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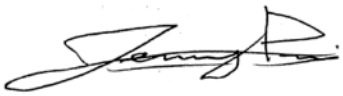
SIGNATURE: 

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The Effect of Sleep Restriction and Daytime Napping on Intra-individual Variability in Cognitive Performance

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Abstract

Healthy sleep is considered essential for peak cognitive performance, especially given that it allows the brain to replenish resources and maintain optimal functioning. In an increasingly work-orientated and competitive society, however, many individuals operate under conditions of sleep restriction (i.e., they sleep less than 6 hours per night), thus incurring a substantial risk of impaired cognitive performance. Daytime napping has been identified as a potentially effective countermeasure to detrimental consequences of sleep restriction. Extant research on this topic is limited, however, because cognitive outcomes are typically measured using relatively crude mean-based statistical analyses (i.e., performance on a single test taken on a single occasion). Measures of intra-individual variability (IIV) in cognitive performance (i.e., performance on a single test taken on multiple occasions separated by minutes, hours, days, or even weeks) may be more sensitive, and are useful because they appear to reflect systematic yet transient changes in behavioural and neural function. Because research investigating the effect of sleep restriction on IIV in performance on reaction time tests (IIV_{RT}) is scarce, we examined this relationship, as well as the possible restorative role of a 10-minute mid-afternoon nap. We recruited healthy university students (N = 105; aged 18-25 years), and collected data on their sleep quality via online survey. Ninety participants subsequently completed an in-person laboratory test session. Each was assigned randomly to either a nap or no-nap condition, after which all completed multiple blocks of computer-based RT tests. Analyses detected no significant differences between the Nap and No-nap groups on all IIV_{RT} outcome measures, and no significant associations between self-reported sleep restriction and IIV_{RT}. To account for this set of negative results, we suggest that IIV_{RT} may lack the required sensitivity to detect subtle changes in cognitive performance in healthy young adults. An alternative explanation may be that cognitive performance in this sample was not susceptible to our experimental manipulation. This may reflect inherent characteristics of the sample (such as resilience or cognitive reserve), or potential limitations of the experimental manipulation and/or the cognitive measures. Nonetheless, this study provides a foundation for research aiming to measure fluctuations in cognitive performance in similar samples, as well as those investigating the malleability of IIV-measured cognitive performance. It also highlights the need for research investigating sleep restriction in healthy young adults.

The Effect of Sleep Restriction and Daytime Napping on Intra-individual Variability in Cognitive Performance

Sleep is a basic physiological need for all living organisms. A large and consistent literature suggests that healthy sleep is essential for optimal cognitive and behavioural performance (Alhola & Polo-Kantola, 2007; Brooks & Lack, 2006; Cipriani, Lucetti, Danti, & Nuti, 2015; Eugene & Masiak, 2015; Lim, Lo, & Chee, 2017). Specifically, a full night's sleep allows individuals to rest from mental and physical activity, allowing the brain and body to replenish resources and, hence, to maintain optimal functioning (Eugene & Masiak, 2015; Gow et al., 2012; Underwood, 2013). Even more specifically, the functional purposes of sleep appear to include regenerating neurons, reducing mental fatigue, aiding in memory consolidation, and promoting efficient cognitive performance (Eugene & Masiak, 2015; Gow et al., 2012; Gujar, Yoo, Hu, & Walker, 2009; Underwood, 2013). However, in an increasingly competitive society, individuals often work and/or study long hours under conditions of sleep restriction (6 or fewer hours of sleep per night). Recent literature suggests that the effects of chronic sleep restriction are equivalent to those experienced following total sleep deprivation (i.e., one extended period of wakefulness; Alameddine, Klerman, & Bianchi, 2014; Eugene & Masiak, 2015).

Numerous studies have demonstrated the direct negative effects of inadequate or poor sleep on cognitive performance (Alhola & Polo-Kantola, 2007; Lo et al., 2016; Mendelsohn & Larrick, 2013). Because performance on any cognitive task has the prerequisite of an ability to sustain attention on that task (Doran, Van Dongen, & Dinges, 2001; Dorrian, Rogers, & Dinges, 2005), the kinds of brief attentional lapses and inattentiveness that typically follow sleep loss are considered the primary drivers of decreased cognitive performance in the wake of sleep restriction or sleep deprivation.

As the day progresses, individuals may feel an increased need to sleep, particularly during the mid-afternoon period (13:00±15:00), as this time corresponds with the peak of daytime sleepiness (Milner & Cote, 2008). Mid-afternoon is often characterized as the time when errors and accidents are most likely to occur, particularly in individuals who are sleep deprived or who have experienced restricted sleep (Tucker, 2003). However, several studies have reported improvements in neurobehavioural and cognitive performance following brief daytime naps (Milner & Cote, 2008). For instance, sleep-inducing build-up of melatonin dissipates after a nap (Lim et al., 2017; Lo et al., 2016). Thus, napping may lead to enhancements in alertness, and in task performance and accuracy, while decreasing

subjective sleepiness and fatigue (Brooks & Lack, 2006; Lim et al., 2017; Louca & Short, 2014). As such, daytime napping has been identified as a potentially effective countermeasure to detrimental consequences of sleep restriction (Alameddine, et al., 2014; Brooks & Lack, 2006; Vgontzas et al., 2007).

Extant research on this topic is limited, however, because cognitive outcomes are typically measured using relatively crude mean-based statistical analyses (i.e., performance on a single test taken on a single occasion). This approach assumes performance or functional stability within individuals or groups. Measures of intra-individual variability (IIV) in cognitive performance (i.e., performance on a single test taken on multiple occasions) may be more sensitive, and are useful because they appear to reflect systematic yet transient changes in behavioural and neural function (Christ, Combrinck, & Thomas, 2017; Jackson, Balota, Duchek, & Head, 2012; MacDonald, Nyberg, & Bäckman, 2006; Mella, de Ribaupierre, Eagleson, & de Ribaupierre, 2013).

Intra-individual variability (IIV) in cognitive functioning is formally defined as the transient within-person variability of an individual's performance across either (a) multiple trials on a single occasion, or (b) multiple testing occasions spanning hours, days, weeks, or even months (Gorus, De Raedt, Lambert, Lemper, & Mets, 2008; Hultsch, MacDonald, & Dixon, 2002; Ram, Gerstorf, Lindenberger, & Smith, 2011). Therefore, these performance fluctuations are distinguishable from enduring changes that result from development or learning, and appear to be a marker of brain health (Bunce et al., 2013; Ram et al., 2011). IIV in performance on reaction time (RT) tests has been established as a useful behavioural marker of underlying neural integrity (Bunce et al., 2013; Dykiert, Der, Starr, & Deary, 2012; Haynes, Bauermeister, & Bunce, 2017). That is to say, the more a person's performance on RT tests varies from one assessment occasion to the next, the more likely it is that that person is experiencing some neuropathological condition (e.g., age-related memory impairment, Alzheimer's disease, or HIV-associated dementia).

Because research investigating the effect of sleep restriction on IIV in performance on reaction time tasks (IIV_{RT}) is scarce, we examined this relationship, as well as the possible restorative role of a 10-minute mid-afternoon nap.

Rationale, Specific Aims, and Questions

In an increasingly work-orientated and competitive society, sleep restriction poses a substantial risk for cognitive performance. The possible positive effects of naps as a countermeasure to sleep deprivation and sleep restriction is thus an important avenue of research (Lim & Dinges, 2008; Naismith et al., 2009). In light of the gap in research

investigating the possible negative effects of sleep restriction on IIV in cognitive performance, and the possible beneficial counter-effects of napping, the present study investigated the following questions:

1) Does chronic sleep restriction impact on cognitive performance, as measured by IIV_{RT}?

2) In participants with and without chronic sleep restriction, will those who experience a mid-afternoon nap subsequently show better cognitive performance, as measured by IIV_{RT}, compared to those not allowed to nap? In other words, does napping serve as an effective countermeasure to the negative effects that restricted sleep has on cognitive performance?

Methods

Design and Setting

We used a cross-sectional, relational design to investigate the association between sleep quality and sleep restriction (as a predictor variable) and cognitive performance (as the outcome variable) in healthy undergraduate students. This design included (1) a screening phase, which we used to check participant eligibility, and (2) a laboratory phase, during which eligible participants completed a series of RT tasks in a one-hour session. Previous research has shown that IIV in cognitive performance may be better captured over short intervals (i.e., by trial-to-trial fluctuations) within one test session (Mella et al., 2013). All study procedures were hosted in research laboratories located within the University of Cape Town's Department of Psychology.

