey for each reporting event required less than 3 minutes of time and consisted of a current stress-level assessment (e.g., "On a scale from

1 to 10, with 10 being the worst, how stressed are you right now") as well as a 20-item mood questionnaire (Positive and Negative Affect Schedule; PANAS). At the conclusion of the SMT, reported stress and affect scores were compiled into a graph, documenting a participant's stress levels throughout the week alongside their mood, and emailed to the participant along with a feedback survey.

Two primary outcome variables were obtained from the SMT. First, an overall adherence measure (HRA) was obtained by taking the number of regimen sessions completed divided by the total number of possible sessions (21). This number was then multiplied by 100. Therefore an individual who completed all regimen appointments would receive a score of 100 (21/21), whereas an individual completing only one appointment would receive a score of 4.7 (1/21).

The second outcome variable derived from these data was a measure of consistency in regimen adherence (HRC). In order to derive this variable, an average time of responding was calculated for each participant, for each reporting event (1, 2, and 3). This was the average time (in minutes past wake time) that they signed into the online site in order to complete their regimen requirements for that reporting event. After an individual's average response time was calculated, a deviation score of their variability in response time was calculating using the number of minutes surrounding their individual average. Effectively, an average deviation of response times was calculated for the 1st, 2nd, and 3rd response periods by pooling all deviation scores for that reporting event, across the 7 days. An average deviation score looking across all three response times was calculated (HRC), as well as time-specific deviation scores for each of the three reporting events.

Demographic Questionnaire. Demographic variables were collected for all individuals using a computer-based questionnaire. Specifically, participants were asked to report their age, socioeconomic status (family yearly earning), and educational status. A paper and pencil version of the demographic questionnaire to be administered is included in Appendix A.

Health Behavior and Lifestyle Questionnaire. A health behaviors questionnaire was administered in order to gain insight into the habits of participants and the ways in which this may affect adherence to the study's prescribed health regimen. Of note, during this questionnaire individuals were asked to provide a prospective wake time for the days of the following week, which was used to control for individual variations in schedule during HRC calculations. Though this questionnaire was administered on the computer, a paper and pencil version is supplied in Appendix A.

Epworth Sleepiness Scale (ESS). The ESS (Johns, 1991) is an 8-item instrument used to measure the degree to which individuals doze or fall asleep during the day. This instrument is widely used in medical and clinical settings in order to screen for sleep difficulties such as sleep apnea and narcolepsy. More broadly, this provided a measure of day-time disturbance due to sleep-related concerns.

Perceived Stress Scale (PSS). The PSS measured the degree to which situations in one's life were perceived as stressful and has previously been correlated with health behavior measures as well as reported health measures (Cohen et al., 1983). The scale consisted of 10 items asking participants to report how often stressful events had occurred during the past month on a scale from 0 (never) to 4 (very often). A total perceived stress score was then derived from the responses. Though a 4-item perceived stress scale was used for screening, the reliability of the 4-item scale has not been established, therefore the 10-item scale was used for formal data collection after individuals have consented to participation in the study.

Positive and Negative Affect Schedule (PANAS). The Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) was administered during each adherence event of the SMT. This questionnaire required participants to report the extent to which they were experiencing a variety of positive and negative emotions at the given time and produces both a positive affect total, a negative affect total, and an overall mood score.

Follow-up Questionnaire. A follow-up questionnaire was administered in order to collect information on participants' experiences of the imposed regimen. The purpose of this questionnaire was primarily to gain insight into strategies used to maintain adherence during the health regimen (e.g., setting an alarm for adherence times). Though this was administered on the remotely via computer or smart phone, a paper and pencil version of the follow-up questionnaire is included in Appendix A.

Estimate of Intellectual Functioning. The Advanced Clinical Solutions Test of Premorbid Functioning (ACS TOPF; Pearson Assessment, 2009) was included as a measure of estimated general intellectual functioning. This measure required individuals to pronounce words aloud that increased in difficulty and feature words with unusual phonemic components (e.g., plumb). Simple demographic characteristics (e.g., region of education, sex, race/ethnicity, years of education, and occupation) were also collected. For the current study, raw word reading score was used given the generally low degree of variability between factors which might impact IQ with regard to norms (i.e., age and years of education).

Simple Executive Functioning Measures. Participants were asked to perform a variety of executive functioning tasks. These tasks will include both "simple" executive functioning tasks, which measure basic aspects of executive functioning (e.g., shifting, updating, & inhibiting; as defined in Miyake et al., 2000). Though executive functioning includes complex problem solving and planning, it has been shown that these basic aspects of cognitive control are vital (though dissociable) to proper executive functioning and relate closely to frontal lobe functioning (Miyake & Friedman, 2012).

The first simple measure of executive functioning, the D-KEFS Color-Word Interference task, Condition 3 (Delis, Kaplan, & Kramer, 2001), was used to measure one's ability to "inhibit". This is a modified version of the traditional Stroop task (Stroop, 1935). Though only condition 3 was used, this test consists of 4 conditions. The first two conditions measure primarily basic attention and ask individuals to name color patches (Condition 1) and read words that denote colors, printed in black ink (Condition 2). The third condition displays words that denote color in different colors of ink (e.g., "red" written in blue ink). During this condition, participants are required to report the color of ink in which the word appears, rather than reading the word. This measures cognitive flexibility and inhibition (Delis et al., 2001). Condition 4 will be described below, as it was used as a measure of complex executive functioning. Raw time to completion scores was the primary measure used in analyses for this variable.

The second measure of simple executive functioning was the WAIS-IV Digit Span Backward, a measure of one's ability to "update" information in working memory, will be also be utilized as a simple executive functioning measure (Wechsler, 2008). This task requires participants to maintain a list of numbers in their head and present the list orally to the examiner in reverse order. For example, the examiner will first read off the list of numbers (e.g., 1, 2, 3) and the participant must then provide the list backward (e.g., 3, 2, 1). The task begins with 2-number long strings and continues up to 8-number strings. Participants receive two opportunities at each number length to provide a correct response. If they are unable to produce at least one correct response after both number strings have been provided, the task is discontinued. The primary outcome measure of this task is their total score, which is derived by adding together the number of strings correctly reversed before the discontinue point.

The final simple executive functioning measure, the Local-Global Task (Navon, 1977), measures one's ability to "switch" between different mental sets. Specifically, this computer-administered task displayed images of letters, themselves made up of letters (i.e., an H made of S's). Stimuli were presented in 16-item blocks, each of which was labelled as either "local" or "global." In "local" blocks, participants were told to report the component letters (i.e., those making up the overall shape, "S" in the example above), whereas in "global" blocks individuals were asked to report the letter displayed as the overall shape (i.e., "H" in the example above). The primary outcome measure on this task was the percentage of correct responses on "conflicting" items within the local condition – conflicting meaning that the overall and component letters were different (i.e., an H made of S's, rather than an S made of S's). Only this measure was used as almost no variability was present in the global condition.

Complex Executive Functioning Measures. To expand on past research by better classifying aspects of executive functioning related to regimen adherence, three complex measures of executive functioning were included in the current study: the Delis –Kaplan Executive Functioning System (D-KEFS) Tower Test (Delis, Kaplan, & Kramer, 2001), the D-KEFS Color-Word Interference Test, Condition 4 (Switching; Delis, Kaplan, & Kramer, 2001), and the Trailmaking Test, Trails B (Reitan, 1955). The D-KEFS Tower Test, a measure of planning and problem solving, assesses key executive functions, including spatial planning, rule learning, inhibition of impulsive and perseverative responding, and the ability to establish and maintain the instructional set (Delis et al., 2001; Strauss et al., 2006). The objective of this task is to build a designated tower in the fewest number of moves possible while following rules regarding appropriate moves (see D-KEFS manual for standard administration procedures; Delis et al., 2001, p. 191). Many outcome measures may be derived from this task, though the primary outcome measure of interest for this study was the total achievement score (a measure of achievement across each administered item of the test).

Condition 4 of the Color-Word Interference Test (i.e., Switching) follows the same rules as Condition 3 (Inhibition), but includes words which are outlined in boxes. If a word has a box around it, participants are instructed to read the word, rather than report the ink color in which it is printed. This is also measure of cognitive flexibility, but has an added component which measures the ability to maintain and shift set (Strauss Sherman, & Spreen, 2006). Given the multi-faceted nature of executive functioning performance on this task, it was included as a complex measure. The primary outcome measure on this test was the time to completion for the task.

Trail Making Test Part B (Reitan, 1955) will also be used as a complex measure of executive functioning abilities. This test requires that individuals flexibly shift set as well as sequence numbers and letters correctly, as quickly as possible. This test has been associated in the literature with executive functioning skills and is considered to be a clinical test sensitive to executive dysfunction (Strauss, Sherman, & Spreen, 2006). The primary outcome measure on this test is the time to completion (TTC), which is measured in seconds. In addition, the number of sequencing and set-loss errors will also be recorded.

Processing Speed Measures. Processing speed was important to measure in the context of this study because it has been shown to affect comprehension of materials and is a basic component of general cognitive functioning. The first test of processing speed included in this study was the Symbol Digit Modalities Test (SDMT; Smith, 1991) which requires individuals to align numbers with corresponding shapes as quickly as possible. Specifically, individuals were provided a key which shows boxes with symbols and corresponding numbers. Below this key are boxes which contain only symbols and participants are asked to fill in the corresponding numbers as quickly as possible. Ninety seconds are allotted during which time the participant serially completes boxes until they are asked to stop. The primary outcome measure of this task was the number of boxes completed correctly in ninety seconds.

A second measure of processing speed was Trail Making Test Part A (Reitan, 1955). This task requires individuals to connect letters of the alphabet as quickly as they can. The letters must be in order (e.g., A, B, C) and the individual's line must touch each circle along the path. The primary outcome measure of this task is the total seconds to completion (TTC).

Basic Attention. As mentioned above, one measure of basic attention in this study was present in the D-KEFS Color-Word Interference Task, with the primary outcomes being time to completion for Conditions 1 and 2. A second measure of basic attention included was the WAIS-IV Digit Span Forward subtest (Wechsler, 2008). This task required individuals to repeat a string of numbers, ranging from 2 digits up to 9. The total number of strings correctly repeated is the primary outcome measure for this task.

Consistency in Decision Making Task. . A modified version of the Iowa Gambling Task (IGT), the Ambivalent Decision Making Task (AmDMT) was created for this study in order to incorporate a more comprehensive measure of decision making consistency than has previously been studied. The purpose of the IGT has traditionally been to gauge the level of risk-taking one will participate in, and their ability to understand the patterns underlying the task in order to gain as many points as possible (Bechara, Damasio, Damasio, & Anderson, 1994). This task was developed to quantify the decision-making deficits of neurological patients and can further be used to determine whether normal participants are more prone to risky decisions (Bechara et al., 2005).

The goal of the AmDMT is primarily to assess consistency in decision making under ambivalent circumstances (i.e., when the participant knows the risk level of their choice and instead must decide on an option knowing the risk it incurs) rather than "risky" circumstances. For this reason, the rewards offered have been (1) lowered and (2) presented in points rather than as a monetary value, so as to mitigate the emotional feelings of risk further. Additionally, options for individual choice have been expanded by presenting a line, upon which individuals must choose a location. An explanation of changes made to the original task is included in Table 3, along with the rationale underlying each change.

<<INSERT TABLE 3>>

For this task, participants were shown a horizontal line with 100 vertical hash marks and were asked to choose a mark along that line (by touching the screen at their desired location), with the goal of gaining as many points as possible in 80 trials. After choosing a position along the line they were shown their result on-screen (i.e., the amount that they either won or lost by choosing that position along the line). Participants were informed that choosing locations near the center of the line represent "riskier" choices, in that individuals are likely to get either larger magnitude of points, though this may be in the positive or negative direction. Choosing positions near the end of the lines results in smaller point magnitudes, in both the positive and negative directions. Ultimately, the distribution of reward and penalty distributions across the line mirrors the risk inherent in the cards of the original task, with more opportunity for variability, and participants are aware of the risk they are taking on with each choice (which is something that must be learned in the original task). Importantly, asking individuals to choose multiple positions along this continuum provides a score of consistency in decision making during a situation where there is not a “correct” response and multiple responses which represent the same level of risk, meant to mirror ambivalence felt when adhering to health regimen prescriptions, particularly with asymptomatic illnesses.

Individuals will be asked to complete 100 trials, across 5 blocks. The 5 blocks were continuous (e.g., no break in between). There were no changes as the task progressed, and an individual’s point total across all 100 trials was displayed as their score for the task, though participants were informed that the first set of 20 trials would be coded as a practice trial.

RESULTS

Statistical Plan

In order to evaluate the primary aims of the study, a two-step analysis was proposed. First, correlations between neuropsychological measures and SMT adherence and consistency was performed. After this, a series of sequential regressions were conducted with 3-4 blocks of variables. Both HRA and HRC had the following blocks: (1) Years of education as a covariate (as this has been identified as important in past literature for adherence) (2) Simple Executive Functioning measures, and (3) Complex Executive Functioning measures. After this, the DMC task was included into the HRC regression equation as a 4^{th} block to understand whether this added to the predictive value of the model and to evaluate its ability to explain variance above and beyond other executive functioning measures. The predictive strength of each block of measures was evaluated following the completion of the overall model.

Data Processing

Identifying Outliers

Prior to completing analyses, outlier analyses were conducted for each variable using a combination of box plots and a leverage-based procedure. Specifically, box plots were first evaluated by variable to quickly determine whether significant outliers were present. Outliers which were at least 3 times the interquartile range were removed from the database. Though it is recognized that this is a somewhat lenient procedure, the relatively homogenous nature of the sample as well as a plan for subsequent leverage-based exclusion were considered to be sufficient to warrant a more lenient outlier cut off for this stage of analysis.

From here, individual scores on each variable of interest in regression analyses (defined below) were evaluated for their impact on a regression weight using DFBETA values. Such values provide a measure of the impact a single point has on a regression line and provide a more customized way of defining outliers. Two recommended cut-offs exist for this analysis, |DFBETA| > 2/sqr (n) (Belsley, Kuh, & Welsh, 1980, p. 28) and |DFBETA| > 1 (Bollen and Jackman, 1990). Though both were explored, the more lenient |DFBETA| > 1 cut-off was used for this study due to the relatively small sample size which implies that individual data points will inherently have a greater influence on the regression line (i.e., than when there is a greater number of data points). Such outlier analyses were completed for each regression equation independently (i.e., all previous outliers were replaced prior to beginning this process for a new regression to determine the weight of said variable on a new regression line). Correlation analyses related to that regression (i.e., with HRA or HRC) were completed following removal of significant outliers.

Testing for Regression Assumptions

Testing of assumptions occurred in a 2-step fashion. Specifically, two major sequential regression analyses were proposed (i.e., one for HRA and one for HRC), and the assumptions for variables on each of these was done separately. First, for the HRA analysis, outliers were identified as described above. Following this, the assumption of homoscedasticity was tested using residual plots to ensure that error in HRA was the same at all levels of each predictor variable (as well as with all variables included in the equation). There were no issues with homoscedasticity between variables of interest and HRA. Multicollinearity was also assessed using a tolerance cut-off of < .1 and a variance inflation factor (VIF) of > 10. No variables in the full regression equation came close to these cut-off numbers. When assessing for normality of predictor and outcome variables, no variables created significant concern about non-normality. Specifically, only average risk score exceeded acceptable skewness and kurtosis values. Given that this was not a primary variable of interest, it was not transformed, though would be log-transformed should it be used in additional analyses. Note that these normality checks were done only once on all variables after outliers were removed from the dataset.

The second set of assumptions for the regression equation looking at HRC as the outcome was conducted in the same manner. Again, there were no concerns about multicollinearity nor homoscedasticity. As mentioned above, no variables of interest required transformation prior to analyses. Of note, one variable was removed from all HRC analyses, namely the local/global task results. The reason for this was that over half of the cases within this variable represented outliers based on high DFBETA values, likely due to the high degree of variability in performance on this task which did not appear to relate in a coherent way to consistency in adherence. Had the variable been included, power would have been too low to detect any subsequent relationship between executive functioning and health regimen consistency.

P-Value Correction for Multiple Comparisons

With regard to correction for inflation of p-value rates due to multiple comparisons, a Bonferroni correction will be applied. Specifically, the primary analyses include 2 major regression analyses, completed in a sequential manner, therefore "significance" will be set at $p < .025$ for regression analyses. It is recognized that this remains somewhat lenient, though this was deemed appropriate for the exploratory nature of this study. In addition, effect sizes are reported throughout and are considered a more appropriate indication of the significance of a given relationship than p-values given the relatively small sample size and expected lack of variability due to the healthy nature of all participants. The traditional cut-off of $p < .05$ will continue to be used for correlation analyses, but an emphasis will be placed on effect strengths, rather than significance, for these relationships. All cut-offs for effect size and strength are in conjunction with accepted norms (Cohen, 1988).

Primary Analyses
Aim 1: HRA

<u>Hypothesis 1:</u> *Scores on Executive Functioning Measures will correlate with overall health regimen adherence (HRA)*

To assess whether relationships exist between HRA, EF, and stress measures, a series of bivariate correlations were utilized. A full correlation table may be viewed in Table 4 (note that this includes both HRA, HRC, and DMC analyses in order to conserve space and to aid in interpretation). Interestingly, no simple or complex executive functioning measures were significantly associated with HRA. However, an individual's overall perceived stress level (as measured by the PSS) did significantly correlate with this variable, $r = .35$ (weak), $p = .05$, such that increased adherence was associated with heightened stress levels. Also note that HRA and HRC did not significantly correlate with one another, $r = -.24$, $p = .24$. This provides preliminary evidence that HRA and HRC may in fact be separate constructs among healthy individuals, and that HRA in particular is not related to one's executive functioning skills within this sample.

<<INSERT TABLE 4>>

Hypothesis 2: Executive Functioning Skills will significantly predict HRA, after controlling for years of education

To evaluate whether simple and complex EF significantly predict HRA, a multiple regression was conducting using a 3-step sequential regression on all 33 participants. First, a regression was conducted with only years of education as a predictor. This was included as the first step as previous studies within the adherence literature have included this as a covariate for analyses. After this simple executive functioning measures were included in a block, yielding a significance value for the overall model including step 1 and step 2. Finally, complex executive functioning measures were included in the third block, again yielding an omnibus test of significance for the overall model being tested. Importantly, values for the variance explained by a given model will be discussed as well.

The first step of the sequential regression included a model in which years of education was regressed on HRA. Overall, this model was nonsignificant, $F(1, 31) = 1.17$, $p = .29$, $R^2 = .04$, $R^2_{adj} = .003$ (no effect, n = 32). Years of education was not a significant predictor of HRA, $b = -.04$, $SE_b = .04$, $p = .29$.

After this, the block of simple executive functioning measures of interest were included in the equation. This overall model was also nonsignificant, $F(4, 28) = 0.64$, $p = .64$, $R^2 = .08$, $R^2_{adj} = -.05$ (no effect). While Table 5 provides all resulting coefficient values and corresponding significance for each variable included, no values significantly predicted HRA (after controlling for all others) after this step of analysis.

<<INSERT TABLE 5>>

Finally, the block of three complex executive functioning measures of interest were included in the equation. The overall model was also nonsignificant, $F(7, 25) = .73$, $p = .65$, $R^2 = .17$, $R^2_{adj} = -.06$ (no effect). Of note, this indicates that no increase in variance explained occurred with the addition of the complex executive functioning measures, after accounting for the number of predictor variables. Though coefficients of individual predictors are again included below (Table 6), all were nonsignificant after accounting for the effects of all others. This makes sense given that no individual EF measures were significantly associated with HRA in preliminary (correlational) analyses.

<<INSERT TABLE 6>>

Hypothesis 3: Complex EF Skills will be a better predictor of HRA than are Simple EF Skills

In order to evaluate the independent contributions of simple and complex EF measures, an additional step was completed on the previous sequential regression analysis. Specifically, the effects of both complex EF and simple EF groups were removed sequentially in order to determine the *R^2 Change* (ΔR^2) or total variance attributed to each group of variables. Note that for each of these, the *change in adjusted R^2* (ΔR^2_{adj}) is a better representation of the change in variability accounted for across steps, and for this reason effect sizes relate to these variables. The overall model fit with all variables is as described above, $F(7, 25) = .73$, $p = .65$, $R^2 = .17$, $R^2_{adj} = -.06$ (no effect). Note that all ΔR^2 values are in reference to the variance explained by this overall model.