Participants

Sample. We used convenience sampling to recruit undergraduate students between the ages of 18 and 24 years. Specific recruitment routes were via the UCT Department of Psychology's Student Research Participation Programme (SRPP; see Appendix A), posters (see Appendix B), and flyers (see Appendix C). An a priori power analysis, using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007), following data presented in an IIV study by Garrett, MacDonald, and Craik (2012), and then setting parameters of Cohen's $f = .35$, $\alpha = .05$, and desired power = .80, suggested that a sample size of 67 participants would be adequate for the laboratory phase of our design.

Eligibility criteria. Individuals were excluded from participation if they reported (a) any current neurological, medical, sleep, or psychiatric disorder; (b) the use of psychoactive medications; (c) previous head injury resulting in the loss of consciousness; or (d) non-corrected visual or physical impairment that might impact on their ability to complete RT

tasks. Participants who reported being severely depressed (on the Beck Depression Inventory-II) or anxious (on the State-Trait Anxiety Inventory-Trait Form) were excluded from the laboratory phase of the study. All of these factors have been identified as potential confounding variables in past research investigating the effects of sleep loss and napping on cognitive performance, as well as that examining IIV in cognitive performance (Dai et al., 2015; Hetherington, Stuss, & Finlayson, 1996; Kaiser et al., 2008; Vaurio, Simmonds, & Mostofsky, 2009).

Figure 1 shows the flow of participants through the various study phases.

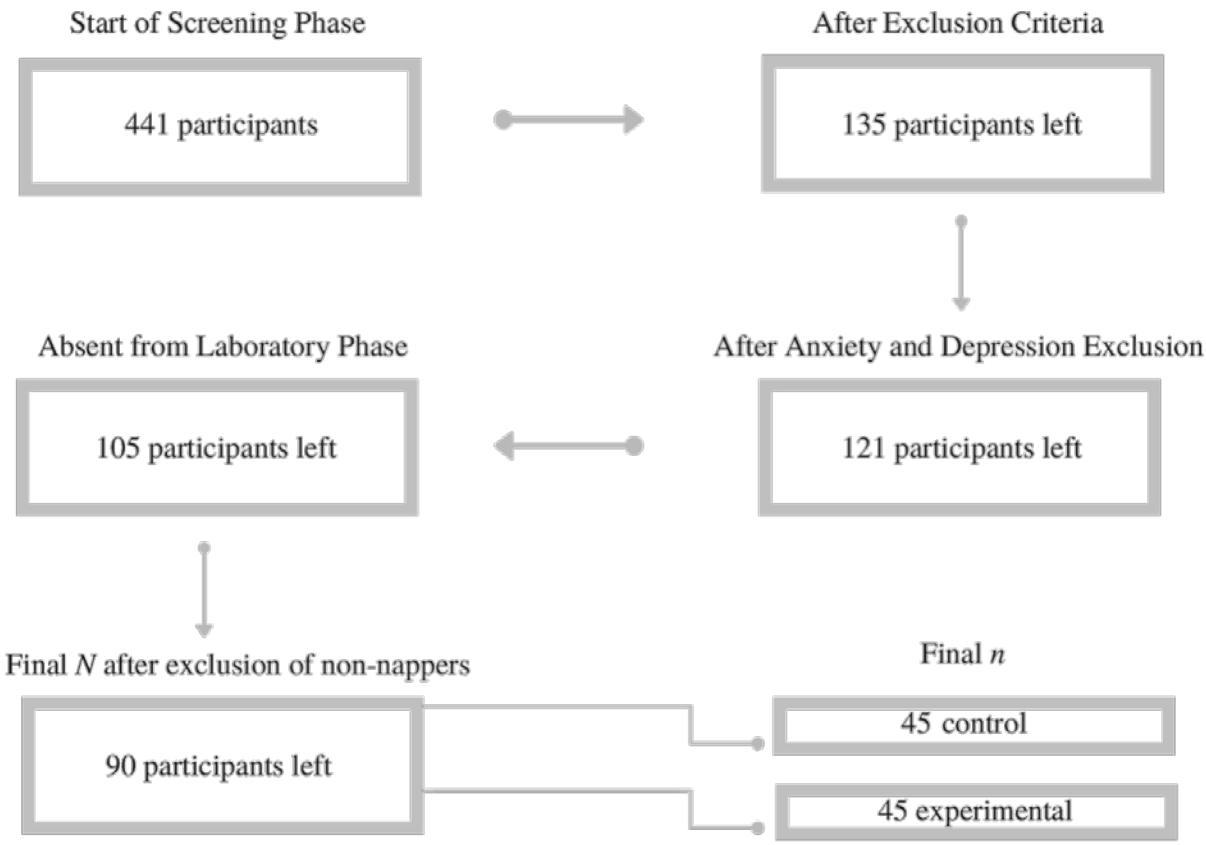

Figure 1. Participant attrition through the study protocol (N = 441 to N = 90).

Measures

Screening phase. All the following instruments were administered online, using the SurveyMonkey platform (www.surveymonkey.com).

Sociodemographic questionnaire. This brief self-report instrument (see Appendix D) gathered information regarding participant age and sex. Previous studies suggest these variables might influence the effects of sleep restriction on cognitive performance (Dillon et al., 2015; Dykiert et al., 2012).

Health index questionnaire. This brief self-report questionnaire was used to confirm that participants were physically and mentally healthy, and that their ability to perform the computer-based testing would not be impaired by any physical disability (see Appendix E).

Pittsburgh Sleep Quality Inventory (PSQI). This 19-item self-report questionnaire assesses sleep quality and disturbances over the past month, with items spanning seven different domains (sleep duration, disturbance, latency, efficiency, quality, day dysfunction due to sleepiness, and the need for medication to sleep; see Appendix F; Buysse et al., 2008). Each domain generates a separate component score. These component scores can be summed to yield a single global score, with a possible range of 0-21 (lower scores indicate better sleep). A global score of ≥ 5 is suggested as cut-off to identify clinically relevant poor sleep quality (Buysse et al., 2008; Dai et al., 2015). To measure sleep restriction, we used only question 4 of the instrument, which asked participants: "During the past month, how many hours of actual sleep did you get at night? This may be different than the number of hours you spent in bed" (Buysse et al., 2008). We coded scores of 2 or 3 (≤ 6 hours of sleep) as indicating restricted sleep, and scores of 0 or 1 (> 6 hours of sleep) as indicating non-restricted sleep.

The PSQI has good psychometric properties, with moderate-to-high internal consistency reliability (α = .78-.80), high test-retest reliability, moderate convergent validity, and good divergent validity (Buysse et al., 2008; Dietch et al., 2015; Manzar et al., 2015). Furthermore, the instrument has been used successfully in studies of tertiary populations and across cultural contexts, including South Africa (Beaudreau et al., 2012; Dietch et al., 2015; Henry, Wolf, Ross, & Thomas, 2015; Lipinska & Thomas, 2017; Manzar et al., 2015).

Beck Depression Inventory-II (BDI-II). This 21-item self-report instrument measures current depressive symptomatology (see Appendix G; Beck, Steer, & Brown, 1996). Respondents are asked to choose, from a list of four options, the statement that best describes their mood over the past 2 weeks. In the current study, individuals scoring ≥ 29 (indicating severe depression) were excluded from participation.

The BDI-II has excellent internal consistency and test-retest reliability (α = .91 and .93, respectively), as well as adequate factorial and content validity (Beck et al., 1996; Dozois, Dobson, & Ahnberg, 1998). Furthermore, South African studies suggest the BDI-II has high internal consistency reliability (α = .90) and construct validity in local samples (Henry et al., 2015; Kagee, Nel, & Saal, 2014; Somhlaba & Wait, 2009).

State-Trait Anxiety Inventory-Trait Form (STAI-Trait). This self-report questionnaire enquires about the presence of general anxiety symptoms in everyday situations

(see Appendix H; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Respondents are asked to use a 4-point scale to answer 20 separate statements. In the current study, individuals scoring ≥ 59 (indicating severe anxiety) were excluded from participation.

The STAI-Trait has been utilised in several undergraduate populations with acceptable levels of internal consistency (α = .92), test-retest reliability (r = .69 to .89), and construct and concurrent validity (Spielberger & Vagg, 1984). Furthermore, Basson et al. (2010) found that the STAI-Trait was a reliable measure when used in South Africa.

Laboratory phase. We measured IIV_{RT} using the tasks described below.

Simple Reaction Time (SRT) and Choice Reaction Time (CRT). Generally speaking, RT is defined as the time that elapses between stimulus presentation and participant response initiation, and is measured in milliseconds (ms). The computer-based tests used to measure RT in this study were based on the Deary-Liewald Reaction Time Task (Deary, Liewald, & Nissan, 2011; http://www.ccace.ed.ac.uk/research/software-resources/software). All tasks were presented on standard 15-inch computer monitors attached to hard drives running Windows 10 operating systems. Standardisation of this aspect of the protocol was important so as to prevent possible confounds emerging from differing refresh rates across computer monitors (Demirci, 1996).