When simple EF measures were removed from this model, the resulting model experienced an $\Delta R^2 = .10$, $\Delta R^2_{adj} = -.001$ (no effect). This indicates that simple executive functioning measures did not have an effect on the overall model. Following this, the simple EF measures were replaced in the model and the complex EF measures were removed to gauge the overall effect of the complex measures. The resulting model experienced an $\Delta R^2 = .09$, $\Delta R^2_{adj} = -.02$ (no effect), indicating that the complex EF measures also do not account for any significant amount of variability in HRA, and further are not a better predictor of HRA than simple EF.

Aim 2: HRC

Hypothesis 4: Scores on EF measures will correlate with overall HRC

To assess whether relationships exist between HRC and EF and stress measures, a series of bivariate correlations were used, utilizing only executive functioning measures of interest and health regimen consistency (as defined previously). A full correlation table is available in Table 4. Importantly, HRC was only found to be significantly associated with scores on the digit span backward test, $r = .50$ (moderate relationship), $p = .01$, such that increased performance on the digit span backward test (i.e., higher DSB scores) were associated with greater deviations on SMT reporting (i.e., poorer consistency in health regimen adherence). Furthermore, the correlation of HRC with a measure of executive functioning in the absence of significant associations between HRA and executive functioning may in fact further suggest that the two are dissociable, and that consistency relates more to cognitive functioning as opposed to current worries or concerns about a health behavior.

Hypothesis 5: EF skills will significantly predict HRC, after controlling for years of education

To evaluate the extent to which simple and complex EF measures predict HRC, a multiple regression was conducting using a 3-step sequential regression with the 26 individuals who had valid HRC scores. Note that an individual was required to have at least 3 events per reporting time (i.e., morning, afternoon, or evening) in order to receive a consistency score for that time. In addition, all HRC scores were corrected for projected wake time (taken from the

HBQ questionnaire the day before tracking began for the entire week). Therefore, their reporting times were in "minutes past wake-time" and these times were based on the wake-time reported for the day of the week which corresponded to the day of reporting. First, a regression was conducted with only years of education as a predictor, as in the HRA analyses. After this simple executive functioning measures were included in a block. Finally, complex executive functioning measures were included. Resulting changes in variance across the three blocks are represented graphically in Figure 1, along with variance changes seen in the corresponding HRA analyses (Hypothesis 2 above) for comparison.

<<INSERT FIGURE 1>>

With only years of education accounted for, the overall model did not significantly predict HRC, $F(1, 24) = .46$, $p = .51$, $R^2 = .02$, $R^2_{adj} = -.02$ (no effect). Said another way, years of education did not significantly predict HRC, $b = -2.80$, $SE_b = 4.15$, $p = .51$.

For the second block, 2 measures of simple executive function were included. Specifically, the local global task was not used in this analysis due to the high number of individuals who showed scores which had high leverage on the overall regression coefficient (i.e., reducing the *n* for analysis to 10). The results of the addition to this block yielded a significant model, $F(3, 20) = 4.05$, $p = .02$, $R^2 = .38$, $R^2_{adj} = .28$ (large effect). This suggests that the addition of the simple executive functioning measures produce an R^2 *adjusted change* of approximately .28, which is considered a large effect. Individual coefficients for variables may be seen below in Table 7. Note that only Digit Span Backward was a significant predictor after controlling for all others, $b = 6.60$, $SE_b = 2.28$, $p < .01$, again, such that better DSB scores were associated with poorer consistency in adherence.

<<INSERT TABLE 7>>

Finally, the last block was included using all 3 complex executive functioning measures of interest. This again produced a significant model, $F(6, 16) = 4.62$, $p < .01$, $R^2 = .63$, $R^2_{adj} = .50$ (large effect). This indicates that the model including complex executive functioning measures produce an $\Delta R^2_{adj} = .22$, which is a medium effect. Individual coefficients for variables may be seen below in Table 8. Note that the only individual predictor that was significant, after accounting for all other predictors, was Digit Span Backward, $b = 6.39$, $SE_b = 2.07$, $p < .01$, and Color-Word Interference, Switching Time to Completion, was trending towards significance $b = -1.00$, $SE_b = .43$, $p = .04$. Here, the pattern for DSB remains the same as previously stated, whereas shorter time to completion on the color-word interference test was associated with better consistency in adherence.

<<INSERT TABLE 8>>

<u>Hypothesis 6:</u> *Complex EF skills will be a better predictor of HRC than are simple EF skills*

In order to evaluate the unique contributions of simple and complex EF measures, an additional step was completed on the previous sequential regression analysis. Specifically, the effects of both complex EF and simple EF groups were removed sequentially in order to determine the ΔR^2 associated with each group of variables individually. Note that for each of these, the ΔR^2_{adj} is a better representation of the change in variability accounted for across steps, and for this reason effect sizes relate to these variables. The overall model fit with all variables is as described above, $F(6, 16) = 4.62$, $p < .01$, $R^2 = .63$, $R^2_{adj} = .50$ (large effect). Note that all ΔR^2 values are in reference to the variance explained by this overall model.

When simple EF measures were removed from this model, the resulting model experienced an $\Delta R^2 = .50$, $\Delta R^2_{adj} = .54$ (large effect). This indicates that simple executive functioning measures did not have a large effect on the overall model, accounting for approximately 54% of the variance in HRC. Following this, the simple EF measures were replaced in the model and the complex EF measures were removed to gauge the overall effect of the complex measures. The resulting model experienced a moderate increase in variance explained, $\Delta R^2 = .25$, $\Delta R^2_{adj} = .22$ (medium effect), indicating that the complex EF measures also account for significant amount of variability in HRC. These results ultimately indicate that both simple and complex measures are strong predictors of HRC, but simple EF seems to be a better predictor. This is depicted visually in Figure 2.

<<INSERT FIGURE 2>>

Exploratory Aim: DMC

Hypothesis 1: *Consistency in decision making on the Ambivalent Decision Making Task (DMC) will correlate with HRC and EF skills*

Bivariate correlations were performed between DMC with HRC in order to determine whether these variables were statistically related to one another. As can be seen in Table 4, DMC was significantly associated with HRC, $r = -.46$, $p = .02$ (weak), indicating that heightened deviation scores on the DMC were associated with lower average deviation on the SMT.

DMC scores were also correlated with simple and complex EF measures, and DMC scores were found to be significantly associated with Digit Span Backward scores, $r = -.44$ (weak), $p = .01$. This indicates that individuals with higher deviations on the AmDMT were likely to have lower Digit Span Backward scores. Taken together, these results seem to indicate that individuals performed in an opposite manner on the DMC than expected, though the relationship with real-world consistency is notable. It is possible that this is due to a misperception of the strategy for this task (i.e., that greater variability relates to greater outcomes), and therefore may explain this relationship.

<u>Hypothesis 2:</u> *DMC will predict additional variance in HRC, above and beyond traditional EF measures*

In addition to the sequential regression analysis completed previously, one additional layer was added the model, Decision Making Consistency from the AmDMT. Since this measures was meant to provide a clinical measure that emulate consistency seen during this task, it was thought that this measure would explain additional variance not accounted for by EF measures. Effectively, a 4th stage of the sequential regression was added, including only the DMC measure. Though this overall model had continued significance, $F(7, 15) = 4.29$, $p < .01$, $R^2 = .67$, $R^2_{adj} = .51$ (large effect). Note that DMC was not a significant predictor of HRC, after controlling for all other variables, $b = -.99$, $SE_b = .81$, $p = .24$, all coefficients may be observed in Table 9. In order to further confirm this, the unique variance explained by DMC was determined. The amount of variance explained by DMC was .04, and $\Delta R^2_{adj} = .05$ (small effect), indicating that DMC accounted for little additional variance above and beyond traditional EF measures. This is represented in Figure 3.

<<INSERT TABLE 9>>

<<INSERT FIGURE 3>>

Secondary and Sub-Analyses

Impact of Perceived Stress on HRA and HRC

As reported previously, one's PSS score was significantly associated with their HRA score. Furthermore, PSS score was a significant predictor of HRA, after controlling for years of education, $b = .033$, $SE_b = .02$, $p = .049$. Moreover, PSS scores were not significantly associated with one's motivation to reduce their stress (on a 1-10 scale), $r = .21$, $p = .24$, nor was motivation level associated with overall adherence, $r = .18$, $p = .32$. This finding likely indicates that one's HRA may be most associated with their current level of concern about a given health behavior (i.e., their current stress level) rather than their cognitive abilities or even their reported motivation for change. Importantly, this association does not exist when considering HRC, further indicating that consistency is a dissociable component of regimen adherence in a healthy population.

Role of Word Reading

The Test of Premorbid Functioning was included in the current study as a proxy measure for IQ. Interestingly, this measure was significantly associated with age, $r = .37$ (weak relationship), $p = .04$, which makes sense given that we would expect older individuals in our relatively young sample to have a higher IQ on a measure of crystalized intelligence. Of note, there was not a significant association between this measure and years of education, as would be expected, $r = .30$, $p = .09$. Higher word reading scores were also significantly associated with greater variability in HRC, $r = .42$ (weak relationship), $p = .03$, higher scores on Digit Span Backward, $r = .58$ (moderate relationship), $p < .01$, and shorter time to complete Trails B, $r = -.38$ (weak relationship), $p = .03$, indicating that the participants' word reading abilities were associated with heightened executive functioning, but higher average deviations in adherence.

Sub-Analysis by Adherence Level

A sub-analysis was conducting comparing three adherence groups: high (> 75% of events completed, $n = 13$), medium (39% to 75% of adherence events completed, $n = 10$), and low (less than 38% of adherence events completed, $n = 10$). These groups were created by splitting groups equally without separating individuals who participated in the same number of adherence events (i.e., the high group has 3 additional individuals because multiple individuals were clustered at 76% adherence). This sub-analysis was conducted to explore differences among those who had varying levels of participation in the study protocol, as it is possible there may be differences in the contribution of cognitive and psychosocial factors for each of these three groups. Demographics for all groups may be viewed in Table 10.