Both SRT and CRT tasks started with 10 practice trials, after which the trials that contributed to data analysis began. If the participant felt unsure of task instructions or requirements after the set of practice trials, s/he was asked to redo that set of trials until feeling comfortable.

The SRT task required participants to respond, as quickly and accurately as possible, to a single stimulus (an “x” in a box) by pressing the space bar every time the “x” flashed on the computer screen (inter-stimulus interval from 1000ms to 3000ms). After the practice trials, the 25 trials that contributed to data analysis began.

The CRT task presented participants with a single stimulus (an “x”). However, this time there were 4 boxes on the screen and the “x” could flash in any one of the boxes (inter-stimulus interval from 1000ms to 3000ms). Participants were required to, as quickly and accurately as they could, press the key (“z”, “x”, “.” , or “,”) that corresponded to the position of the stimulus presented. For example, participants would press “z” if the “x” flashed in the last block to the left and “,” if the “x” flashed in the last block to the right. After the practice trials, the 50 trials that contributed to data analysis began. Previous research confirms that 20-60 trials are sufficiently reliable as IIV_{RT} measures (Bielak, Hultsch, Strauss, MacDonald, & Hunter, 2010; Haynes et al., 2017; Yao, Stawski, Hultsch, & MacDonald, 2016).

The Deary-Liewald Reaction Time Task has good internal consistency (SRT α = .94, CRT α = .97) and validity (Deary et al., 2011). Additionally, cognitive performance has been measured using SRT and CRT tasks in a multitude of previously published studies (see, e.g., Mair & Starr, 2011; Vaughan et al., 2014; Jones-Odeh, Yonova-Doing, Bloch, Williams, Steves, & Hammond, 2016).

Procedure

Screening phase. Participants completed all materials online. After reading an informed consent document and indicating their understanding of the contents thereof, they completed (in this order): the sociodemographic questionnaire, health index questionnaire, PSQI, BDI-II, and STAI-Trait. Total completion time was approximately 15 min.
Those who did not meet the abovementioned eligibility criteria were excused from the further participation. In addition, the 14 participants excused due to high BDI-II or STAI-Trait scores were advised to seek counselling (if desired) and were given contact details for the UCT Student Wellness Centre.

Participants eligible for the laboratory phase of the study were informed by email. We sent them an invitation to join the study and to sign-up for a suitable time slot.

Laboratory phase. We sent participants a reminder email approximately 24 hours before their allocated test session. In the email, we asked them to refrain from drinking carbonated or caffeinated drinks at least 2 hours prior to the session, as these substances have been identified as effective countermeasures to sleep restriction. Specifically, they combat fatigue by increasing alertness, RT, vigilance, and performance (Alameddine et al., 2014; Kamimori, McLellan, Tate, Voss, Niro, & Lieberman, 2015; McIntire, McKinley, Goodyear, & Nelson, 2014). All laboratory test sessions were held between 13h00 and 15h00.

Upon arrival at the laboratory, we gave the participant a consent form (see Appendix J) to read and sign. We explicitly noted and explained the contents, which included assertions regarding confidentiality and the right to terminate participation at any point with no penalty.

Each participant was randomly assigned to either the experimental (Nap) or control (No-nap) group. Those assigned to the Nap group were exposed to the manipulation described below. At the conclusion of the manipulation, they were oriented to the requirements of the cognitive tests (specifically, they were told that speed and accuracy of performance are equally important on all tasks) and were administered the blocks of practice trials. Testing comprised two blocks of each of the SRT (25 trials per block) and the CRT (50 trials per block) tasks.

Those assigned to the No-Nap group proceeded directly from the consent procedures to the cognitive testing procedures.

Upon completion of the study protocols, which took approximately 30 min, participants were thanked for their time and effort, and received a verbal and written debriefing (see Appendix K). Thereafter, they were dismissed. Regarding compensation, psychology students who completed the screening phase only received 1 SRPP point, whereas those who completed both the screening and laboratory phases received 3 SRPP points. Students from outside of the Department of Psychology were entered into a prize-giving draw.

Experimental manipulation: Nap group. Those assigned to this group were taken to one of the bedrooms (a quiet, dark room featuring soothing wall colours and a murphy bed) in the ACSENT / UCT Sleep Sciences sleep laboratory. Once inside the room, they were asked to take a nap on the bed. They were not told the nap duration to avoid potentially counterproductive feelings of pressure to fall asleep. We then left them to settle on the bed, and monitored them via a one-way mirror between the bedroom and the sleep laboratory control room.

After the participant had settled (we allowed 5 minutes) and appeared to be asleep, we allowed a nap period of 10 minutes. We used a 10-min nap duration to minimize the risk of decreased cognitive performance due to sleep inertia (described as a feeling of confusion and grogginess that often follows slow-wave sleep; Brooks & Lack, 2006; Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010; Groeger, Lo, Burns, & Dijk, 2011). Additionally, 10-min naps are suitable when testing performance speed and accuracy (as measured by IIV_{RT}); paradigms featuring longer naps are used more frequently in studies examining sleep-dependent memory consolidation (Brooks & Lack, 2006; Fogel, Smith, & Cote, 2007).

At the end of the 10-min nap period, we woke the participant and administered a brief questionnaire enquiring about the estimated duration, latency, and depth of sleep (see Appendix I).

Data Management and Statistical Analyses

We used SPSS (version 24) to complete all data preparation and statistical analytic procedures, and set α at .05 for all decisions regarding statistical significance. We began by filtering the RT data and then extracting from those filtered datasets intraindividual standard deviations (*iSD*) needed to run inferential statistics.

RT tasks: Filtering data. First, we excluded from further consideration RT scores collected from participants who did not fall asleep within the allocated time slot (n = 15). We

then prepared the remaining data by removing any outliers (i.e., unusually fast or slow responses), as these scores may reflect spurious performance (e.g., temporary distractions, interruptions, and/or guesses). Using an approach previously adopted within several IIV studies (see Dixon et al., 2004; Garrett et al., 2012; Hultsch, Strauss, Hunter, & MacDonald, 2008), we defined outliers as those scores below 150ms or above 3 *SD* of the group RT mean for each block of testing. To maintain a complete dataset, we imputed the missing data using a regression-based multiple imputation method, which based missing-value estimates on the relationships among responses across all trials (Lachaud & Renaud, 2011). This method of filtering data offers conservative estimates of performance variability (Hultsch et al., 2002).

Extracting intraindividual variability outcomes. Although several indices of IIV exist, we chose to employ *iSD* as it filters out typical group differences and systematic effects (e.g., practice effects and fatigue) associated with mean RT (Garrett et al., 2012; Hultsch et al., 2008). Before computing *iSD*s, we removed any factors that may influence mean RT performance. To determine which factors significantly influenced RT performance, and to thus extract *iSD*s, we ran a random intercept model on the sample data for each of the SRT and CRT variables, and then added two sets of main effects. The first set (featuring test order, blocks, and session – the average of blocks 1 and 2) evaluated the impact of time-on-task effects, and the second (featuring group status, sex, age, PSQI total score, and sleep restriction scores) evaluated the impact of group effects.

Inferential statistical analyses. The first part of our analysis involved analyzing between-group differences in sociodemographic (sex and age) and sleep-related (PSQI total score, sleep restriction, and group assignment) variables. Independent-samples *t*-tests assessed differences relating to continuous variables (age and PSQI total score), and chi-squared tests of contingency assessed differences relating to the categorical variable (sex and sleep restriction). We used effect size estimates of eta squared (η^2) for one-way ANOVA and phi (ϕ) for chi-squared tests.

The second part of our analysis examined bivariate associations (using Pearson's *r* correlation coefficient) between PSQI total score and each cognitive performance outcome variable (*iSD*s for SRT and CRT).

The final part of the analysis involved a series of six separate univariate general linear models (GLMs), each testing whether group assignment and sleep restriction, either independently or in interaction, accounted for a significant proportion of the variance in *iSD* scores. The outcome variables were SRT *iSD*s for Block 1, Block 2, and the complete session,

and CRT *iSD*s for block 1, block 2, and the complete session. As an initial modelling step for each GLM, we entered age, sex, PSQI total score, PSQI sleep restriction score, group assignment, and interactions between those variables as predictors. We then removed non-contributing variables, starting with the most complex (e.g., five-way interactions before four-way interactions), and worked iteratively toward the best-fitting model.