<<INSERT TABLE 10>>

Upon inspecting correlation analyses for the low adherence group, only digit span backward was significantly associated with HRC, $r = .99$, $p = .03$ (strong), such that increased performance on DSB was associated with poorer consistency. Moreover, HRC and HRA remain unrelated, r - .91, $p = .27$. Note also that HRA was not associated with PSS score, $r = .30$, $p = .41$, or motivation to reduce stress, $r = .31$, $p = .39$. In addition, HRC was not associated with PSS score, $r = .50$, $p = .67$, or motivation to reduce stress, $r = .46$, $p = .70$. Table 11 shows all correlations for the low adherence group.

<<INSERT TABLE 11>>

In the medium adherence group, correlation analyses revealed no significant association between executive functioning measures and HRA. However, HRC was associated with time to complete color-word interference, $r = .65$, $p = .04$ (moderate), such that a greater time to complete this task was associated with poorer consistency in adherence. Moreover, HRC and HRA remain unrelated, $r = -.13$, $p = .73$. Note that HRA was associated with PSS score, $r = .77$, $p = .01$ (strong), but not motivation to reduce stress, $r = -.05$, $p = .90$. HRC was not significantly associated with PSS, $r = -.14$, $p = .69$, nor motivation to reduce stress, $r = .32$, $p = .36$. Table 12 shows all correlations for the medium adherence group.

<<INSERT TABLE 12>>

In the high adherence group, HRA was associated with color-word switching, $r = .56$, $p = .046$ (moderate), such that greater time to completion on this task (i.e., poorer EF) is associated with higher adherence. Further, greater consistency in adherence is associated with reduced digit span backward performance, $r = .62$, $p = .02$ (moderate), and longer time to completion on the color-word switching task, $r = -.75$, $p < .01$ (strong). Moreover, HRC and HRA remain unrelated, $r = -.10$, $p = .74$. HRA was not associated with PSS score, $r = .27$, $p = .37$, nor motivation to reduce stress, $r = .52$, $p = .07$. Similarly, HRC was unrelated to both PSS score, $r = .04$, $p = .90$, and motivation to reduce stress, $r = .45$, $p = .12$. Table 13 shows all correlations for the high adherence group.

<<INSERT TABLE 13>>

DISCUSSION

The aim of the current study was to explore the relationships between health regimen adherence, health regimen consistency, and executive functioning (see Table 14 for a summary of hypotheses and exploratory analyses with corresponding results). This was completed with a series of correlational and regression analyses which revealed a few key findings.

<<INSERT TABLE 14>>

First, these findings suggest that HRA and HRC are dissociable components of adherence. The potential for these constructs to be dissociable is important as it provides evidence that they may be governed by separate aspects of cognition. Past research within medically compromised populations has shown that one's adherence was highly related to consistency, such that greater consistency was associated with higher levels of adherence to a rehabilitation regimen (Rosen et al., 2003). In light of this, the data indicate that consistency can be conceptualized as a component of adherence that may be amenable to training as a method of improving overall adherence in medically compromised populations.

Given this potential for consistency as a behavior targetable by adjustments to recommendations or improvements in the components which underlie consistency, it was also an aim of this study to understand cognitive functions that sub-serve consistency. It was hypothesized (based on past literature) that one's ability to regularly adhere to a regimen depends on planning and problem solving abilities, as well as other cognitive skills related to "executive functioning." The results of the current study are mixed with regard to this. In particular, the measures related to complex executive functioning skills (i.e., planning) were less related to consistency than were more simple cognitive skills (i.e., updating and inhibiting), and indicate that, in general, individuals with stronger executive functioning skills on testing had poorer consistency in adherence, as did those with higher overall word reading scores (considered a proxy for overall ability level). This is contrary to past findings in this area, which have shown that the overall cognition is associated with increased consistency in adherence to medication in patients with Type-II Diabetes (Rosen et al., 2003). This same study found executive functioning measures to be related to overall adherence, which is also different that patterns found in the current study. Multiple studies have also identified executive functioning as a cognitive facet associated with improved outcomes of rehabilitation, regardless of overall adherence to on-site regimens (Kakos et al., 2010, Spitznagel et al., 2013). Figure 4 shows the results of current research compared to past findings (and unstudied relationships in medically compromised individuals).

<<INSERT FIGURE 4>>

Taken together, this pattern of results continues to support consistency as a facet of adherence sub-served, at least in part, by executive functioning. It is likely that adherence is a construct that requires multiple aspects of executive functioning, including things such as the ability to switch between tasks, adequate decision-making, and planning, which may explain the relationships between simple and complex measures in this study. Specifically, the simple measures of executive functioning spanned a broader spectrum of EF (in particular updating and inhibiting), and therefore may better account for the basic skills needed for consistency, whereas the complex measures looked at more specific skills and therefore likely accounted for less of the skills required for consistency, without measuring skills specific to consistency. As seen in Figure 5, the wide-reaching impact of simple EF measures make them more likely to account for variance in the complex construct of overall EF than complex EF measures, which target more specific skills, a notion supported by studies looking at the structure of EF (Miyake et al., 2000).

<<INSERT FIGURE 5>>

Secondary analyses conducted in this study indicate that the relationships between executive functioning and consistency became more pronounced as adherence improved (i.e., in the high adherence group), though they remained in the direction that poor consistency was related to better EF in all groups. Furthermore, the relationship between perceived stress and overall adherence was slightly different within each sub-group. In particular, the middle adherence group continued to show an association between perceived stress score and overall adherence, while the high adherence group showed a trend toward as association between adherence and motivation to reduce stress, rather than overall perceived stress. Of note, correlational analyses in the current study indicate that inconsistency in regimen adherence was associated with both high word reading scores (i.e., higher IQ) as well as higher executive functioning scores on multiple measures, which is counter to the hypothesized relationship between executive functioning, IQ, and consistency, and is in fact counter to past findings that higher overall functioning is related to heightened adherence (Kakos et al., 2010). This, along with the counter-intuitive relationships seen between executive functioning measures and consistency, indicate that further research is needed to understand whether these findings are generalizable to individuals experiencing cognitive compromise.

With regard to clinical implications, the suggestion that consistency is an independent facet of adherence provides some indication that it is an area that can be either targeted or controlled by clinicians to improve adherence. Though a link between consistency and adherence was not shown in this study, is has been shown to be significantly related is medication adherence studies which analyzed consistency post-hoc (Rosen et al., 2003). Moreover, the potential link between executive functioning and consistency in adherence may indicate that targeting this aspect of adherence requires increased a priori planning by the clinician or potentially training of compensatory strategies to improve problem solving around remaining consistent (i.e., setting alarms for adherence or maintaining a system of accountability).

Another important clinical implication of the study is the finding that overall adherence was best predicted by an individual's perceived stress level. This suggests that understanding a patient's overall distress about their condition may be an important first step in understanding whether they are likely to continue with an assignment completed at home. Once someone has described significant distress due to their current condition, motivation is a second target area that may provide insight into the likelihood that an individual will complete at-home assignments. As is commonly known, motivation can often be increased in a clinical setting using motivational interviewing – a technique for which this study provides support may be an important tool in any setting which is providing behavioral recommendations (Rollnick & Miller, 1995).

With regard to limitations, it is unlikely that the healthy individuals provide a representative understanding of adherence in individuals experiencing cognitive or physical deficits. Importantly, all participants in the study were current college students, so it is possible that individuals with higher IQ and EF abilities were less likely to adhere because of their desire to focus their attention to other areas of their lives (i.e., their classes). However, the strong effect of EF in predicting consistency, and not adherence, provides evidence that consistency itself may be a component of adherence that is mediated by executive functioning abilities. Moreover, the general "wellness" of the current sample is also a limitation of the study, as it is likely that individuals who are invested in completing the assigned regimen would provide a better (and more clinically relevant) picture of which neuropsychological functions or factors may be important in predicting consistency and adherence. Similarly, the homogeneity of neuropsychological test scores within the given sample weakened analyses because of the lack of variability (and the increased number of outliers for slightly discrepant scores). In particular, this limited the realized power of the study and ultimately reduced power below 80% for both HRA and HRC analyses.

Future studies should look to more clinically impaired populations in order to better understand how consistency and adherence may impact individuals who are in more serious distress (i.e., heart failure, cognitive decline, etc.). In particular, establishing a relationship between HRA and HRC will be important in future literature to further confirm the relationship between these related variables. In addition, future studies should focus on the impact of executive functioning on consistency over longer periods of time, as it is likely that a greater demand for planning and problem solving occurs with longer regimens which do not have strict prescriptions.

The current study succeeded in implementing a behavioral regimen performed with minimal instructions in an unstructured environment. Importantly, outcome measures of both adherence and consistency were gleaned from this regimen, which has not been systematically explored in previous literature. In addition, the current findings do suggest that consistency may be an independent aspect of adherence, which warrants further study.

Table 1. Demographic Variables for Entire Sample (*n* = 33).

Demographic Variable	Mean (SD)
Age	20.03 yr (2.0)
Education	13.64 yr (1.6)
Sex	63.6% Male
Race	51.5% Caucasian
	27.3% Asian
	12.1% African American
	3% Hispanic
	3% Other

Table 2. Descriptive Statistics for Self-Report Questionnaires, Stress Monitoring Task, and Cognitive Variables of Interest (*n* = 33).

Measure	Outcome Measure	Mean (SD)
Self-Report Questionnaires		
Perceived Stress Scale	Total Stress Score	24.33 (3.3)
Epworth Sleepiness Scale	Total Sleepiness Score	9.42 (3.7)
HBQ Physical Activity	Days/Week of Phys Activity	2.73 (2.07)
HBQ Time Spent Sitting	Hours/Day Spent Sitting	8.67 (3.66)
HBQ Breakfast Frequency	Days/Week Breakfast Eaten	3.42 (2.19)
Stress Monitoring Task		
Adherence (HRA)	Proportion Completed Events	0.55 (.32)
Consistency (HRC)	Average Deviation (min)	104.07 (31.75)
Motivation to Reduce Stress	Motivation Score (0-10)	7.24 (2.66)
Cognitive Measures		
TOPF Word Reading	Raw Score Correct	40.66 (11.15)
SDMT – Processing Speed	Raw Score Correct	58.91 (10.24)
Ambivalent DM Task	DM Consistency	20.26 (7.92)
Simple EF		
CW Interference – Inhibition	Time to Completion (sec)	44.44 (9.89)
Local Global Conflicting	Proportion Correct	0.57 (0.21)
Digit Span Backward	Total Score Correct	8.5 (2.28)
Complex EF		
CW Interference – Switching	Time to Completion (sec)	56.12 (13.04)
Trailmaking Test B	Time to Completion (sec)	56.48 (14.03)
Tower Test Achievement	Total Achievement Score	16.93 (3.36)

Table 3. Deviations from the Iowa Gambling Task for the AmDMT

Deviation	Rationale
Using a number line instead of cards	Allows for greater variability in responses and has an cleaner distribution w/ increased burden of choice for the participant
Touchpad rather than computer screen	Reduces limitations due to motor deficits. May also pull for more realistic decision rate and allows for more individualized pacing.
Tempered rewards and penalties (e.g., points rather than money) – also smaller penalties & rewards	Pulls more for ambivalence rather than risk – want to reduce risky behavior and pull more for the need to balance dual values (and the effect of this on consistency)
Multiple blocks (5)	Reduces the learning curve and allows us to look across the trials.

Table 4. Full Correlation Matrix for SMT Adherence and Consistency as well as Decision Making Consistency on the Ambivalent Decision Making Task.

	PSS	**CWI3**	**LG Conflict**	**DSB**	**Trails B**	**CWI4**	**TTA**	**HRA**	**HRC**	**DMC**
PSS	1									
CWI3	-.03 *.87*	1								
LG Conflict	-.14 *.45*	.03 *.88*	1							
DSB	.01 *.96*	-.22 *.21*	.11 *.54*	1						
Trails B	-.24 *.17*	.40* *.02*	-.40* *.02*	-.29 *.10*	1					
CWI4	-.22 *.21*	.54** *.001*	-.05 *.79*	-.09 *.61*	.34 *.06*	1				
TTA	-.11 *.55*	-.41* *.02*	.22 *.22*	.14 *.43*	-.45** *.01*	-.32 *.07*	1			
HRA	.35* *.05*	.10 *.56*	.02 *.92*	-.24 *.18*	-.08 *.65*	-.19 *.30*	.024 *.89*	1		
HRC	.04 *.85*	-.01 *.98*	.12 *.55*	.50* *.01*	-.22 *.29*	-.04 *.83*	-.20 .33	-.24 *.24*	1	
DMC	.04 *.81*	-.34 *.052*	-.22 *.23*	-.44* *.01*	-.07 *.72*	-.12 *.50*	.05 *.76*	.08 *.66*	-.46* *.02*	1

* significant at $p < .05$, **significant at $p < .01$

PSS = Perceived Stress Scale; CWI3 = Color-Word Interference, Condition 3 Switching; LG Conflict = Local Global, Local Condition Conflicting Trials; DSB = Digit Span Backward; Trails B = Trailmaking Test, Trial B; CWI4 = Color-Word Interference, Condition 4, Inhibition/Switching; TTA = Tower Test Achievement; HRA = Health Regimen Adherence; HRC = Health Regimen Consistency; DMC = Decision Making Consistency on the Ambivalent Decision Making Task.

Table 5. HRA Model with Blocks 1 (Covariate) and 2 (Simple EF) (*n* = 33)

Variable	*beta*	*SEb*	*p*
Years of Education	-.03	.04	.42
Simple EF			
CWI 3	.002	.01	.76
Local Global	.06	.24	.80
DS Backward	-.03	.02	.31

Overall model was nonsignificant, $F(4, 28) = 0.64$, $p = .64$, $R^2 = .08$, $R^2_{adj} = -.05$ (no effect).

Table 6. HRA Model Including Blocks 1 (Covariate), 2 (Simple EF), and 3 (Complex EF) (*n* = 33)

Variable	*beta*	*SEb*	*p*
Years of Education	-.02	.04	.56
Simple EF			
CWI 3	.01	.01	.27
Local Global	-.06	.27	.84
DS Backward	-.03	.03	.26
Complex EF			
Trails B	-.004	.01	.43
CWI 4	-.01	.01	.22
Tower Test	-.002	.02	.91

Overall model was nonsignificant, $F(7, 25) = 0.73$, $p = .65$, $R^2 = .17$, $R^2_{adj} = -.06$ (no effect).

Table 7. HRC Model 2 Including Blocks 1 (Covariate) and 2 (Simple EF) (*n* = 25)

Variable	*beta*	*SEb*	*p*
Years of Education	3.83	3.04	.22
Simple EF			
CWI 3	.21	.48	.67
DS Backward	6.60	2.28	.009*

Overall model was significant, $F(3, 20) = 4.05$, $p = .02$, $R^2 = .38$, $R^2_{adj} = .28$ (large effect).
*Significant individual predictor (with adjusted p-value)

Table 8. HRC Model 3 Including Blocks 1 (Covariate), 2 (Simple EF), and 3 (Complex EF) (*n* = 23)

Variable	*beta*	*SEb*	*p*
Years of Education	1.70	2.89	.56
Simple EF			
CWI 3	.86	.61	.18
DS Backward	6.39	2.07	.01*
Complex EF			
Trails B	0.61	.36	.11
CWI 4	-1.00	.43	.04
Tower Test	-1.09	1.37	.43

Overall model was significant, $F(6, 16) = 4.62$, $p < .01$, $R^2 = .63$, $R^2_{adj} = .50$ (large effect).
*Significant individual predictor (with adjusted p-value)

Table 9. DMC Model 4 Values (*n* = 23)

Variable	*beta*	*SEb*	*p*
Years of Education	.84	2.93	.78
Simple EF			
CWI3	.39	.72	.59
DS Backward	4.09	2.78	.16
Complex EF			
Trails B	-.74	.37	.07
CWI 4	-.92	.43	.05
Tower Test	-1.54	1.39	.29
AmDMT			
DMC	-.99	.81	.24

Overall model was significant, $F(7, 15) = 4.29$, $p < .01$, $R^2 = .67$, $R^2_{adj} = .51$ (large effect).

Table 10. Adherence Group Demographics and Descriptive Statistics

Demographic Variable	Low (*n* = 10) Mean (SD)	Medium (*n* = 10) Mean (SD)	High (*n* = 13) Mean (SD)
Sex	50% Male	60% Male	93% Male
Age	20.2 yr (2.1)	21.2 yr (1.9)	19.0 yr (1.5)
Education	13.9 yr (1.6)	14.5 yr (1.5)	12.8 yr (1.2)
Questionnaire	Mean (SD)	Mean (SD)	Mean (SD)
PSS Score	22.9 (2.56)	25.6 (3.8)	24.5 (3.2)
ESS Score	7.0 (2.9)	6.8 (2.9)	7.77 (2.4)
HRA Score	.12 (.1)	0.61 (.1)	0.84 (.1)
HRC Score	100.78 (11.6)	121.81 (38.1)	91.32 (23.4)
SMT Motivation	7.0 (2.94)	6.8 (2.90)	7.77 (2.35)

Table 11. Correlation Matrix for the Low Adherence Group (*n* = 10)

	PSS	**CWI3**	**LG-L/Con**	**DSB**	**Trails B**	**CWI4**	**TTA**	**HRA**	**HRC**	**DMC**
PSS	1									
CWI3	-.42	1								
	.23									
LG – L/Con	-.20	.23	1							
	.59	*.52*								
DSB	.23	-.34	-.05	1						
	.53	*.34*	*.89*							
Trails B	-.28	.33	-.59	-.32	1					
	.44	*.35*	*.07*	*.36*						
CWI4	-.34	.55	-.01	-.29	.29	1				
	.33	*.10*	*.99*	*.42*	*.41*					
TTA	.36	-.46	-.10	.24	-.34	-.28	1			
	.31	*.18*	*.78*	*.50*	*.34*	*.43*				
HRA	.30	.03	.45	-.16	-.62	-.08	-.14	1		
	.41	.93	*.20*	*.66*	*.06*	*.83*	*.71*			
HRC	.50	-.86	-.45	.99*	-.71	-.98	.01	.91	1	
	.67	*.34*	*.70*	*.03*	*.49*	*.13*	.99	*.27*		
DMC	.29	-.03	-.48	-.37	.09	.08	.04	-.01	.99	1
	.41	*.93*	*.16*	*.29*	*.80*	*.83*	*.92*	*.99*	*.09*	

* significant at $p < .05$, **significant at $p < .01$

PSS = Perceived Stress Scale; CWI3 = Color-Word Interference, Condition 3 Switching; LG – L/Con = Local Global, Local Condition Conflicting Trials; DSB = Digit Span Backward; Trails B = Trailmaking Test, Trial B; CWI4 = Color-Word Interference, Condition 4, Inhibition/Switching; TTA = Tower Test Achievement; HRA = Health Regimen Adherence; HRC = Health Regimen Consistency; DMC = Decision Making Consistency on the Ambivalent Decision Making Task.