Results

Sample Characteristics

As Table 1 shows, analyses detected no significant differences with regards to age, sex distribution, and PSQI sleep restriction score across three groups of participants (those in Nap group, those in the No-Nap group, and those who completed the screening survey and were study-eligible but decided not to participate in the laboratory session). One-way ANOVA did, however, detect a significant between-group difference in terms of PSQI total score. Post-hoc comparisons, using Tukey's honest significant difference (HSD) test, suggested that participants in the No-nap group had significantly higher PSQI scores than those in the Nap group (i.e., they reported relatively poorer sleep quality in the past month), $p = .031$. There were no other significant pairwise differences in that regard, however, ps > .325.

Table 1
Descriptive Statistics and Between-group Differences: Experimental groups and excluded participants (N = 106)

	Group						
	No-nap	Nap	Excluded				
Variable	(*n* =45)	(*n* = 45)	(*n* = 16)	*df*	F / χ^2	*p*	ESE
Age (years)	19.98 (1.55)	20.47 (1.29)	19.94 (1.44)	2, 103	1.60	.208	.030
Sex (M:F)	9:36	11:34	3:13	89	.358	.836	.058
PSQI							
Total score	5.42 (2.58)	4.11 (2.22)	5.13 (2.50)	2, 103	3.45	.035*	.063
Sleep restriction	.820 (.984)	.530 (.757)	.630 (.806)	6	4.61	.595	.208

Note. For the variables *Age* and *PSQI total score*, the second, third, and fourth columns present means with standard deviations in parentheses. For the variables *Sex* and *PSQI sleep restriction score*, those columns present raw counts. PSQI = Pittsburgh Sleep Quality Inventory; ESE = effect size estimate (in this case, η^2 for one-way ANOVA and ϕ for chi-square tests). Data for the PSQI sleep restriction variable are gathered from Question 4 of that questionnaire.
*$p < .05$.

Extraction of *iSD*s

Using the extraction approach described by Hultsch et al. (2008), we captured the residuals (*z*-scores) from the random intercept model and converted them to *t*-scores (i.e., [*z*-score*10] + 50). Lastly, we computed the within-person *SD*s for each block of *t*-scores to get each participants *iSD*s.

Hypothesis Testing

As Table 2 shows, a set of independent-sample *t*-tests detected no significant between-group differences with regard to either intraindividual variability in performance or mean performance across trials on both the SRT and CRT tasks.

Table 2
Descriptive Statistics and Between-group Differences: Outcome variables (N = 90)

		Group					
		No-nap	Nap	*df*	*t*	*p*	Cohen's *d*
iSD							
	SRT	6.03 (1.37)	6.31 (1.46)	88	-.924	.358	.198
	CRT	9.50 (1.59)	9.97 (1.95)	88	-1.26	.213	.264
Mean							
	SRT	321.50	322.69 (24.27)	88	-.231	.818	.048
	CRT	484.31	490.57 (50.52)	88	-.591	.566	.125

Note. Data presented are means, with standard deviations in parentheses. *iSD* = intraindividual standard deviation; SRT = simple reaction time; CRT = choice reaction time. All *p*-values are two-tailed.

As Table 3 shows, correlational analyses detected no significant correlations between performance on the RT tasks and sleep quality / sleep restriction.

Table 3
Bivariate Correlations: Predictor and outcome variables (N = 90)

		Cognitive Performance Outcome Variables					
		SRT			CRT		
Predictor Variables		Block 1	Block 2	Session	Block 1	Block 2	Session
PSQI							
Total score	*r*	-.098	.041	-.003	-.042	.022	-.010
	p	.179	.352	.487	.348	.420	.462
Sleep restriction	T_b	-.038	-.051	-.070	.044	.083	.061
	p	.322	.269	.198	.298	.156	.230

Note. Data presented are Pearson's *r* correlation coefficients and associated *p* values. PSQI = Pittsburgh Sleep Quality Inventory; SRT = simple reaction time; CRT = choice reaction time. Data for the PSQI sleep restriction variable are gathered from Question 4 of that questionnaire. *r* = Pearson's r. T_b = Kendall's Tau-b. All *p*-values are one-tailed.

None of the three GLMs seeking to predict IIV_{RT} outcomes for the SRT task (i.e., for *iSD*s on Block 1, Block 2, and across the entire session) detected statistical significance, even when the model was reduced to a single main-effect predictor (i.e., age, sex, and sex respectively), *ps* > .111.

Tables 4, 5, and 6 present the final (best-fitting) models for IIV_{RT} outcomes on the CRT task (i.e., for *iSD*s on Block 1, Block 2, and across the entire session). As the Tables show, PSQI total score, PSQI sleep restriction, and group status (Nap versus No-nap) were all non-significant predictors (singly or interaction) of the outcome. The only significant predictor, in each case, was age: As age increased, so did the variability of performance on the CRT task (see Figure 2). However, there is a slight dip in variability of performance after age 23. The strength of that predictor was quite poor, however, in that it accounted for less than 10% of the variance in the outcome in each case.

Table 4
Univariate General Linear Model: Predicting IIV_{RT} on CRT Block 1 (N = 90)

	Type III SS	*df*	MS	*F*	*p*	R^2
Corrected model	29.53	1	29.53	8.45	.005*	.088
Age	29.53	1	29.53	8.45	.005*	.088

Note. SS = sums of squares; MS = mean square. For the overall model, ΔR^2 = .011.
*p < .05.

Table 5
Univariate General Linear Model: Predicting IIV_{RT} on CRT Block 2 (N = 90)

	Type III SS	*df*	MS	*F*	*p*	R^2
Corrected model	20.83	1	29.53	20.83	.027*	.054
Age	20.83	1	29.53	20.83	.027*	.054

Note. SS = sums of squares; MS = mean square. For the overall model, $\Delta R^2 = .01$.
*$p < .05$.

Table 6
Univariate General Linear Model: Predicting IIV_{RT} for CRT across the session (N = 90)

	Type III SS	*df*	MS	*F*	*p*	R^2
Corrected model	24.99	1	24.99	8.49	.005*	.088
Age	24.99	1	24.99	8.49	.005*	.088

Note. SS = sums of squares; MS = mean square. For the overall model, $\Delta R^2 = .01$
*$p < .05$.

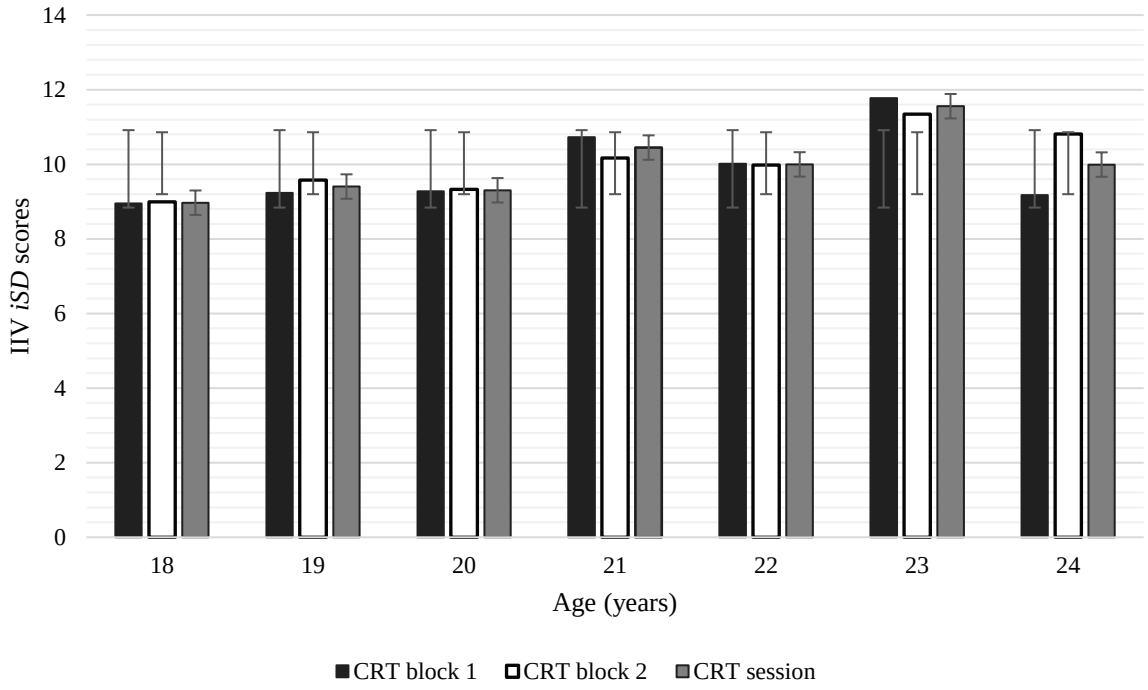

Figure 2. The relationship between age and *iSD* (intraindividual standard deviation) scores on cognitive performance as measured by IIV_{RT}.

Discussion

This study addressed two main questions. The first was whether chronic sleep restriction impacts on cognitive performance, as measured by intra-individual variability on reaction time tasks (IIV_{RT}). We pursued this question by inspecting correlations between total score on the Pittsburgh Sleep Quality Index and intraindividual standard deviations on the reaction time tasks, as well as between PSQI sleep restriction score and *iSD*s, on the SRT and CRT tasks. The observed associations correlations were weak. Nonetheless, we use general

linear modeling to further investigate whether sleep quality/sleep restriction served as a predictor of cognitive performance. Despite considerable evidence to the contrary (e.g., Gow et al., 2012; Van Dongen, Maislin, Mullington, & Dinges, 2003), our analyses did not detect any significant associations between sleep quality/sleep restriction, as measured by overall PSQI score and/or sleep duration (Q4 of the PSQI), and IIV_{RT}.

The second question we addressed was whether a brief mid-afternoon nap might serve as an effective countermeasure to the negative effects that restricted sleep has on cognitive performance. Our GLMs detected no association between group assignment and IIV_{RT}, or between PSQI total score or sleep restriction score, and IIV_{RT}. This set of findings suggests that cognitive performance following a 10-minute nap did not improve, regardless of prior sleep quality or duration.

Numerous studies have consistently reported a main effect of age on IIV in SRT and CRT tasks, such that IIV scores increase with age (Dykiert et al., 2012; Garrett et al., 2012; Gorus et al., 2008; Jackson et al., 2012). In an attempt to control for such age effects, we restricted our sample to participants between the ages of 18 and 25 years. However, the best fitting GLM suggests that age, was in fact, the only significant predictor of IIV_{CRT}. As shown in Figure 2 above, IIV in performance increased in with age from 18 to 23 years, but dropped again at age 24. Although the initial positive relationship between age and IIV is in line with previous findings, the subsequent drop in IIV at age 24 does not reflect the expected age-related pattern in IIV performance (e.g. Jackson et al., 2012; MacDonald et al., 2006). Therefore, we suggest that the currently observed main effect of age is a spurious finding due to extraneous factors unrelated to current study.

Given the general tenor of extant research on cognitive performance following chronic sleep restriction (e.g., Alhola & Polo-Kantola, 2007; Eugene & Masiak, 2015; Van Dongen et al., 2003), we expected to see poorer cognitive performance (as indexed by higher IIV_{RT} scores) in individuals who reported poor quality sleep (PSQI </=5) or restricted sleep (6 or less hours per night). We do not however, take the non-significant results obtained in this study as conclusive evidence that sleep restriction does not affect cognitive performance, but rather suggest that these somewhat unexpected findings may be due to inherent characteristics of our sample (young, healthy university students), and/or to limitations of the measures used here. We also expected, again given previously published results (e.g., Alameddin et al., 2014; Brooks & Lack, 2006; Milner & Cote, 2008; Vgontzas et al., 2007), to see better cognitive performance (as indexed by lower IIV_{RT} scores) in participants assigned to the Nap condition.

Of particular interest here is that our analyses did not detect any significant differences in cognitive performance regardless of an individual's sleep quality and/or duration, or the condition to which they were assigned. Post-hoc power analysis of the sample size obtained in this study (N = 90), using an effect size of η^2 = .35, in accordance with previous IIV_{RT} research (Garrett et al., 2012), showed that our study was sufficiently powered (1-β = .90) to detect these differences. The discussion that follows addresses the implications and possible explanations for the non-significant results we report.

Despite the relative lack of research examining restricted sleep as opposed to total sleep deprivation, the studies that do exist have consistently found that chronic sleep restriction is detrimental to cognitive performance (Alhola & Polo-Kantola, 2007; Eugene & Masiak, 2015; Van Dongen et al., 2003). The cognitive performance deficits experienced as a result of chronic sleep restriction have been equated with those experienced after two nights of total sleep deprivation. These deficits encompass poor performance on tests of memory, attention, judgement, decision-making and a host of other higher-order executive functions. As discussed below, various cognitive and neural level mechanisms have proven useful in accounting for these deficits.

Any form of sleep loss (i.e., either chronic sleep restriction or total sleep deprivation) is associated with chronic and unreconstructed neural damage, possibly as a result of the build-up of toxic metabolites such as amyloid beta (Nedergaard, 2013; Xie et al., 2013). During sleep, the glymphatic system transports waste in cerebrospinal fluid (CSF) in the para-arterial space (Iliff et al., 2013; Nedergaard, 2013; Underwood, 2013). A process of convective exchange takes place whereby CSF inter-changes with interstitial fluid (ISF) to remove toxic metabolites such as amyloid beta (Eugene & Masiak, 2015; (Jessen, Munk, Lundgaard, & Nedergaard, 2015). Numerous studies have shown that this metabolite accumulates during wakefulness and may form plaques, of the kind found commonly in Alzheimer's disease, on the outside of cells (Eugene & Masiak, 2015; Underwood, 2013). Within this theoretical framework, one prediction is that lack of sufficient sleep will result in build-up of toxic metabolites and thus, due to chronic and unreconstructed neural damage, impair cognitive functioning relatively subtly in the short-term and relatively severely in the long-term (Nedergaard, 2013; Underwood, 2013; Xie et al., 2013).

A separate strand in the literature suggests, on the basis of functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) data, that structural and functional changes in the brain, including lesions in frontal grey matter and deficits in white-

matter integrity (WMI), are also associated with increased IIV (Bunce et al., 2013; Gow et al., 2012; Jackson et al., 2012). According to Mella et al. (2013), the relationship between increased IIV and decreased WMI might be attributable to the breakdown of myelin and disconnectivity between associative pathways, which may result in neural noise and less effective communication between disparate brain areas (see also MacDonald et al., 2006; Phillips, Rogers, Haworth, Bayer, & Tales, 2013). Because our sample comprises only healthy young adults, the long-term structural and functional changes associated with WMI, as well as the unreconstructed neural damage associated with a build-up of toxic metabolites, are not likely to play a role in cognitive performance fluctuations in our sample.

Lifespan studies suggest that a U-shaped pattern captures the relationship between age and IIV in cognitive performance (Jackson et al., 2012; MacDonald et al., 2006). Put simply, this pattern indicates that cognitive decline in old age is positively associated with increased IIV (Jackson et al., 2012; Mella et al., 2013; Phillips et al., 2013). Age is particularly relevant to our study as it not only affects cognitive performance, but also influences an individual's ability to cope with sleep loss (Alhola & Polo-Kantola, 2007). Taken together, these age-related effects may account for the non-significant results in IIV_{RT} associated with sleep loss in our study.

IIV_{RT} has been reliably and extensively established as a behavioural marker of underlying neuropathology such as those related to the endogenous influence of WMI, age-related degeneration, and traumatic brain injury (TBI), among others (Bunce et al., 2013; Mella et al., 2013; Haynes et al., 2017). However, surprisingly little research has been conducted to explore the influence of exogenous factors on IIV_{RT} (Garrett et al., 2012). As such, it is still largely unknown if IIV_{RT} can be experimentally manipulated. Garrett and colleagues (2012) found that IIV_{RT} could be significantly modulated by means of motivational feedback in older adults, but found no significant effects on the performance of young male and female adults. Consistent with these findings, our research suggests that IIV_{RT} in young adults is not susceptible to influence by the nap-paradigm condition used in this study. This may in turn suggest that IIV_{RT} is reflective of more stable, within-person markers of nervous system integrity. Although IIV is a more sensitive and accurate indicator of cognitive performance than measures of central tendency, SRT and CRT tests may be too simple to pick up subtle and transient IIV fluctuations (as a result of exogenous influence or experimental manipulation) in young adults who are likely performing at the lifetime peak of RT speed and accuracy (Garrett et al., 2012; MacDonald et al., 2006). Therefore, we suggest

that the SRT and CRT tests used may have been below the cognitive threshold of useful tests required to elucidate variability in performance associated with sleep restriction or napping.

We further propose that the current non-significant results may be due to cognitive reserve given that our sample comprised healthy, young, well-educated individuals. The concept of cognitive reserve was originally proposed and developed as a means to account for often-observed, and remarkable, individual differences in the association between degree of brain pathology and clinical manifestations thereof (Stern, 2009). Accordingly, life experiences marked by high levels educational exposure, occupational attainment, and many different leisure-time activities (all of which increase one's cognitive reserve), are associated with decreased risk of developing neurological deficits. Hence, the concept of cognitive reserve suggests that some individuals cope better with brain damage or pathology than others. Stern (2009) suggests that the concept can be extended to account for performance variations in any situation where brain function is disrupted. In the context of this study, we suggest that the cognitive deficits resulting from restricted sleep may be mediated by the high levels of cognitive reserve inherent in our sample, given that all individuals are highly educated university students. Those individuals who self-identified as experiencing chronic sleep restriction, as well as those not exposed to the nap condition, may have employed compensatory processes during cognitive performance testing, thus effectively minimizing between-group differences in performance on the RT tests.