Table 12. Correlation Matrix for the Medium Adherence Group (n = 10)

	PSS	**CWI3**	**LG-L/Con**	**DSB**	**Trails B**	**CWI4**	**TTA**	**HRA**	**HRC**	**DMC**
PSS	1									
CWI3	-.33	1								
	.35									
LG – L/Con	-.19	.35	1							
	.60	*.32*								
DSB	-.06	-.07	-.09	1						
	.86	*.85*	*.80*							
Trails B	-.44	.35	-.25	-.04	1					
	.20	*.32*	*.49*	*.92*						
CWI4	-.43	.71	.01	.23	.59	1				
	.21	*.02*	*.98*	*.53*	*.07*					
TTA	-.39	-.57	.22	.10	-.42	-.40	1			
	.27	*.09*	*.54*	*.79*	*.23*	*.25*				
HRA	.77**	.07	.04	-.21	-.17	-.07	-.50	1		
	.01	.86	*.92*	*.56*	*.64*	*.84*	*.14*			
HRC	-.14	.65*	.26	.21	-.06	.39	-.36	-.13	1	
	.69	*.04*	*.47*	*.56*	*.88*	*.26*	.30	*.73*		
DMC	.67*	-.49	-.32	-.50	-.25	-.61	-.11	.45	-.65*	1
	.04	*.15*	*.37*	*.14*	*.49*	*.06*	*.76*	*.19*	*.04*	

* significant at $p < .05$, **significant at $p < .01$

PSS = Perceived Stress Scale; CWI3 = Color-Word Interference, Condition 3 Switching; LG – L/Con = Local Global, Local Condition Conflicting Trials; DSB = Digit Span Backward; Trails B = Trailmaking Test, Trial B; CWI4 = Color-Word Interference, Condition 4, Inhibition/Switching; TTA = Tower Test Achievement; HRA = Health Regimen Adherence; HRC = Health Regimen Consistency; DMC = Decision Making Consistency on the Ambivalent Decision Making Task.

Table 13. Correlation Matrix for the High Adherence Group (*n* = 13)

	PSS	**CWI3**	**LG- L/Con**	**DSB**	**Trails B**	**CWI4**	**TTA**	**HRA**	**HRC**	**DMC**
PSS	1									
CWI3	.14 *.57*	1								
LG – L/Con	-.09 *.72*	-.04 *.89*	1							
DSB	.19 *.45*	-.26 *.29*	.15 *.56*	1						
Trails B	-.26 *.30*	.41 *.09*	-.33 *.19*	-.40 *.10*	1					
CWI4	-.01 *.97*	.51* *.03*	-.11 *.66*	-.24 *.33*	.37 *.13*	1				
TTA	-.32 *.20*	-.31 *.22*	.28 *.26*	.09 *.72*	-.45 *.06*	-.29 *.24*	1			
HRA	-1.4 *.58*	.27 *.29*	.18 *.47*	-.11 *.68*	-.03 *.92*	-.17 *.50*	.12 *.63*	1		
HRC	.19 *.46*	-.11 *.66*	.24 *.33*	.53* *.02*	-.22 *.37*	-.18 *.46*	-.24 .34	-.43 *.08*	1	
DMC	-.22 *.39*	-.53* *.02*	-.11 *.67*	-.36 *.15*	-.20 *.43*	-.19 *.45*	.16 *.52*	.09 *.74*	-.39 *.11*	1

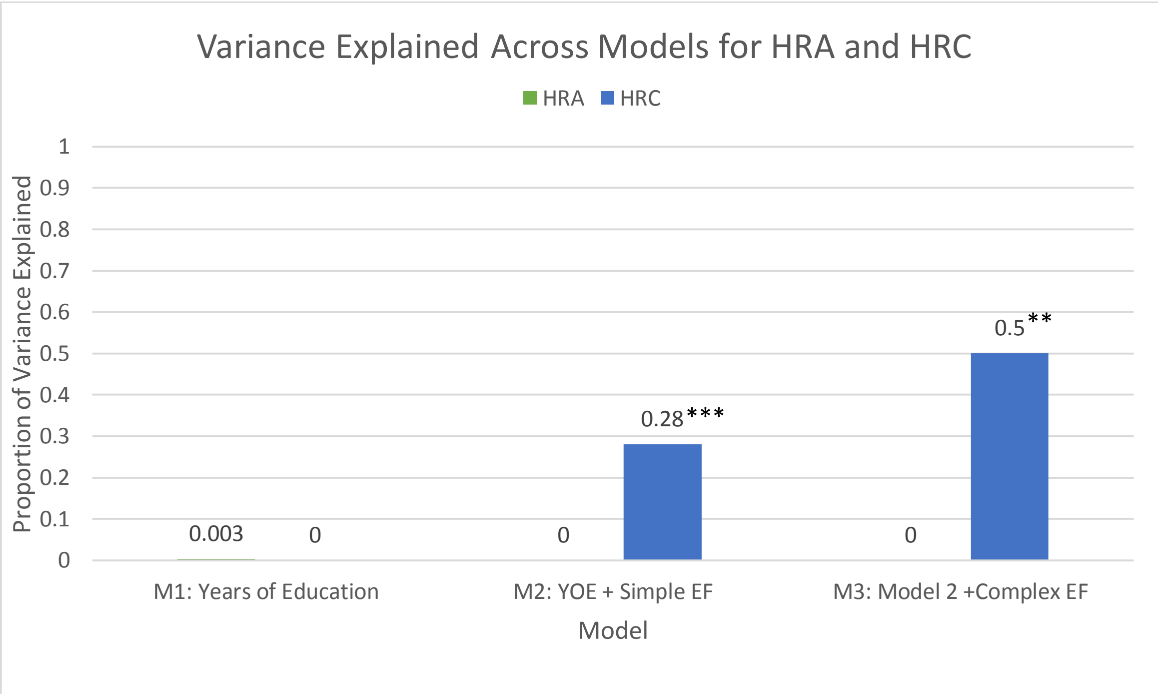
* significant at $p < .05$, **significant at $p < .01$

PSS = Perceived Stress Scale; CWI3 = Color-Word Interference, Condition 3 Switching; LG – L/Con = Local Global, Local Condition Conflicting Trials; DSB = Digit Span Backward; Trails B = Trailmaking Test, Trial B; CWI4 = Color-Word Interference, Condition 4, Inhibition/Switching; TTA = Tower Test Achievement; HRA = Health Regimen Adherence; HRC = Health Regimen Consistency; DMC = Decision Making Consistency on the Ambivalent Decision Making Task.

Table 14. Summary of Findings for Primary and Exploratory Hypotheses

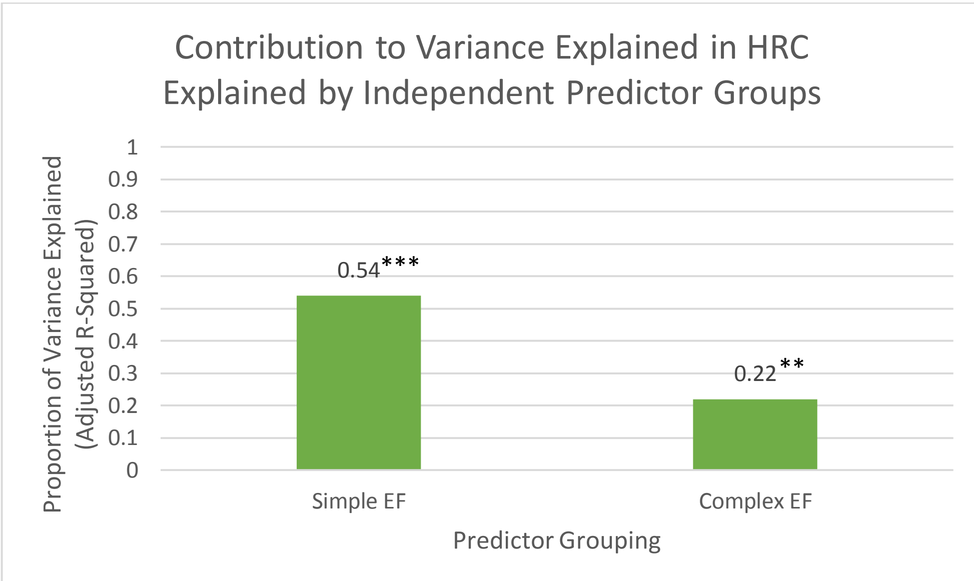
	Hypothesis	Finding
Aim 1		
Hypothesis 1	Higher EF will be related to Higher HRA	No EF measures were related to HRA
Hypothesis 2	EF Skills will account for a significant amount of variance in HRA	EF Skills did not account for significant variance in HRA
Hypothesis 3	Complex EF will predict HRA better than Simple EF	Both were poor predictors of HRA (no effect)
Aim 2		
Hypothesis 4	Higher EF will be related to greater HRC	Better performance on Digit Span Backward was associated with poorer HRC
Hypothesis 5	EF Skills will account for a significant amount of variance in HRC	Simple & Complex EF skills together account for significant variance in HRC (large effect)
Hypothesis 6	Complex EF will predict HRC better than Simple EF	Simple EF measures were a better predictor of HRC than were Complex EF
Exploratory		
Hypothesis 1	Greater consistency on the AmDMT (DMC) will be related to EF and greater HRC.	Better DMC performance was associated with better Digit Span Backward performance and poorer HRC
Hypothesis 2	Consistency scores on the AmDMT (DMC) will account for additional variance in HRC, above and beyond other EF measures	DMC was not significant as an individual predictor of HRC, but accounted for a small amount of additional variance, above and beyond simple and complex EF

Figure 1. Proportion of Variance in HRA Explained by Executive Functioning Measures, Adjusted for Number of Predictors



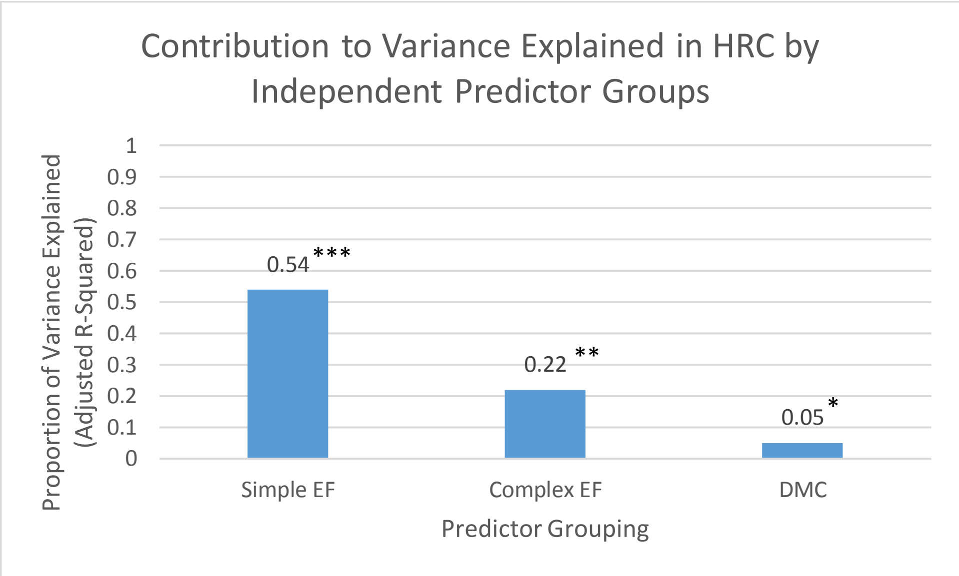
Note: Values less than 0 were recorded as 0 for ease of interpretation. They continue to represent no significant effect. * indicates a small effect, ** indicates a medium effect, and *** indicates a large effect for change in proportion of variance explained in each model iteration (i.e., from 1 to 2).