An alternative or additional explanation for the non-significant results obtained in this study may relate to the nap condition itself. Both nap timing and nap duration are important factors to consider (Brooks & Lack, 2006). A mid-afternoon nap is considered ideal (even for sleep-satiated individuals) because the timing corresponds with the circadian dip in alertness when one's sleep propensity is highest (Brooks & Lack, 2006; Milner & Cote, 2008). A nap duration of 10 minutes is recommended as studies have shown immediate improvements in cognitive performance without the risk of experiencing sleep inertia, which is common after longer nap periods (Ficca et al., 2010; Milner & Cote, 2008; Van Dongen et al., 2003). Brooks and Lack (2006) further tested the hypothesis that sleep onset alone may be sufficient for restoration, but found this was not the case, concluding that a 5-min nap (or even less) is equivalent to not napping at all. Electroencephalography (EEG) recordings taken during and after their nap manipulation revealed that entry into Stage 2 sleep resulted in immediate objective improvements in alertness, whereas entry into Stage 1 sleep (typical in naps of 5-mins or less) resulted in no objective benefit, and entry into Stage 3 sleep (common in naps of 20 minutes or more) showed its benefits only after a delay due to the effects of sleep

inertia (Brooks & Lack, 2006). Because our study did not involve EEG monitoring, it is quite possible that participants did not enter into Stage 2 sleep within the allocated 10-minute nap period, and thus, did not benefit from the restorative effects of napping.

Limitations and recommendations for future research

The Discussion itself highlights a few notable limitations of this study. The first of these is the reliance on researcher observation and participant self-report regarding nap duration. Based on the non-significant results obtained in this study, we recommend the use of biomarkers such as EEG recordings in future research employing nap paradigms. This would allow for more accurate monitoring of depth and duration of sleep, thus ensuring participants enter into Stage 2 sleep, and that they sleep for the full 10-minute nap period. More accurate measures of long-term sleep patterns could be elicited by means of a sleep diary as opposed to relying on retrospective indices of subjective experience as utilized in this study.

Simple and choice reaction time tests have been used successfully as measures of cognitive performance in a number of studies. However, given the non-significant results in this and other studies using sample populations with similar characteristics (see, e.g. Dykiert et al., 2012; Garrett et al., 2012), it may be surmised that more complex tasks might have elicited more accurate indices of cognitive performance. Additionally, RT tasks only measure performance speed and accuracy, both of which are largely dependent on attention and effort. Given the unexpected significant age effect in this study, it is possible that participant effort influenced performance validity on RT tests. We suggest that younger participants (18/19 years – typically in their first year of study) may have exerted more effort throughout testing, thereby accounting for the significantly higher IIV scores for older participants on the CRT trials. To minimize or at least account for this confound in future RT studies, we recommend the use of an embedded measure of effort to assess performance validity (DeRight & Jorgensen, 2015).

There may be alternate and more complex ways to analyze these data. For example, in addition to the standard deviation, alternate indicators of IIV can be calculated using the coefficient of variation; or ex-Gaussian distribution parameters (Epstein et al., 2011; Van Geert & van Dijk, 2002; Wang, Hamaker, & Bergeman, 2012). The analyses used in this study were selected based on their successful use in extant IIVRT research (Hultsch et al., 2008; Garrett et al., 2012). However, we cannot rule out the possibility that alternate methods of analyses may have returned different results, as it was beyond the scope of the current study to employ these methods.

There may be alternate and complex ways to re-analyze these data. For example, different indicators of IIV can be calculated using standard deviation; coefficient of variation; or ex-Gaussian distribution parameters (Epstein et al., 2011; Van Geert & van Dijk, 2002; Wang, Hamaker, & Bergeman, 2012). The analyses used in this study were selected based on their successful use in extant IIV_{RT} research. However, we cannot rule out the possibility that alternate methods of analyses may have returned different result, as it was beyond the scope of the current study to employ these methods.

Furthermore, a wider, more complex range of tasks, capable of assessing a variety of cognitive domains, such as memory, executive function, divergent thinking, and creativity may have extracted more variable performance through increased cognitive load. In short, we recommend the use of multiple and varied tests which assess different levels and domains of cognitive functioning in order to obtain more accurate indices of IIV in young, healthy, well-educated populations.

Summary and Conclusion

In an increasingly work-orientated and competitive society, sleep restriction poses a substantial risk for cognitive performance. Investigations of the negative effects of sleep restriction on cognitive performance, and the possible positive effects of naps as a countermeasure, is thus an important yet under-researched avenue of study. Furthermore, research using IIV_{RT} to investigate this relationship is scarce. Such investigation is important because of the potential for IIV_{RT} to serve as a behavioural marker of neurological integrity. This study makes a valuable contribution to the sparse extant research on the topic.

To our knowledge, this is the first study to investigate the role of sleep restriction and napping as it relates to cognitive performance, measured by IIV_{RT}, in healthy young adults. The non-significant results obtained in this study serve to inform future research investigating similar associations and/or populations. More specifically, our findings suggest that studies employing nap paradigms as an experimental manipulation should use biometric sleep measures to ensure participants enter into Stage 2 sleep. Additionally, we submit that measures of cognitive performance (indexed by IIV) in healthy young adults, should draw on a broader scope of more complex and demanding cognitive tests, along with an embedded measure of effort, in order to generate more accurate measures of within-person performance variability.

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Appendix A

SRPP Announcement to Undergraduate Students for Recruitment

Subject Get your SRPP points for the semester from this study!

Organiser Angela Harwood and Jenny Pan

Hi Everyone,

We are honours students currently running a research study through the Department of Psychology. This project is a first of its kind and it attempts to see if there is a relationship between cognition and sleep.

In order to participate in this study, you need to:

1. Be an undergraduate student at UCT

2. Be between the ages of 18-25 years

3. Have NO history of:

- **psychological or psychiatric illness (e.g., depression, anxiety, eating disorder) etc.**
- **chronic medical illness (e.g., severe asthma, tuberculosis)**
- **sleep disorder (e.g., sleep apnea, insomnia)**
- **neurological illness (e.g., multiple sclerosis, epilepsy, stroke)**

If you meet the above criteria and you decide to participate in this study, you will be asked to complete several online questionnaires that will gather general information about your health, mood, and sleep. The questionnaires can be found find at: [https://www.surveymonkey.com/r/F9Q9GGN]. These questionnaires should take about 30 minutes to complete. If you are eligible, you will receive **1 SRPP point** for completing them.

Thereafter, if you ARE eligible for the study, you will be emailed and asked to schedule a time for the test session. The test session will be held in the ACSENT and/or GCS lab in the Psychology Department and will involve taking a brief nap (or not – depending on group assignment) and completing computerised cognitive tests focusing on accuracy and speed in

reaction time. This should take about 45-60 minutes. You will receive a further **2 SRPP points** after this test session.
Alternatively, if you participate in our study and you could stand a chance to win 1 of 3 vouchers for Cavendish Square (1 x R1000, 1 x R500, 1 x R250).
NOTE: you must select to **either** receive SRPP point **OR** enter into the draw.

If you have any further questions, please don't hesitate to email us:
iivandsleepstudy@gmail.com.
Thanks!
Kind regards,
Angela Harwood and Jenny Pan
Psychology Honours Students

(*Please not*e: It is generally accepted that the decision to include or exclude individuals from participating in a study depends on the focus, objective, nature of research and context in which the research is conducted. Some research may be focused on a certain individual (such as a person's life history), or a group of individuals who share a specific characteristic (e.g., an identifiable group of asthma sufferers who happen to be all of one sex; a religious order that is restricted to one sex). Other examples include research that is focused on specific cultural traditions or languages, or on one age group (e.g., a study of posture corrections in adolescents). These are regarded as appropriate forms of inclusion and exclusion of individuals or groups in research studies - so long as the selection criteria for those to be included in the research are relevant to answering the research question.)

Appendix B

Poster

SLEEP AND COGNITIVE PERFORMANCE

Participate in our short study
and stand a chance to win 1 of 3
vouchers for Cavendish Square.
(1 x R1000, 1 x R500, 1 x R250)
In order to participate in this study, you need to:

1. Be an undergraduate student at UCT
2. Be between the ages of 18-25 years
3. Have NO history of psychological, psychiatric, medical, sleep, or neurological illness.

- Psychological and psychiatric e.g., depression, anxiety, eating disorder etc.
- Chronic medical illness e.g., severe asthma, tuberculosis
- Sleep e.g., sleep apnea, insomnia etc.
-Neurological illness e.g., multiple sclerosis, epilepsy, stroke

TO PARTICIPATE
Please email us:
iivandsleepstudy@gmail.com

We are honours students currently running a research study through the Department of Psychology. This project is a first of its kind and it attempts to see if there is a relationship between cognition and sleep. If you meet the above criteria and you decide to participate in this study, you will be asked to complete several questionnaires online that will gather general information about your health, mood and sleep. These questionnaires should take about 30 minutes to complete. Thereafter, if you ARE eligible for the study, you will be emailed and asked to schedule a time for the test session. The test sesion will be held in the ACSENT lab in the Psychology Department and will involve taking a brief nap (or not – depending on group assignment) an computerised cognitive tests focusing on accuracy and speed in reaction time. This should take about 45-60 minutes.

If you have any further questions, please don't hesitate to email us:
iivandsleepstudy@gmail.com

Appendix C
Flyer
(front)

SLEEP AND COGNITIVE PERFORMANCE

Participate in our short study and stand a chance to win 1 of 3 vouchers for Cavendish Square. (1 x R1000, 1 x R500, 1 x R250)
In order to participate in this study, you need to:

1. Be an undergraduate student at UCT
2. Be between the ages of 18-25 years
3. Have NO history of psychological, psychiatric, medical, sleep, or neurological illness.

- Psychological and psychiatric e.g., depression, anxiety, eating disorder etc.

- Chronic medical illness e.g., severe asthma, tuberculosis

- Sleep e.g., sleep apnea, insomnia etc.

-Neurological illness e.g., multiple sclerosis, epilepsy, stroke

TO PARTICIPATE
Please email us: iivandsleepstudy@gmail.com

(back)

We are honours students currently running a research study through the Department of Psychology. This project is a first of its kind and it attempts to see if there is a relationship between
cognition and sleep.
If you meet the above criteria and you decide to participate in this study, you will be asked to complete several questionnaires online that will gather general information about your health, mood and sleep. These questionnaires should take about 30 minutes to complete.
Thereafter, if you ARE eligible for the study, you will be emailed and asked to schedule a time for the test session. The test session will be held in the ACSENT lab in the Psychology Department and will involve taking a brief nap
(or not – depending on group assignment)
and computerised cognitive tests
focusing on accuracy and speed in reaction time. This should take about 45-60 minutes.
If you have any further questions, please don't hesitate to email us:
iivandsleepstudy@gmail.com

Appendix D

Sociodemographic Questionnaire

Sociodemographic Questionnaire

GENERAL INFORMATION

Full name:	
Student number: (needed only for allocation of SRPP points)	
Telephone:	Home: Cell:
Email address:	
Sex:	
Age:	

Appendix E

Health Index

1. Have you ever experienced a head injury (e.g., being hit on the head with an object and losing consciousness as a result)?

YES **NO**

If yes, please give details of the injury:

_____

2. Have you ever been involved in a motor vehicle accident?

YES **NO**

If yes, how old were you at the time?

_____

If yes, how serious was it? (Loss of consciousness? post-traumatic amnesia? Admitted to hospital? Or other injuries?)

_____

3. Have you ever been referred to a psychologist/psychiatrist?

YES **NO**

If yes, please elaborate on the nature of the referral:

_____

4. How often do you consume (within a week):

- **a.** Alcohol _____
- **b.** Cigarettes _____
- **c.** Other, please specify _____

5. Do you now, or have you ever, experienced any of the following medical conditions:

- **a.** Allergies

  YES **NO**

  If yes, please specify:

  _____

b. Tuberculosis

YES **NO**

c. Hypertension (high blood pressure)

YES **NO**

d. Epilepsy (i.e., seizures or fits)

YES **NO**

e. Neurological problems (i.e., Parkinson's disease, Huntington's disease, stroke, etc.)

YES **NO**

If yes, please specify:

_____

f. Depression

YES **NO**

g. Memory problems

YES **NO**

If yes, please specify:

_____

h. Learning difficulties (dyslexia, ADD/ADHD)

YES **NO**

If yes, please specify:

_____

i. Problems with your vision

YES **NO**

If yes, please specify:

_____

j. Problems with your hearing

YES **NO**

If yes, please specify:

_____

k. Do you have any family history of any of the above medical conditions?

YES **NO**

If yes, please specify:

_____

l. Are you currently taking any prescription medication(s)?

YES **NO**

If yes, please specify:

_____

m. Do you have any form physical disability that may impact on your ability to perform computer tasks?

YES **NO**

If yes, please specify:

_____

Appendix F

Pittsburgh Sleep Quality Inventory

INSTRUCTIONS:

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

   _____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

   _____

3. During the past month, what time have you usually gotten up in the morning?

   _____

4. During that past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed)

   _____

5. During the past month, how often have you had trouble sleeping because you…

a) Cannot get to sleep within 30 minutes?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

b) Wake up in the middle of the night or early morning?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

c) Have to get up to use the bathroom?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

d) Cannot breathe comfortably?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

e) Cough or snore loudly

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

f) Feel too cold?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

g) Feel too hot?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

h) Had bad dreams?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

i) Had pain?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

j) Other reason(s), please describe:

_____

How often during the past month have you had trouble sleeping because of this?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

6. During the past month, how would you rate your sleep quality overall?

__ Very good

__ Fairly good

__ Fairly bad

__ Very bad

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__Three or more times a week

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

__ Not a problem at all

__ Only a very slight problem

__ Somewhat of a problem

__ A very big problem

10. Do you have a bed partner or room mate?

__ No bed partner or room mate

__ Partner/room mate in other room

__ Partner in same room, but not same bed

__ Partner in same bed

If you have a room mate or bed partner, ask him/her how often in the past month you have had …

a) Loud snoring

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

__ N/A (if you answered "no" to Q.18)

b. Long pauses between breaths while asleep

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

__ N/A (if you answered "no" to Q.18)

c. Legs twitching or jerking while you sleep

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

__ N/A (if you answered "no" to Q.18)

d. Episodes of disorientation or confusion during sleep

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

__ N/A (if you answered "no" to Q.18)

e. Other restlessness while you sleep, please describe:

_____

__ Not during the past month

__ Less than once a week

__ Once or twice a week

__ Three or more times a week

__ N/A (if you answered "no" to Q.18)

Appendix G

Beck Depression Inventory-II

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the one statement in each group that best describes the **way you have been feeling during the past two weeks, including today**. Select the number beside the statement that you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleep Pattern) and Item 18 (Changes in Appetite).

1. Sadness 0 I do not feel sad. 1 I feel sad much of the time. 2 I am sad all of the time. 3 I am so sad or unhappy that I can't stand it. **2. Pessimism** 0 I am not discouraged about my future. 1 I feel more discouraged about my future than I used to be. 2 I do not expect things to work out for me. 3 I feel my future is hopeless and will only get worse. **3. Past Failure** 0 I do not feel like a failure 1 I have failed more than I should have.	**6. Punishment Feelings** 0 I don't feel I am being punished. 1 I feel I may be punished. 2 I expect to be punished. 3 I feel I am being punished. **7. Self-Dislike** 0 I feel the same about myself as ever. 1 I have lost confidence in myself. 2 I am disappointed in myself. 3 I dislike myself. **8. Self-Criticalness** 0 I don't criticise or blame myself more than usual. 1 I am more critical of myself than I used to be. 2 I criticise myself for all my faults. 3 I blame myself for everything bad that

2 As I look back, I see a lot of failures. 3 I feel I am a total failure as a person. **4. Loss of Pleasure** 0 I get as much pleasure as I ever did from the things I enjoy. 1 I don't enjoy things as much as I used to. 2 I get very little pleasure from the things I used to enjoy. 3 I can't get any pleasure from the things I used to enjoy. **5. Guilty Feelings** 0 I don't feel particularly guilty. 1 I feel guilty over many things I have done or should have done 2 I feel quite most of the time. 3 I feel guilty all of the time.	happens. **9. Suicidal Thoughts or Wishes** 0 I don't have any thoughts of killing myself. 1 I have thoughts of killing myself, but I would not carry them out. 2 I would like to kill myself. 3 I would kill myself if I had the chance **10. Crying** 0 I don't cry anymore than I used to. 1 I cry more than I used to. 2 I cry over every little thing. 3 I feel like crying, but I can't.