Figure 2. Proportion of Variance in HRC Explained by Simple and Complex Executive Functioning (EF), Independent of One Another



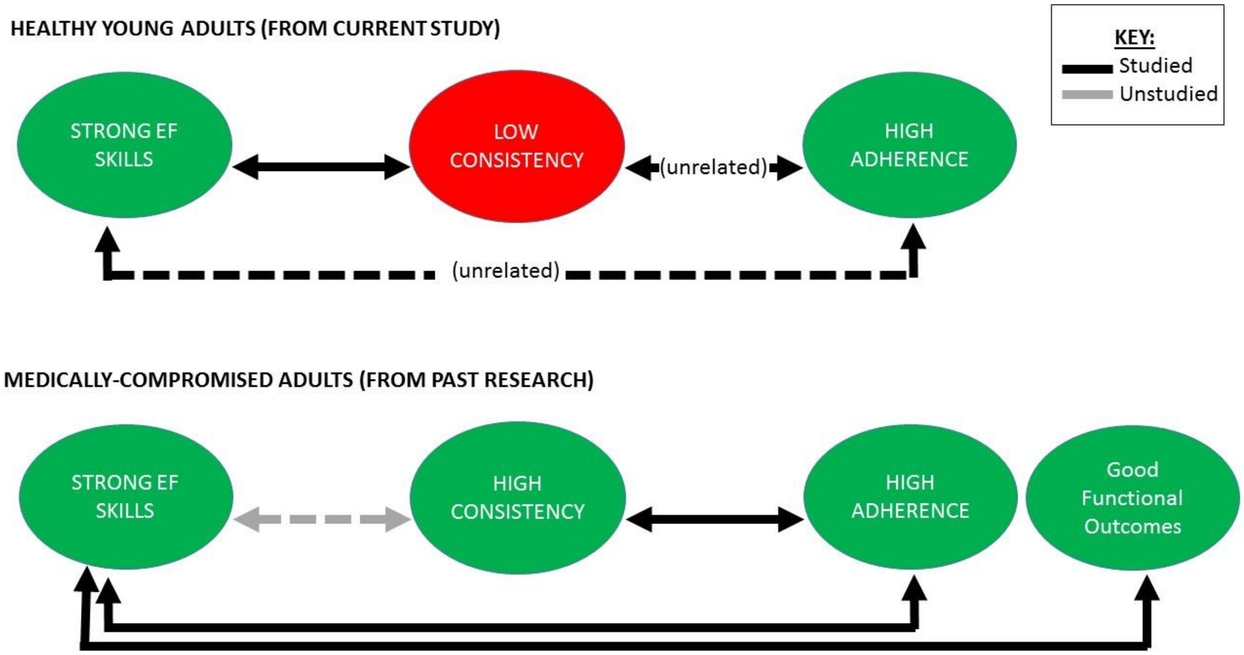
Note: * indicates a small effect, ** indicates a medium effect, and *** indicates a large effect for change in proportion of variance explained in each model iteration (i.e., from 1 to 2).

Figure 3. Proportion of Variance in HRC Explained by Simple and Complex Executive Functioning (EF) and AmDMT Decision Making Consistency (DMC), Independent of One Another



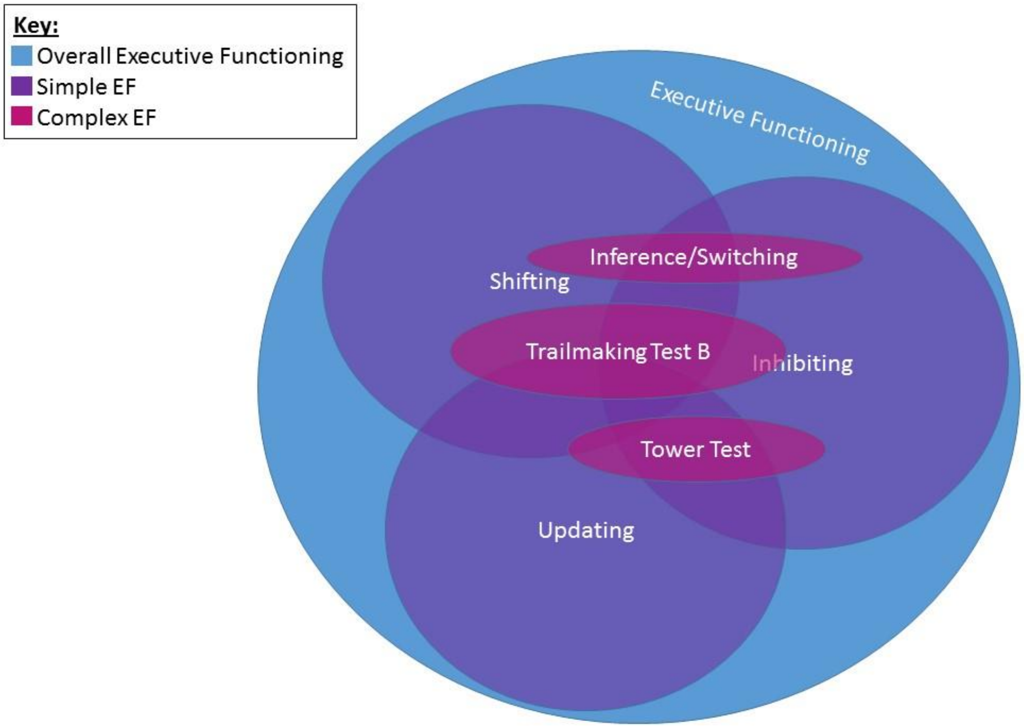
Note: * indicates a small effect, ** indicates a medium effect, and *** indicates a large effect for change in proportion of variance explained in each model iteration (i.e., from 1 to 2).

Figure 4. Summary of Current and Past Research Findings for the Relationship between Executive Functioning, Consistency, Adherence, and Functional Outcomes.



Past studies have shown a significant relationship between EF skills and adherence, as well as EF skills and outcomes (i.e., quality of life, cardiac conditioning, etc.), but have not shown a relationship between consistency and EF. Only one study (Rosen et al., 2003) has shown that higher consistency in adherence was related to greater adherence. The current study did not find relationships between consistency and adherence, or EF skills and adherence. Moreover, stronger EF skills related to poorer consistency.

Figure 5. Conceptual Model of the Amount of Overall Executive Functioning Explained by Simple and Complex EF Measures.



Note that the area consumed by simple EF is greater than the area consumed by complex EF, indicating that simple measures are more likely to explain variance in executive functioning.

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Appendix A.

Self-Report Measures

Perceived Stress Scale – 4-item (For Flyers)

Instructions: The questions in this scale ask you about your feelings and thoughts during the last month. Fill out the 4 items below and add up the numbers next to each selection you have marked. This is your stress score. If your stress score is greater than 7, you are eligible for the current study!

1. In the last month, how often have you felt that you were unable to control the important things in your life?

___Never(0) ___Almost Never(1) ___Sometimes(2) ___Fairly Often(3) ___Very Often(4)

2. In the last month, how often have you felt confident about your ability to handle your personal problems?

___Never(4) ___Almost Never(3) ___Sometimes(2) ___Fairly Often(1) ___Very Often(0)

3. In the last month, how often have you felt that things were going your way?

___Never(4) ___Almost Never(3) ___Sometimes(2) ___Fairly Often(1) ___Very Often(0)

4. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

___Never(0) ___Almost Never(1) ___Sometimes(2) ___Fairly Often(3) ___Very Often(4)

Demographic Questionnaire

Name:	________________
Age:	________________
Gender:	F M Other
# of Years of Education:	________________
Average Family Income in your household growing up:	< 10,000 10,000-25,000 25,000-50,000 50,000-75,000 75,000-100,000 > 100,000
Please list any medications you are currently taking:	________________

Health Behaviors Questionnaire

How many days per week do you complete physical activity?	1 2 3 4 5 6 7
How many hours per day do you spend sitting?	________________
How many hours of sleep do you get each night on average?	________________
How much sleep did you get last night?	________________
How many days per week to do eat a healthy breakfast?	1 2 3 4 5 6 7
How many servings of fruits and vegetables do you eat per day?	________________
How much alcohol do you consume per week?	________________
How often do you smoke cigarettes?	________________

Please fill in your average wake-time and bed-time for each day of the week. Base this on your current schedule (e.g., for the upcoming week).

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Wake-time							
Bed-time							

Follow-Up Questionnaire

Please answer the following questions regarding your experiences throughout the course of this study.

1. On a scale from 1-10, how important do you feel it is to track your stress (with 1 being not at all important and 10 being extremely important)

1	2	3	4	5	6	7	8	9	10
Not at all important									Very Important

2. Please describe any strategies you employed in order to remember to fill out the online surveys three times per day (e.g., completing them at meal-times, setting an alarm, etc.)
3. Please describe any difficulties you encountered throughout the week.

Thank you for completing our study! You will receive 4 points of extra credit on SONA. Please contact us (via email or phone) with any questions or concerns.

Appendix B.

Stress Monitoring Task (SMT) Script

What is stress?

Stress arises when individuals perceive that they cannot cope with the demands being made on them or with threats to their well-being (Lazarus, 1966). There are physical components to stress, involving the direct material or bodily challenge that one experiences (e.g., stress on the body during a long run), as well as psychological stress, which involves the way in which individuals perceive situations that arise in their lives (Lovallo, 2005). Our ancestors felt stress when their lives were in danger. For example, stress might arise if there was an imminent threat nearby, such as a hungry tiger. Though the mechanism is the same, the things that trigger our stress response have changed because the way we live our lives has changed. For example, we now rarely encounter tigers, but we continue to feel stress when we are experiencing heightened demands at work, when we experience difficult social interactions with others, or when we have poor health habits. Before we get into how stress affects our bodies, I want to take a second to think about how stress impacts your life.