11. Agitation

0 I am no more restless or wound up than usual.

1 I feel more restless or wound up than usual.

2 I am so restless or agitated that it's hard to stay still.

3 I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest

0 I have not lost interest in other people or activities.

1 I am less interested in other people or things than before.

2 I have lost most of my interest in other people or things.

3 It's hard to get interested in anything.

13. Indecisiveness

0 I make decisions as well as ever.

1 I find it more difficult to make decisions than usual.

2 I have much greater difficulty in making decisions than I used to.

3 I have trouble making any decisions.

14. Worthlessness

0 I do not feel I am worthless.

17. Irritability

0 I am no more irritable than usual.

1 I am more irritable than usual.

2 I am much more irritable than usual.

3 I am irritable all the time.

18. Changes in Appetite

0 I have not experienced any changes in my appetite

1a My appetite is somewhat less than usual.

1b My appetite is somewhat more than usual.

2a My appetite is much less than usual.

2b My appetite is much more than usual.

3a I have no appetite at all.

3b I crave food all the time.

19. Concentration Difficulty

0 I can concentrate as well as ever.

1 I can't concentrate as well as usual.

2 It's hard to keep my mind on anything for very long.

3 I find I can't concentrate on anything.

20. Tiredness or Fatigue

0 I am no more tired or fatigued than usual.

1 I don't consider myself as worthwhile and useful as I used to be. 2 I feel more worthless as compared to other people. 3 I feel utterly worthless. **15. Loss of Energy** 0 I have as much energy as ever. 1 I have less energy than I used to have. 2 I don't have enough energy to do very much. 3 I don't have enough energy to do anything. **16. Changes in Sleep Pattern** 0 I have not experienced any change in my sleeping pattern. 1a I sleep somewhat more than usual. 1b I sleep somewhat less than usual. 2a I sleep a lot more than usual. 2b I sleep a lot less than usual. 3a I sleep most of the day. 3b I wake up 1-2 hours early and can't get back to sleep.	1 I get more tired or fatigued more easily than usual. 2 I am too tired or fatigued to do a lot of the things I used to do. 3 I am too tired or fatigued to do most things I used to do. **21. Loss of Interest in Sex** 0 I have not noticed any recent change in my interest in sex. 1 I am less interested in sex than I used to be. 2 I am much less interested in sex now. 3 I have lost interest in sex completely.

Appendix H

State-Trait Anxiety Inventory-Trait Form

A number of statements which people have used to describe themselves are given below. Read each statement and then select the appropriate number to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	Almost never	Sometimes	Often	Almost always
1. I feel pleasant	1	2	3	4
2. I feel nervous and restless	1	2	3	4
3. I feel satisfied with myself	1	2	3	4
4. I wish I could be as happy as others seem to be	1	2	3	4
5. I feel like a failure	1	2	3	4
6. I feel rested	1	2	3	4
7. I am "calm, cool, and collected"	1	2	3	4
8. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
9. I worry too much over something that really doesn't matter	1	2	3	4
10. I am happy	1	2	3	4
11. I have disturbing thoughts	1	2	3	4
12. I lack self-confidence	1	2	3	4
13. I feel secure	1	2	3	4
14. I make decisions easily	1	2	3	4
15. I feel inadequate	1	2	3	4
16. I am content	1	2	3	4

17. Some unimportant thought runs through my mind and bothers me	1	2	3	4
18. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
19. I am a steady person	1	2	3	4
20. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Appendix I

Informed Consent Document

University of Cape Town

Sleep and Intra-Individual Variability in Cognitive Performance

This form provides you with information about this study and seeks your informed consent to participate. Before you agree to take part in this study, please read the information below and ask the researcher (Angela Harwood and Jenny Pan: iivandsleepstudy@gmail.com) questions about anything that you do not understand.

Purpose

We are UCT Psychology Honours students investigating the effect of sleep on intraindividual variability (IIV) in cognitive performance (in other words, how people perform differently every time they take a cognitive test). What we want to do in this study is see how sleep is related to IIV in cognitive performance.

Procedure

If you decide to participate in this study, you will be asked to complete online questionnaires. These questionnaires will gather general information about your health, sleep and mood. The questionnaires should take about 30 minutes to complete and you will receive **1 SRPP** point.

If you are eligible for the study, we will notify you via email and ask you to schedule a time when you can attend a test session in the Department of Psychology's ACSENT and/or GCS Laboratory. The session will involve taking a brief nap (or not – depending on group assignment) as well as computerised cognitive tests which will focus on things like accuracy and speed in reaction time. This should take about 60 minutes and you will receive **2 SRPP** points.

Possible Risks

There are no risks of social, psychological, or physical harm.

Possible Benefits

If you complete the online questionnaires, you will receive 1 SRPP point. If you complete the computerised testing session, you will receive 2 SRPP points. In addition, participate in our study and you could stand a chance to win 1 of 3 vouchers for Cavendish Square (1 x R1000, 1 x R500, 1 x R250).

Voluntary Participation

Participation in this study is completely voluntary. You are free to refuse to answer any question without giving reasons for your refusal. Your decision regarding participation in this study will not affect your grades or academic career. If you decide to participate, you are free to change your mind and stop participation at any time without any negative consequences.

Confidentiality

Information about you obtained for this study will be kept confidential. Your name, consent form and other identifying information will be kept in a separate, locked file cabinet, and there will be no link between the consent form, questionnaires and cognitive tests. Your student number won't be linked to you or your study results. It is only needed to award you SRPP points. The results of the cognitive tests will not be available to your university or any current or future employers, nor will it be made available to anyone else. Any reports or publications about the study will not identify you or any other study participant by name.

Principal Investigators, Ethics Committee, and Telephone Numbers

Angela Harwood and Jenny Pan
Department of Psychology
University of Cape Town
iivandsleepstudy@gmail.com

Björn Christ
Department of Psychology
University of Cape Town
budoch@gmail.com

Kevin G. F. Thomas, Ph.D
Department of Psychology
University of Cape Town
kevin.thomas@uct.ac.za

Questions

If you have any study-related questions, problems or emergencies you can contact us on:

Angela Harwood and Jenny Pan iivandsleepstudy@gmail.com

If you have questions about your rights as a study participant, or any comments or complaints about the study, please contact:
Rosalind Adams at the UCT Department of Psychology.
Phone: 021 650 3417
Email: rosalind.adams@uct.ac.za.

I have read the above and am satisfied with my understanding of the study and its possible benefits and risks. My questions about the study have been answered. I hereby voluntarily consent to participation in the research study as described.

_____

Name of Participant

_____ _____

Signature of Participant Date

Appendix J

Debriefing Form

Sleep and Intra-Individual Variability in Cognitive Performance

Debriefing Form

Thank you for participating in this research study.

This form provides you with information about the study in which you have just participated, and explains in full the methods of collection of data for this research study. The Principle Investigator (Angela Harwood and Jenny Pan) or a representative of the Principle Investigator will also explain this study to you in full and answer your questions.

1. Name of Participant

_____

2. Title of Research Study

Sleep and Intra-Individual Variability in Cognitive Performance

3. Principal Investigators, Ethics Committee, and Telephone Numbers

Angela Harwood and Jenny Pan
Department of Psychology
University of Cape Town
iivandsleepstudy@gmail.com

Björn Christ
Department of Psychology
University of Cape Town
budoch@gmail.com

Kevin G. F. Thomas, Ph.D
Department of Psychology
University of Cape Town
kevin.thomas@uct.ac.za

4. What is the purpose of this research study?

The purpose of this research study is to better understand how sleep restriction can affect your cognitive performance as measure by intra-individual reaction time tests.

5. What was done during this research study?

During this study, you were required to complete a number of online questionnaires about your general health, sleep, and mood. These should have taken about 30 minutes to complete. You received **1 SRPP** point for completing them. You were also required to complete a 60-minute cognitive testing session in the Department of Psychology's ACSENT and/or GCS Laboratory. You received a further **2 SRPP** points for completing that session. The session involved taking a brief nap (or not – depending on group assignment) as well as computerised cognitive tests which focused on things like accuracy and speed in reaction time.

6. Was there any deception used in this research study?

No.

7. Is there anything further required of you?

Please do not disclose anything that happened during these research sessions to anyone else, as this may bias future participants and their performance. If you feel stressed at the end of the research study, please inform us so that we can provide you with the contact details of a clinical psychologist who can provide you with post-session counselling.

Signatures

As a representative of this study, I have explained to the participant, in detail, the purpose, the procedures, and any deception used in this research study.

_____ _____

Signature of study representative Date

I have been informed, in detail, about this study's purpose, procedures, and deceptions. I have been given the opportunity to ask questions before I sign. By signing this form, I am not waiving any of my legal rights.

_____ _____

Signature of participant Date

Appendix K

Duration, Latency and Depth of Sleep Questionnaire

1. How long do you estimate you were asleep for?

   _____ minutes

2. How long do you estimate it took you to fall asleep?

   _____ minutes

3. Would you describe your sleep as:

   - ☐ Light
   - ☐ Moderate
   - ☐ Deep