Table 15. Stress and Motivation Assessment

When do you notice you are most stressed?
On a scale from 1 to 10, with 10 being very much, how much do you feel stress affects your life?
(Not at all) 1 2 3 4 5 6 7 8 9 10 (Very Much)
On a scale from 1 to 10, with 10 being very much, how much would you like to reduce your stress?
(Not at all) 1 2 3 4 5 6 7 8 9 10 (Very Much)

Biological Basis of Stress

When one becomes stressed, their physiology changes quickly to accommodate the stressor, this is called reactivity (Sarafino, 2008, p. 67). One's reactivity is based heavily on personal factors, including but not limited to your genetics, how long you have been experiencing high stress levels, and your emotional state. Your reaction to perceived danger (as was described in the tiger example above) is often referred to as the fight-or-flight response. When the body is exposed to an extreme stressor, brain signals the sympathetic nervous system to activate, which stimulates the adrenal glands of the endocrine system, resulting in increased arousal of the body (Sarafino, 2008, p. 67). Ultimately, this stress reaction allows your body to be in its best "fighting" or "running" shape. Changes that occur include accelerated heart rate, dilated pupils, secretion of stress hormones, and reduced metabolic activity throughout the body.

Let's go back to the example of being attacked by a lion. When you recognize this threat, you need your body to essentially focus all of its energy on getting out of this dangerous situation, whether this be confronting the threat (fighting) or avoiding it (running away). For this reason, increased heart rate allows for more blood flow throughout your body, which allows more oxygen to reach your muscles, allowing for their best performance. The pupils also dilate so that your vision is at its best and you can take in as much information about your environment in as possible. Finally, less important systems in your body, such as the digestive and reproductive systems, postpone what they are doing in order to allow for all of your internal resources to be allocated where they are most needed.

Though our bodies are evolutionarily primed to react to physical stressors, most of the stressors we experience in our lives today are psychological (Straub, 2007, p. 85). Imagine that you are walking into a test that you haven't studied for. In this instance, the test likely represents a threat for you (like the tiger) and therefore your body reacts much like it would to any perceived threat. You'll likely notice that your heart begins to race and your blood pressure rises. Interestingly, your body initially responds in the same way to the threat of the test as it does to the tiger. Though this is your body's quickest response, your body cannot maintain this reaction long periods of time.

If an individual is facing a longer-term stressor which is not strong enough to cause death, they begin the resistance stage. During this physiological stage, the body attempts to adapt to the present stressor. It does this by maintaining a heightened level of arousal while replenishing the hormones released by the adrenal glands. Though individuals in this stage of stress likely show few signs of distress, their ability to react to new stressors may become impaired. This impairment causes them to be more likely to develop health problems including high blood pressure asthma, and illness due to poor immune system functioning (Sarafino, 2008, p. 69).

A third stage of stress is exhaustion. Exhaustion is the result of prolonged physiological arousal produced by severe long-term or repeated stress (Sarafino, 2008, p. 69). This serves to further weaken one's immune system, causing the body to have very impaired levels of resistance to additional stressors as well as to diseases and general health decline (Sarafino, 2008, p. 69).

Effects of Stress

As has been alluded to, stress (particularly chronic stress) can have many damaging effects on one's physical and psychological well-being. Stress has been shown to have detrimental effects on cognition, particularly on attention and memory functioning (Sarafino, 2008, p. 69). Chronic stress tends to cause us to focus in on stressors (e.g., remember these better and pay better attention to these aspects of our environment), ultimately leaving us less able to attend to other aspects of our environment, which reduces our ability to remember well those aspects of our environment (Straub, 2008, p.69). As you can imagine, this makes things such as studying difficult and can make optimal academic performance impossible.

Stress has also been shown to affect people's mood-levels. Specifically, fear and anger are common reaction to stress, and individuals experiencing long-term stress often experience increased feelings of fear in the form of anxiety (Straub, 2008, p. 70). Anxiety and continued stress can lead to feelings of sadness and depression. Both anxiety and depression can be serious mental health issues which impede one's ability to function normally, and directly affect one's ability to interact with others as well as their ability to perform in the classroom (Straub, 2008, p. 70).

Chronic or repeated stress can also greatly affect one's immune system. This causes wounds to heal more slowly, and reduces quality of life further. Additionally, with reduced immune responses, individuals are more prone to disease and are less able to fight diseases if contracted.

Models of Stress

As mentioned before, there are many factors which contribute to the saliency of a stressor including the emotional impact of that stressor for you, the duration of the stressor, as well as the immediacy of the threat. Two main models have been developed to explain the ways in which humans evaluate stress and attempt to explain how everyday hassles can become extreme stressors.

The first of these models is the transactional model of stress (Lazarus, 1993). This model emphasizes that we must look at environmental stressors and individuals responses to those behaviors are entirely separate entities, with the latter relating to the psychological appraisal of a given event. Specifically, the model suggests that stress occurs when an individual is unable to cope with a stressor (regardless of the magnitude of this stress) due to a lack of current resources. Importantly, this allows for different individuals to have very different reactions to the same stressor.

This model begins with the potential stressor, which could be any trigger that causes stress (e.g., an argument with a friend). After the onset of the stressor, there is a primary appraisal. The purpose of this first appraisal is to determine whether one is in danger. One then determines the level of danger by interpreting the event to be either irrelevant (e.g., the friend is having a difficult day and this argument has no bearing on your relationship), benign-positive (e.g., the argument with the friend was productive and necessary), challenging, harmful, or threatening (e.g., the argument with the friend was damaging and causes you to feel concern for the future of your relationship). Once an event has been perceived as a threat or challenge, a secondary appraisal occurs, wherein the individual determines their ability to cope with the situation. Here, one's goal is to determine whether their current resources are adequate enough to address the stressor and to overcome it (e.g., can the relationship with a friend be fixed). Stress is particularly likely to occur when one's resources are low (e.g., due to chronic stress). One then responds in accordance with their appraisals and the opportunity for reappraisal exists. This means that after acting, an individuals can monitor the effectiveness of their response and may reappraise the situation (e.g., although the argument was heated, my friend and I had an important discussion following it about the importance of our friendship – therefore the outcome was ultimately positive). Importantly, one's appraisals and reappraisal are subject to their mood, health, and motivational state at the time that the stressor presents, which can greatly affect the ways in which they cope to the stressors.

A second model which is widely accepted in the current literature is the diathesis-stress model. In this model, it is proposed that two interacting factors determine an individual's susceptivility to stress and illness: predisposing factors in the person (e.g., genetic vulnerability) and precipitating factors from the environment (e.g., traumatic experiences) (Straub, 2007 p. 97). From this point of view, it is the interaction of one's biological vulnerabilities (e.g., greater reactivity response) and the environment cause stress, though one's perception of the stress stimulus remains an important factor. Due to the agreement among accepted model's that the magnitude of stress felt from an environmental stimulus is a result of the degree to which one perceives a situation to be threatening, these appraisals are often the target of stress-reduction interventions (Straub, 2007, p. 143).

The Importance of Tracking Stress

Common stress-management techniques include exercise, relaxation therapies, and cognitive therapies (Straub, 2007). As mentioned above, our appraisals of environmental factors often leads to our understanding of an event as stressful. As such, these appraisals act as the primary target in cognitive therapies, with the goal of raising awareness of automatic appraisals and working to restructure them so that they become irrelevant or positive, rather than negative (Straub, 2007, p. 148).

Though cognitive therapy and restructuring thoughts of this nature takes many weeks of guided practice to master, the first step toward changes of this nature is to begin to raise awareness about one's reactions and thoughts surrounding stress. For example, if you are seeking cognitive therapy for stress management, you will likely be asked to track your stress levels and triggers over the course of a week or two in order to establish a baseline level of stress, along with some potential triggers that you find particularly stressful. Raising awareness about stressors unique to your life is invaluable for this form of therapy, and more generally can provide valuable insights into one's stress patterns as well as understanding of one's stress level and how this is affected by the environment.

Because this is a common first step for stress management, and because of the benefits one receives from understanding their stress patterns, you will be asked to track your stress over the next week. Specifically, before you leave today I will email you a link to a survey. This survey will be open to you beginning tomorrow morning (e.g., 12:01am) and will remain open until 11:59 7 days from now. In order to begin to understand patterns in your stress throughout the day, you will be asked to log into the survey three times per day and will be asked a series of 21 questions. The first question will always ask you to rate your current stress level on a scale from 1 to 10, with 10 being extremely stressed and 1 being not at all stressed. You will then be given a mood questionnaire which is made up of 20 items. All of the items on this questionnaire provide a series of feelings/emotions. For each one of the emotions, you will be asked to rate how much you are feeling that emotion at the current moment. A final item will be included at the end which will allow you to enter any notes that you wish to leave for yourself (e.g., triggers specific to this time period or stressors present this day).

You will be expected to complete the survey three times per day. There are no specific times during which you must complete the survey, but you must complete all surveys for a given day before midnight of that day (e.g., at 11:59pm or earlier). Additionally, after completing the survey, you will be locked out of the system for two hours. This is primarily to encourage reporting across different times of the day. On that note, it is recommended that you determine three time points across the day that will be feasible based on your schedule, keeping in mind that understanding how stress changes in response to unique triggers may depend partially on the time of day during which the survey is taken. For this reason it is recommended that one survey take place in the morning, one in the afternoon, and one in the evening.

At the end of the week, you will receive an email which includes a graph of your stress and mood levels from each survey throughout the week. In addition, a list of the comments left on the surveys will be returned to you with the dates for each, so that you may match up your comments to the specific stress- and mood-level response to which it corresponds. Also in this email, you will receive a feedback survey which must be completed prior to the disbursement of any extra credit in the SONA system. Of note, you will receive 4 SONA credits as long as you complete the follow-up survey after the duration of the week is completed, though the credit cannot be applied until this is received by the research staff. I will now email you the survey link and we will complete a survey together in order to allow you to ask any questions and so that I may address any concerns you have.

References

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